Exploring the Impact of Fruit and Vegetable Enzyme Supplementation on Aerobic Performance and Lactate Response in the Elderly Following High-Intensity Interval Exercise Combine Exergaming: Usability Study

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Abstract

Background: The potential role of fruit and vegetable enzymes might have positive effect in modulating fatigue in elderly population after extremely low-volume high-intensity interval exercise (ELVHIIE) though ex-ergaming

Objective: We aimed to investigate the impact of a 14-day supplementation with fruit and vegetable enzymes on aerobic capacity and blood lactate response in elderly individuals following ELVHIIE through exer-gaming.

Methods: Sixteen female elderly participants were recruited in this study (Pairwise Grouping Based on Lactate Levels into an enzyme group and a placebo group). Participants engaged in exergaming using Ninten-do Switch Ring Fit Adventure, which involved ELVHIIE comprising 8 sets of 20 seconds of maximal effort exercise with 30 seconds of rest between sets, resulting in a total exercise duration of 380 seconds. Blood lactate levels, heart rate, rating of perceived exertion, and training impulse (TRIMP) were as-sessed. The enzyme group received fruit and vegetable enzyme supplementation twice daily (30 c.c.) for 14 days.

Results: The enzyme group exhibited significantly lower blood lactate levels compared to the placebo group. Specifically, after the 4th and 8th exercise sessions, the enzyme group had lower lactate levels, respec-tively. Moreover, at 5- and 10-minutes post-exercise, the enzyme group also demonstrated lower lactate lev-els, respectively. Both groups exceeded 85% of their estimated maximum heart rate during exercise.

Conclusions: Supplementation with fruit and vegetable enzymes significantly reduced blood lactate levels, suggest-ing a potential role in modulating lactate production or clearance during and after exercise. Clinical Trial: National Cheng Kung University Human Research Ethics committee, Taiwan (ID: 112-419).

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Exploring the Impact of Fruit and Vegetable Enzyme Supplementation on Aerobic Performance and Lactate Response in the Elderly Following High-Intensity Interval Exercise Combine Exergaming: Usability Study

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Abstract

Introduction:

Exercise offers significant health benefits but can induce oxidative stress and inflammation, especially in high-intensity formats like high-intensity interval exercise (hereafter "HIIE" for brevity). Exergaming has become an effective, enjoyable fitness tool for all ages, particularly seniors. Enzyme supplements may enhance exercise performance by improving lactate metabolism and reducing oxidative stress.

Purpose:

This study investigates the efficacy of fruit and vegetable enzyme supplementation in modulating fatigue and enhancing aerobic capacity in the elderly following HIIE through exergaming.

Methods:

The study included sixteen elderly female participants who were divided into two groups, enzyme and placebo, based on their lactate levels, utilizing pairwise grouping to ensure comparability between the groups. They engaged in HIIE using the Nintendo Switch Ring Fit Adventure, performing 8 sets of 20 seconds of maximum effort exercise interspersed with 30 seconds of rest, totaling 370 seconds of exercise. Key metrics assessed included blood lactate levels, heart rate (hereafter "HR" for brevity), rating of perceived exertion (hereafter "RPE" for brevity), and training impulse (hereafter "TRIMP" for brevity). Participants in the enzyme group were administered a fruit and vegetable enzyme supplement at a dosage of 30 c.c. twice daily over a period of 14 days.

Results:

The enzyme group showed significantly lower blood lactate levels compared to the placebo group, particularly notable after the 4th (4.29 ± 0.67 vs. 6.34 ± 1.17 mmol/L, P = .001) and 8th (5.84 ± 0.63 vs. 8.20 ± 1.15 mmol/L, P < .001) exercise sessions. This trend continued at 5 (6.85 ± 0.82 vs. 8.60 ± 1.13 mmol/L, P =.003) and 10 minutes (5.91 ± 1.16 vs. 8.21 ± 1.27 mmol/L, P =.002) post-exercise. Although both groups exceeded 85% of their estimated maximum HR during the exercise, enzyme supplementation did not markedly affect the perceived intensity or effort.

Conclusion:

The study indicates that fruit and vegetable enzyme supplementation can significantly reduce blood lactate levels in the elderly following HIIE through exergaming. This suggests a potential role for these enzymes in modulating lactate production or clearance during and after high-intensity exercise. These findings have implications for developing targeted interventions to enhance exercise tolerance and recovery in older adults.

Keywords: ring fit adventure, training load, elderly training, training impulse

Introduction

Exercise represents a paradoxical element in health management, offering substantial benefits yet posing potential risks if not properly moderated [1, 2]. High-intensity exercise, while efficacious in improving various health parameters, can lead to oxidative stress, muscle damage, and inflammation [3, 4]. The oxidative stress primarily arises from increased reactive oxygen species production during intensive physical activities [5]. Moreover, exercise-induced fatigue serves as a protective mechanism against overexertion and consequent injuries[6, 7]. In contemporary fitness regimes, HIIE, particularly the Tabata training method, has gained prominence for its effectiveness in enhancing aerobic power, fat oxidation, and muscular endurance [8-10]. These attributes are especially crucial for the elderly population, a demographic that significantly benefits from regular physical activity [11-13] .

Exergaming, an innovative blend of physical exercise and interactive gaming, has emerged as a transformative approach to fitness, especially in engaging diverse age groups in regular physical activity. Its efficacy in enhancing key fitness parameters like aerobic capacity, agility, and coordination, coupled with its ability to make exercise more enjoyable, has been well documented [14-16]. This fusion of technology and exercise not only caters to the digital age but also opens avenues for personalized fitness experiences, adaptable to various demographic needs [17, 18]. While exergaming has been effective across a range of ages, its application in elderly populations presents unique opportunities and challenges. As the elderly population seeks safe, engaging, and effective exercise methods, exergaming could offer a solution that aligns with these requirements. However, integrating HIIE concepts into exergaming for the elderly remains a relatively uncharted territory. HIIE, known for its efficiency in improving cardiovascular health and metabolic function, could significantly benefit older adults, particularly in terms of enhancing functional capacity and overall quality of life [12, 19].

The potential of HIIE within exergaming for the elderly hinges on the balance between intensity and safety. While HIIE is beneficial, it is crucial to adapt its intensity to suit the physiological capabilities and limitations of older individuals. Research indicates that tailored HIIE programs can be both feasible and beneficial for older adults, leading to improvements in cardiovascular health, muscle strength, and metabolic function [20, 21]. Integrating these concepts into exergaming could further enhance adherence and enjoyment, crucial factors in maintaining regular exercise habits in this demographic. Furthermore, the interactive and immersive nature of exergaming can address common barriers to exercise among the elderly, such as lack of motivation or fear of injury. By providing a safe, controlled environment for engaging in HIIE, exergaming can potentially transform the perception and experience of high-intensity workouts for older adults. This is particularly pertinent given the increasing need for innovative exercise interventions that cater to the aging global population [11].

Nutritional supplementation, especially with natural fruit and vegetable enzymes, presents a promising avenue in augmenting exercise performance through their antioxidant, anti-inflammatory, and metabolic benefits [21-28] Such supplementation could potentially optimize lactate metabolism and enhance muscle function during exercise. Recent advancements in nutritional science have highlighted the significant role of natural fruit and vegetable enzymes in enhancing exercise performance. These enzymes are increasingly recognized for their multifaceted health benefits, including their antioxidant, anti-inflammatory, and metabolic-enhancing properties [21, 22]. Notably, their potential impact on exercise physiology, particularly in the context of high-intensity workouts, offers a new perspective on improving athletic performance and recovery.

One of the critical areas where these enzymes show promise is in the modulation of lactate metabolism. Lactate, often produced in higher quantities during intense physical activity, can lead to fatigue and decreased muscle efficiency. The traditional view of lactate as merely a byproduct of anaerobic metabolism has evolved, with current research acknowledging its role as a valuable energy source during prolonged exercise [23]. This shift in understanding opens up new avenues for utilizing enzyme supplementation to optimize lactate utilization. Enzymes such as bromelain and papain, found in pineapples and papayas respectively, have been studied for their potential in improving lactate metabolism. These enzymes are known to facilitate faster clearance of lactate from the bloodstream, thereby enhancing recovery and reducing fatigue [26, 28]. Furthermore, the antioxidant properties of these enzymes play a crucial role in combating oxidative stress, which is often elevated during intense exercise regimes [24, 25]. This reduction in oxidative stress is not only beneficial for immediate recovery but also contributes to long-term muscle health and function. Moreover, the anti-inflammatory actions of these natural enzymes can mitigate the inflammatory response often triggered by high-intensity exercise [27]. By reducing inflammation, these enzymes may enhance muscle recovery and function, thus allowing for more efficient and prolonged exercise performance. This aspect is particularly relevant in training regimens where recovery is as crucial as the exercise itself.

The primary aim of this feasibility study is to examine the effects of fruit and vegetable enzyme supplementation on aerobic capacity and blood lactate response in elderly individuals engaged in HIIE through an exergaming framework. This study is dual-faceted, focusing firstly on the physiological responses and feasibility of an exergaming-HIIE regimen tailored for the elderly, and secondly, on the impact of enzyme supplementation on enhancing these exercise outcomes.

Methods

Sample Size

The sample size computation was based on the study by Flanagan and Jakeman [29].Based on a statistical power analysis, a total sample size of 16 participants (8 per group) was needed to achieve a statistical power of 0.8 to detect a large effect size (ES) for supplement-time interaction at an alpha level of 0.05[30].

Participants And Experimental Design

After recruiting a total of 30 healthy elderly participants, and following screening and explanation, 12 individuals did not meet the inclusion criteria, and 2 politely declined to participate. Ultimately, 16 female elderly participants were recruited for this study. Consequently, a single-blind, randomized matched-pair design was employed to allocate the 16 participants into two groups: the enzyme group and the placebo group. All participants reported a regular exercise habit (3 times per week within the past year). They also completed the Physical Activity Readiness Questionnaire and confirmed no history of upper limb skeletal muscle injury or major injury. Participants were instructed to avoid strenuous activities and the intake of caffeine or muscle-enhancing supplements for 24 hours prior to the experiment. Before the study commenced, all participants provided personal information, completed health questionnaires, disclosed personal medical history, and signed informed consent forms.

The 16 participants underwent the Exergaming HIIE test as an initial assessment (pre-test). Participants engaged in a 5-minute warm-up on a stationary bike, followed by HIIE using the Nintendo Switch Ring Fit Adventure design. The training method was adapted from the research of

[8, 9] and consisted of 8 sets of 20 seconds of maximum effort exercise with 30 seconds of complete rest between each set, resulting in a total exercise time of 370 seconds. The HIIE design incorporated training modes targeting the deltoid, pectoralis major, latissimus dorsi, and quadriceps muscles in the Nintendo Switch Ring Fit Adventure. Blood lactate levels, heart rate, and ratings of perceived exertion were recorded before, during, and after exercise, and training load was quantified using TRIMP. Participants were matched and divided into two groups, the enzyme group, and the placebo group, based on their blood lactate levels during HIIE. Each group comprised 8 individuals. Supplementation with vegetable and fruit enzymes or maltodextrin commenced three days after the pre-test and lasted for a total of 14 days. On the 14th day, following the completion of supplementation, the participants underwent the Exergaming HIIE test as a post-test. (Figure 1)

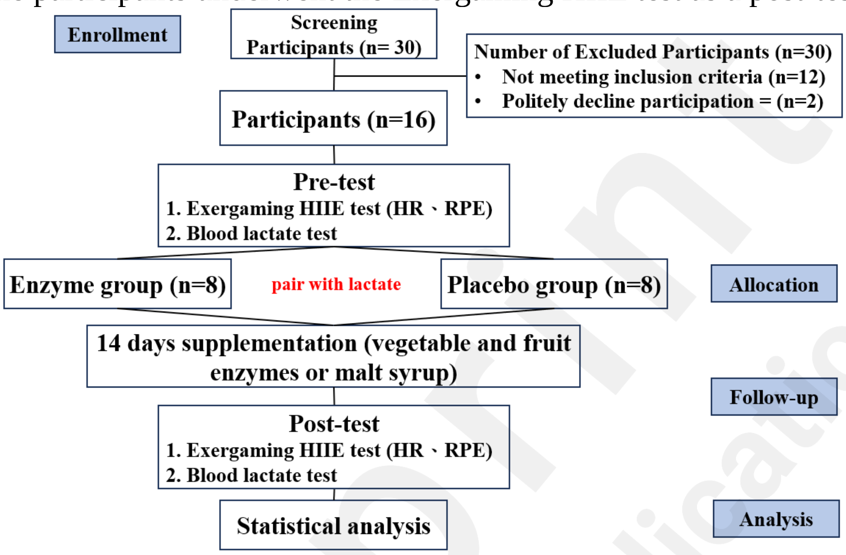


Figure 1. CONSORT and Experimental Procedure Diagram

Ethical Considerations

The human research ethics committee of the local university approved this study, which was also approved by the human research ethics committee of the National Cheng Kung University, Taiwan. (Approval No. NCKU HREC-E-112-419-2). Users volunteered for this study and agreed to participate by signing an informed consent form.

Supplementation Protocol

After the pre-test, the enzyme group consumed 30 mL of vegetable and fruit enzymes (The contents include needle-leaf cherries, cherries, apples, cranberries, blackberries, black currants, blueberries, beets, broccoli, cabbage, carrots, Concord grapes, cranberries, elderberries, kale, oranges, peaches, papayas, parsley, pineapples, raspberries, red currants, spinach, and tomatoes, etc.) (Enzyme Village, Chiayi, Taiwan) mixed with 150 mL of water twice a day (at breakfast and dinner) for 14 consecutive days. The placebo group followed the same protocol but consumed malt syrup (Amazon, USA) instead until the end of the study. Participants returned to the laboratory each morning to receive the daily supplement, which was administered on-site. Following supplementation, participants reported their dinner intake to the researchers, ensuring compliance with the prescribed supplementation regimen.

Exergaming HIIE Test-Combination Of Exergaming And HIIE

The experimental participants engaged in HIIE using the Nintendo Switch Ring-Con, conducted within a laboratory setting. All participants underwent pre-test and post-test assessments on the same day. The exergame selected for this study is "Nintendo Switch Fitness Adventure," which combines exercise, adventure, and entertainment, allowing players to enjoy both physical workouts and gaming fun simultaneously. The game features an intuitive and user-friendly interface, suitable for players of all ages. It comes with a specialized fitness ring device, an intelligent accessory that connects to the Switch console. Through this ring, players can engage in various physical activities such as weightlifting, yoga, and aerobic exercises. The fitness ring sensor accurately captures players' movements and incorporates them into the gameplay. The game content involves unlocking levels and participating in fitness competitions through real-life physical movements. It offers a variety of fitness activities, each targeting different muscle groups, while also providing enjoyable gaming challenges. The exercise protocol involved eight sets of 20 seconds of maximum effort exercise, with 30 seconds of complete rest intervals between each set, for a total of 370 seconds of exercise time. The fitness game used for the Nintendo Switch Ring-Con was the Adventure Mode in Ring Fit Adventure, including two sets of pectorales major, two sets of latissimi dorsi, two sets of deltoids, and two sets of quadriceps exercises. (Figure 2-3)

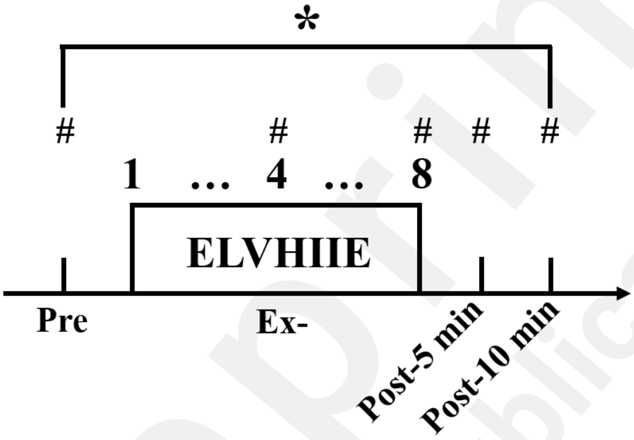
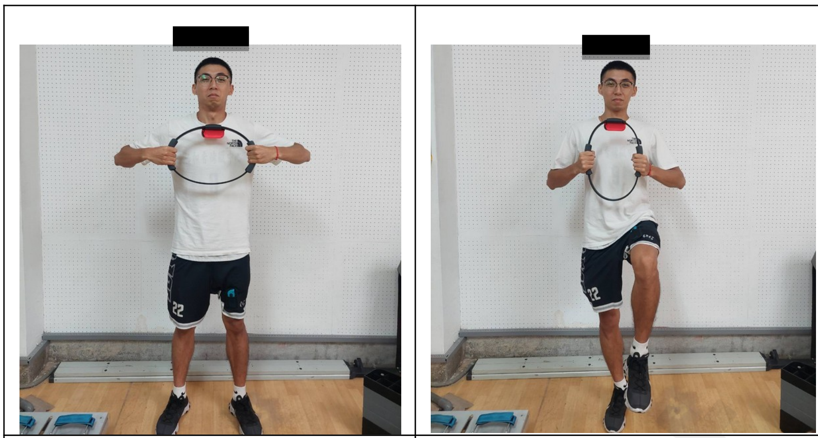


Figure 2. Experimental flowchart. Ex-: bout of HIIE test; Post-5 min: after 5 minutes of HIIE test; Post-10 min: after 10 minutes of HIIE test. Asterisk (*) indicates lactate test. Asterisk (#) indicates test heart rate and RPE.

	
Pectoralis major	Deltoid



Latissimus dorsi	Quadriceps

Figure 3. Exercises training model

Blood Lactate Test

The blood lactate was measured at five time points: before exercise, after the fourth and eighth bouts of exercise, and at 5 and 10 minutes after exercise. The blood lactate were analyzed using a Biosen Cline blood analysis system (EKF-diagnostic, Germany). Capillary blood samples of 10 μL were collected and added to red blood cell lysis reagent and stored at low temperature until analyzed. Prior to analysis, instrument standardization and test calibration were performed, and the coefficient of variation was determined to be ≤1.5%. The detection range for blood lactate was 0.5-40 mM [31].

Training Impulse

In this study, the exercise load was represented by the TRIMP [32], which is calculated as the product of exercise intensity and duration. To accommodate the convenience of the experiment, two different TRIMP calculation methods were used, including % HRmax (objective) and RPE (subjective). At the end of each exercise bout (8 bouts in total) and during the recovery period before the next bout (7 bouts in total), participants were asked to report their RPE, and their heart rate was recorded. This process was repeated 8 times.

% HRmax Calculation Method

During the entire HIIE, the participant's HR was recorded every 5 seconds using a heart rate monitor (iHeart Polar, Taiwan) to calculate % HRmax. The block TRIMP method developed by S. Edwards [33] was used, which divides the exercise intensity into 5 blocks with corresponding weighting factors (Table 1). The weighted score of each block was multiplied by the exercise time (min) and then summed to obtain the exercise load (arbitrary unit [AU]). The calculation formula is as follows: Exercise load = (Z1 exercise time × 1) + (Z2 exercise time × 2) + (Z3 exercise time × 3) + (Z4 exercise time × 4) + (Z5 exercise time × 5)

Table 1 The Edwards' block TRIMP calculation method

Zone	Intensity	Weighted score
Z1	50%-60% HRmax	1

Z2	60%-70% HRmax	2
Z3	70%-80% HRmax	3
Z4	80%-90% HRmax	4
Z5	90%-100% HRmax	5

RPE Calculation Method

The TRIMP calculation method of Foster, Hector [34] and Foster, Florhaug [35] was used to calculate the exercise load by multiplying the RPE value of each exercise segment by the exercise time and summing them up. The RPE scale used in this method was the CR-10 version modified by Foster, Florhaug [35] based on Borg, Ljunggren and Ceci [36] (Table 2). The calculation formula is as follows: Exercise load (AU) = Borg's CR-10 RPE score × exercise time (min)

Table 2. Borg’s CR-10 RPE

0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

Statistical Analysis

All the data were analyzed by SPSS for Windows 20.0. Data are expressed as the mean ± standard deviation (SD) and 95% confidence interval (95% CI). A mixed design two-way analysis of variance (ANOVA) (group × time) was used to compare the variables of lactate, heart rate and training impulse between two groups before and after the 14-days of supplementation. Graphs were generated using GraphPad Prism 8.0 (GraphPad Software, San Diego, California, USA). Cohen’s conventions for ES (Cohen d) were calculated by the G*Power 3.1 software program (Heinrich-

Heine-Universität, Düsseldorf, Germany), where the ESs of 0.2, 0.5, and 0.8 are considered small, medium, and large, respectively. Statistical significance was set as $p < 0.05$.

Results

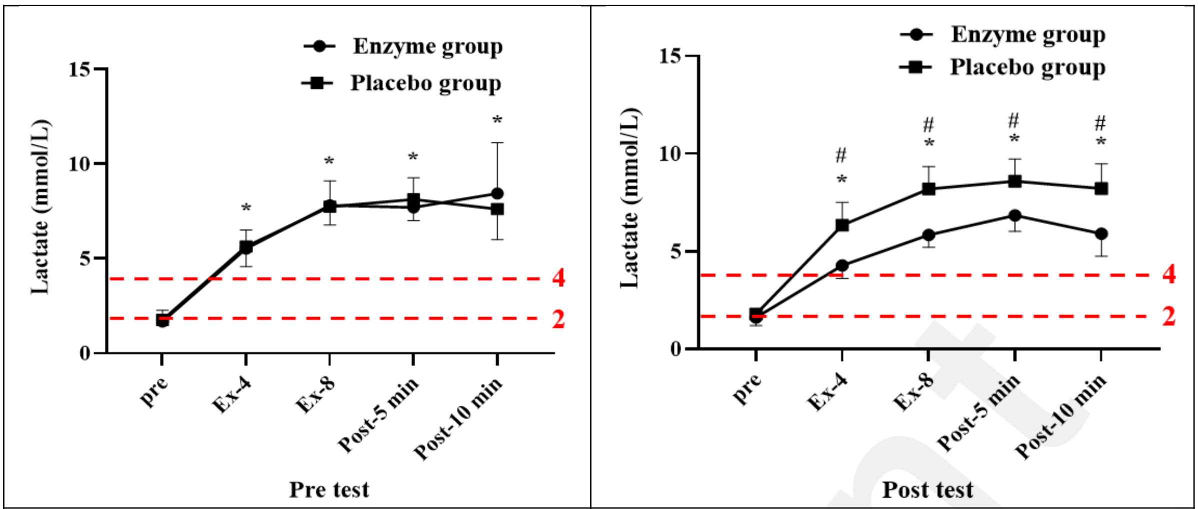
Table 3 outlines the baseline characteristics of participants in the study, divided into the enzyme and placebo groups. The average age of participants was slightly higher in the placebo group (66.50 ± 1.31 years) compared to the enzyme group (65.75 ± 0.88 years). Heights were similar across both groups, with the enzyme group averaging 160.50 ± 2.67 cm and the placebo group at 160.13 ± 2.75 cm. The enzyme group members were slightly heavier (56.75 ± 4.27 kg) than those in the placebo group (53.5 ± 3.42 kg), which also reflected in a higher average BMI (22.02 ± 1.41 kg/m² in the enzyme group vs. 20.89 ± 1.71 kg/m² in the placebo group). Regarding exercise habits, both groups engaged in regular physical activity, with the enzyme group exercising 3.75 ± 0.71 days per week and the placebo group slightly more at 4.00 ± 0.76 days per week. The daily exercise duration was comparable between groups, with the enzyme group averaging 76.25 ± 41.04 minutes and the placebo group 78.75 ± 31.82 minutes.

Table 3. Participants' baseline characteristics

	Enzyme group, mean (SD)	Placebo group, mean (SD)
Age (years)	65.75 (0.88)	66.50 (1.31)
Height (cm)	160.50 (2.67)	160.13 (2.75)
Weight (kg)	56.75 (4.27)	53.5 (3.42)
BMI (kg/m^2)	22.02 (1.41)	20.89 (1.71)
Frequency of Regular Exercise Habits (per week within the past year)(day)	3.75 (0.71)	4.00 (0.76)
Daily Exercise Duration (minute)	76.25 (41.04)	78.75 (31.82)

Enzyme Supplementation's Impact On Lactate Response With Exergaming And HIIE

Effects of enzyme supplementation on Blood lactate response to the combination of exergaming and HIIE. The results demonstrated that blood lactate levels surpassed 4 mmol/L after the 4th exercise bout, indicating the presence of high-intensity exercise. Additionally, the study examined the effects of 14 days of enzyme or placebo supplementation on blood lactate levels (F=6.99, P=0.001). The enzyme group exhibited significantly lower blood lactate levels than the placebo group after the 4th [4.29 ± 0.67 (3.56-5.01) vs. 6.34 ± 1.17 (5.61-7.06) mmol/L, ES = -2.14, P =.001] and 8th [5.84 ± 0.63 (5.14-6.54) vs. 8.20 ± 1.15 (7.50-8.90) mmol/L, ES = -2.56, P=.001] exercise bouts, as well as at 5 [6.85 ± 0.82 (6.10-7.60) vs. 8.60 ± 1.13 (7.85-9.35) mmol/L, ES = -1.78, P=.003] and 10 [5.91 ± 1.16 (4.99-6.84) vs. 8.21 ± 1.27 (7.29-9.14) mmol/L, ES = -1.89, P=.002] minutes after exercise (Figure 4). These findings suggest that the combination of HIIE and exergaming can lead to high-intensity exercise, while enzyme supplementation can contribute to a reduction in lactate levels.

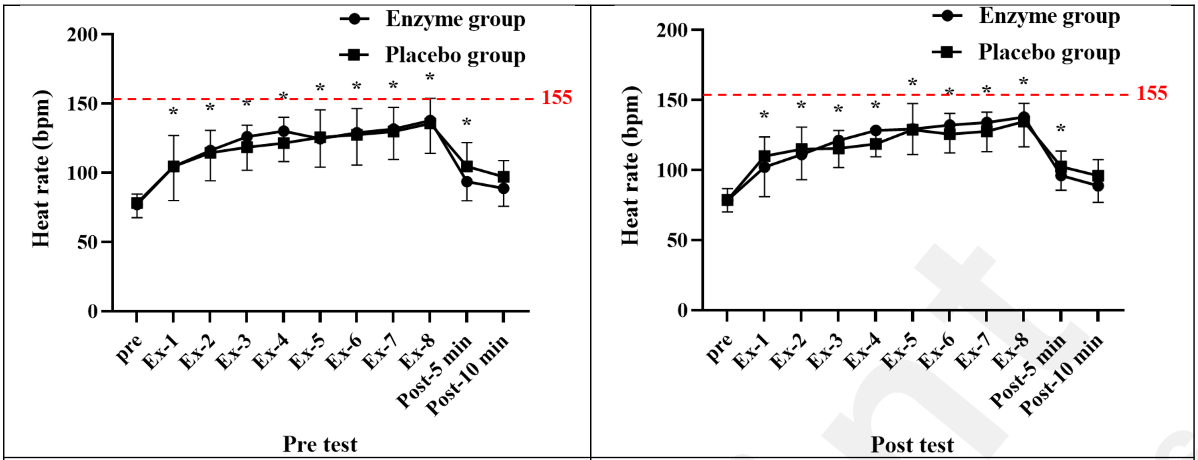


(a) Pre supplementation | (b) Post supplementation

Figure 4. Blood lactate response before and after fourteen days of enzyme or placebo supplementation. (a) Pre supplementation. (b) Post supplementation. Data are the means ± standard deviation. Ex-= bout of HIIE test; Post-5 min= after 5 minute of HIIE test; Post-10 min= after 10 minute of HIIE test. Asterisk (*) indicates a significant difference ($p < 0.05$) from the pre-exercise value within the group. Asterisk (#) indicates a significant difference ($p < 0.05$) between the group.

Enzyme Impact On Heart Rate In Exergaming And HIIE

The results demonstrated that during exergaming combined with HIIE, elderly participants experienced a significant increase in heart rate compared with before exercise. The estimated maximum heart rate (220 - age) ± 10 for the elderly was 155 ± 10 bpm, and the observed heart rates during exercise exceeded the estimated 85% of the maximum heart rate for both groups. However, there was no significant difference in the average heart rate of the elderly between the enzyme and placebo groups before and after supplementation. Before supplementation, there was no significant difference in the heart rates of the elderly participants between the enzyme and placebo groups during the 1st [104.63 ± 24.71 (86.77-122.48) vs. 104.63 ± 22.32 (86.77-122.48) bpm, ES = 0], 2nd [116.13 ± 21.81 (101.54-141.72) vs. 114.38 ± 16.26 (99.79-128.96) bpm, ES = 0.09], 3rd [126.13 ± 24.30 (110.53-141.72) vs. 118.38 ± 15.96 (102.78-133.97) bpm, ES = 0.38], 4th [130.13 ± 21.97 (114.63-145.62) vs. 121.38 ± 18.77 (105.88-136.87) bpm, ES = 0.43], 5th [124.63 ± 20.49 (109.37-139.88) vs. 125.63 ± 19.73 (110.37-140.88) bpm, ES = -0.05], 6th [128.88 ± 23.34 (112.71-145.04) vs. 127.38 ± 19.06 (111.21-143.54) bpm, ES = 0.07], 7th [131.63 ± 22.01 (116.56-146.69) vs. 129.75 ± 17.45 (114.69-144.81) bpm, ES = 0.09], and 8th [137.75 ± 23.60 (121.78-153.73) vs. 135.63 ± 18.19 (119.65-151.60) bpm, ES = 0.10] sets (Figure 2). Similarly, after supplementation, there was no significant difference in the heart rates of the enzyme and placebo groups during the 1st [102.13 ± 21.21(88.87-115.67) vs. 109.88 ± 13.64 (96.33-123.42) bpm, ES = -0.43], 2nd [111.13 ± 18.04 (98.32-123.93) vs. 114.88 ± 15.63 (102.07-127.68) bpm, ES = -0.22], 3rd [121.13 ± 19.38 (108.63-133.62) vs. 115.38 ± 12.95 (102.88-127.87) bpm, ES = 0.35], 4th [128.25 ± 18.75 (116.57-139.93) vs. 118.5 ± 11.10 (106.82-130.18) bpm, ES = 0.63], 5th [129.25 ± 18.12 (115.29-143.21) vs. 128.75 ± 18.68 (114.79-142.71) bpm, ES = 0.03], 6th [132.00 ± 19.79 (118.70-145.30) vs. 125.50 ± 14.95 (112.20-138.80) bpm, ES = 0.37], 7th [133.88 ± 20.84 (120.50-147.25) vs. 127.63 ± 13.70 (114.25-141.00) bpm, ES = 0.35], and 8th [137.75 ± 21.18 (124.42-151.08) vs. 134.63 ± 13.02 (121.30-147.95) bpm, ES = 0.18] sets (Figure 5). In summary, the findings indicate that exergaming combined with HIIE leads to a significant increase in heart rate among elderly individuals. However, there was no significant difference in heart rate between the enzyme and placebo groups before and after supplementation.

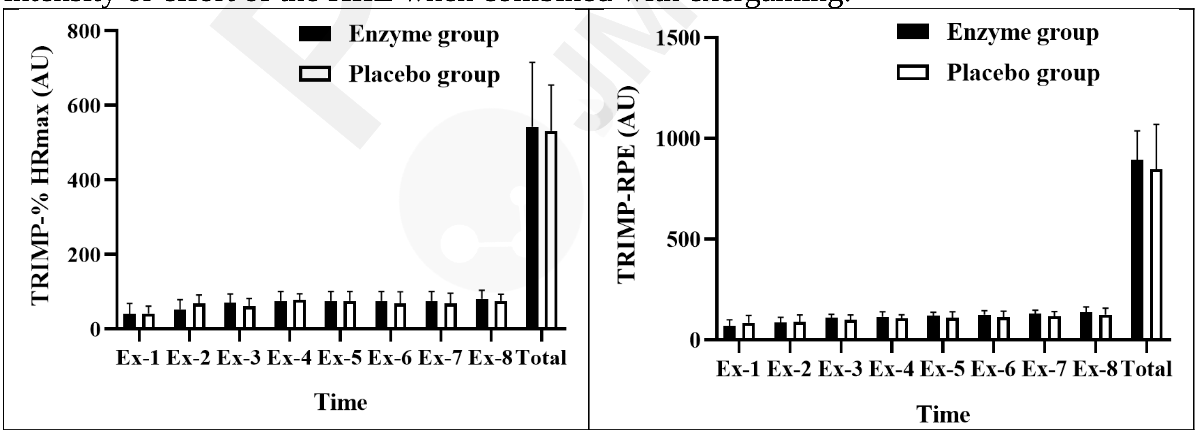


(a) Pre supplementation	(b) Post supplementation

Figure 5. Heat rate response before and after fourteen days of enzyme or placebo supplementation. (a) Pre supplementation. (b) Post supplementation. Data are the means ± standard deviation. Ex-= bout of HIIE test; Post-5 min= after 5 minute of HIIE test; Post-10 min= after 10 minute of HIIE test. Asterisk (*) indicates a significant difference ($p < 0.05$) from the pre-exercise value within the group.

Training Impulse in Enzyme vs. Placebo Groups Post-Supplement in Exergaming HIIE

The training impulse, representing both objective and subjective training loads, was compared between the enzyme and placebo groups post-supplementation. Analysis revealed no significant differences in either the objective (542.5 ± 172.19 vs. 531.25 ± 123.34 AU, ES = 0.08, *P* = .883) or subjective training loads (895 ± 143.73 vs. 847.50 ± 223.46 AU, ES = 0.25, *P* = .621) between the groups (Figure 6). This suggests that the supplementation did not significantly alter the perceived intensity or effort of the HIIE when combined with exergaming.



(a) objective	(b) subjective

Figure 6. Comparison of training impulse between enzyme and placebo groups after supplementation during HIIE with exergaming. Data are the means ± standard deviation. Ex-= bout of HIIE test.

Discussion

The study investigated the effects of enzyme supplementation on lactate response and heart rate in elderly individuals engaging in a combination of exergaming and high-intensity interval exercise (HIIE). Results indicated that enzyme supplementation significantly reduced blood lactate levels post-exercise, particularly after the 4th and 8th exercise bouts, demonstrating the potential of enzymes to mitigate exercise-induced lactate accumulation. Despite a notable increase in heart rate during the exercise sessions, which surpassed 85% of the estimated maximum for elderly participants, there was no discernible difference in heart rate responses between the enzyme and placebo groups, either before or after supplementation. Furthermore, the analysis of training impulse, encompassing both objective and subjective measures of training load, revealed no significant differences between the enzyme and placebo groups post-supplementation. This suggests that while enzyme supplementation may aid in lactate management, it does not significantly impact the overall perceived intensity or cardiovascular demand of HIIE combined with exergaming in elderly individuals.

Lactate Response In Exergaming

This study contributes valuable insights into the efficacy of fruit and vegetable enzyme supplementation in optimizing exercise outcomes for the elderly, particularly when combined with HIIE and exergaming. The notable finding that blood lactate levels surpassed the 4 mmol/L threshold after the fourth exercise bout underlines the high intensity and physiological rigor of the exercise protocol. This study’s emphasis on enzyme supplementation's impact on blood lactate levels is especially pertinent. Enzyme supplementation significantly lowered blood lactate levels post-exercise, as compared to placebo, after both the 4th and 8th exercise bouts, and at 5- and 10-minutes post-exercise. This observation suggests a potential role of enzyme supplementation in enhancing lactate metabolism, either through its reduction or improved clearance during and after high-intensity exercise. The metabolic-enhancing attributes of fruit and vegetable enzymes, such as bromelain and papain, may facilitate this reduction in lactate accumulation [22, 37]. Furthermore, their antioxidant and anti-inflammatory properties could lead to enhanced muscle function, thereby contributing to lower lactate production [38].

Exergaming, when integrated with HIIE, presents an innovative and engaging exercise modality, particularly for the elderly. It has been established as an effective and enjoyable exercise option, capable of achieving intensities comparable to traditional exercise forms [16]. This study reinforces the feasibility of exergaming combined with HIIE as a viable strategy for older adults, achieving substantial exercise intensity as evidenced by elevated lactate levels. However, the study is not without limitations. The relatively small sample size and focus on a specific demographic and exercise protocol may restrict the broader applicability of the findings. Further research with larger, more diverse populations is necessary to validate and extend these preliminary results.

Heart Rate Response In Exergaming

Interestingly, while exergaming combined with HIIE effectively elevated physiological parameters like heart rate and lactate levels, no significant difference in heart rate response was observed between the enzyme and placebo groups. This suggests that the subjective perception of effort might not accurately reflect the actual physiological demands of the exercise, echoing previous research [32, 33]. In summary, this study illustrates that enzyme supplementation can potentially reduce blood lactate levels during and post high-intensity exercise in an elderly cohort engaged in HIIE combined with exergaming. These findings underscore the value of enzyme supplementation in enhancing metabolic responses and optimizing exercise outcomes. Future research should aim to unravel the underlying mechanisms and investigate the long-term impacts of enzyme supplementation across diverse populations. A deeper understanding of the interplay between nutritional supplementation, exercise modality, and physiological responses is crucial in tailoring effective interventions for optimal exercise performance and overall health promotion.

Training Impulse Response In Exergaming

An additional focal point of our study was the evaluation of TRIMP in relation to enzyme supplementation during HIIE combined with exergaming. TRIMP is a quantifiable measure of training load, incorporating both objective and subjective elements of exercise intensity[32]. In our study, the analysis revealed no significant differences in TRIMP between the enzyme and placebo groups post-supplementation. This outcome suggests that enzyme supplementation does not significantly alter the perceived intensity or exertion levels during HIIE with exergaming. This finding aligns with previous studies that have explored the multifaceted nature of TRIMP. For instance, research by Laursen and Jenkins [39] highlighted the complexity of accurately measuring training load, emphasizing the need to consider both physiological and psychological factors. The lack of significant difference in TRIMP in our study could be attributed to the stable physiological response (heart rate and lactate levels) observed across both groups. This observation is consistent with the work of MANZI, IELLAMO [40], who noted the importance of physiological markers in determining training load, particularly in endurance sports.

Furthermore, the subjective component of TRIMP, which relates to athletes' perceived exertion, is a crucial aspect of training load assessment [35]. Our study's findings, where the subjective perception of effort did not significantly differ between the enzyme and placebo groups, resonate with the notion that perceived exertion is a complex interplay of physical and psychological factors [33]. This complexity might explain why enzyme supplementation, primarily impacting physiological responses, did not significantly alter the subjective experience of the training load. The implication of these results is significant for designing exercise programs for the elderly. As suggested by Bethancourt, Rosenberg [41], understanding and managing training load is crucial in preventing overtraining and optimizing exercise benefits, especially in older adults. The lack of difference in TRIMP between the groups in our study indicates that enzyme supplementation, while beneficial in reducing lactate levels, does not necessarily impact the overall training load as perceived by the participants. This insight is vital for practitioners and researchers in tailoring exercise regimens that are both physiologically effective and psychologically manageable for older adults.

In conclusion, our study contributes to the growing body of knowledge on TRIMP and its applications in exercise science. While enzyme supplementation shows promise in reducing lactate levels, its impact on the overall training load, as measured by TRIMP, appears minimal. Future research should continue to explore this area, considering both physiological and psychological aspects of exercise, to develop comprehensive training strategies for various populations, including the elderly.

Conclusions

This study aimed to evaluate the impact of fruit and vegetable enzyme supplementation on aerobic capacity and blood lactate response in elderly individuals participating in HIIE combined with exergaming. The results demonstrate that enzyme supplementation significantly reduced blood lactate levels post-exercise compared to a placebo. This finding is indicative of the potential role of such supplementation in enhancing lactate metabolism during and after high-intensity exercise. Additionally, the integration of HIIE with exergaming has proven to be a novel and effective approach to exercise for the elderly, achieving significant physiological intensities while maintaining engagement and enjoyment. However, enzyme supplementation did not exhibit a noticeable effect on heart rate response or the overall perceived training load, as measured by TRIMP. This suggests that while enzyme supplementation may influence specific physiological responses, such as lactate production and clearance, it does not significantly alter the overall perceived exertion or exercise experience for participants.

These findings contribute to the growing body of literature on the synergistic effects of nutritional supplementation and innovative exercise modalities like exergaming in the elderly population. They highlight the potential of enzyme supplementation in optimizing exercise outcomes, particularly in reducing lactate accumulation, which is a crucial aspect of high-intensity exercise tolerance. Moreover, the study underscores the feasibility and effectiveness of exergaming combined with HIIE as a strategy to enhance physical activity levels in older adults. The study's implications extend beyond exercise physiology, offering practical insights for health practitioners, fitness professionals, and researchers in the development of targeted, effective, and enjoyable exercise interventions for the elderly. Future research should aim to further elucidate the mechanisms behind enzyme supplementation's impact on exercise performance and explore the long-term effects of such interventions in a wider demographic.

In summary, this research supports the notion that carefully tailored nutritional and exercise interventions, like enzyme supplementation combined with HIIE and exergaming, can significantly enhance exercise outcomes in the elderly. These interventions hold promise for improving overall health and well-being in this demographic, contributing to the growing field of serious games and their application in health and fitness.

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Author Contributions

Author S.-C.L. carried out the laboratory experiments, analyzed the data, interpreted the results, prepared figures, and tables, and prepared the manuscript. Authors C.-Y.W., T.-H.H., C. C. and H.-C.C. assisted in the data collection and the discussion of the literature. Author C.-C.W. designed the study, supervised the experimental procedure, and reviewed the entire preparation of the manuscript.

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Abbreviations

HIIE: high-intensity interval exercise

RPE: rating of perceived exertion

HR: heart rate

TRIMP: training impulse

Ex-: bout of HIIE test

Post-5 min: after 5 minute of HIIE test

Post-10 min: after 10 minute of HIIE test

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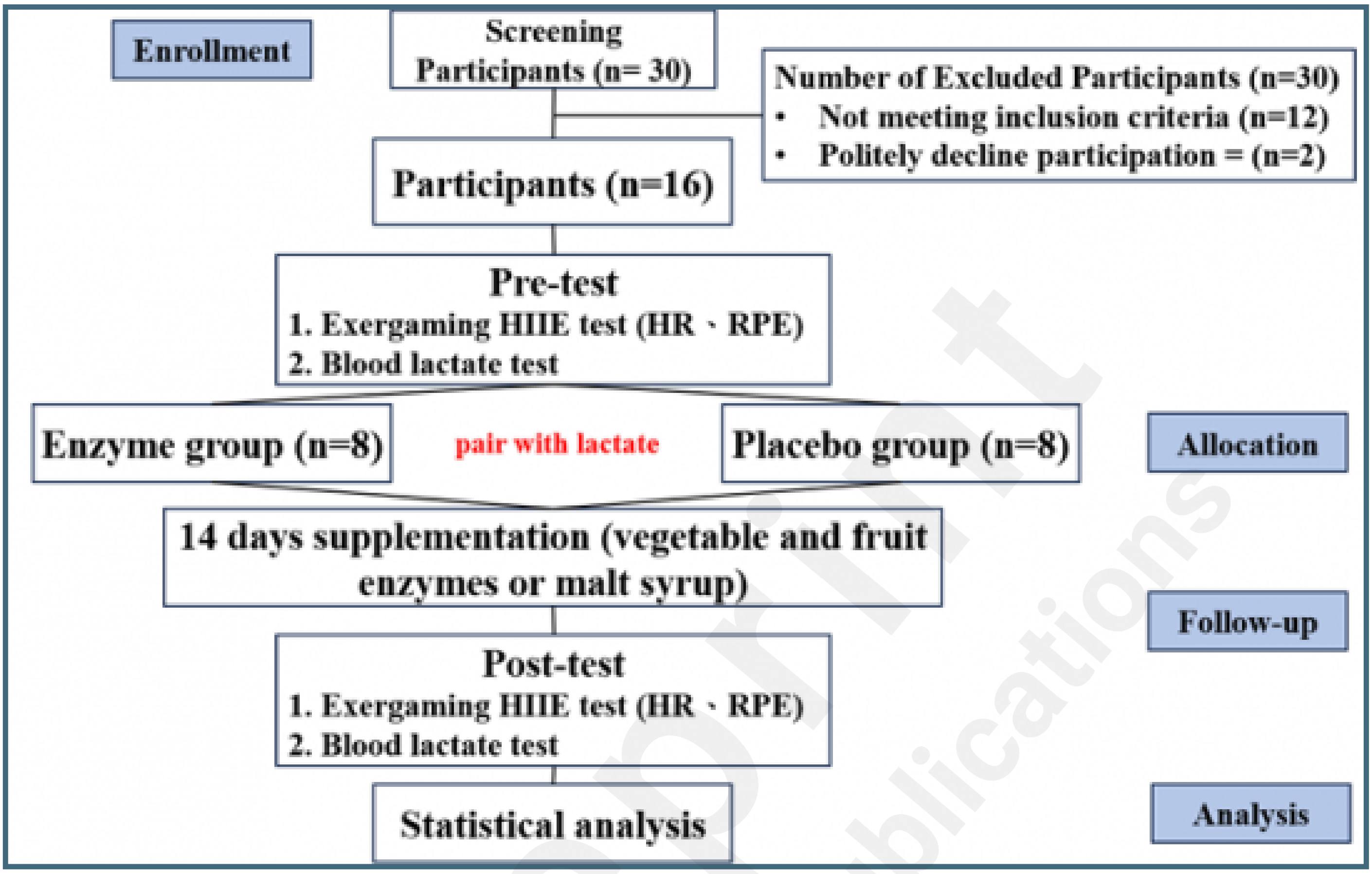
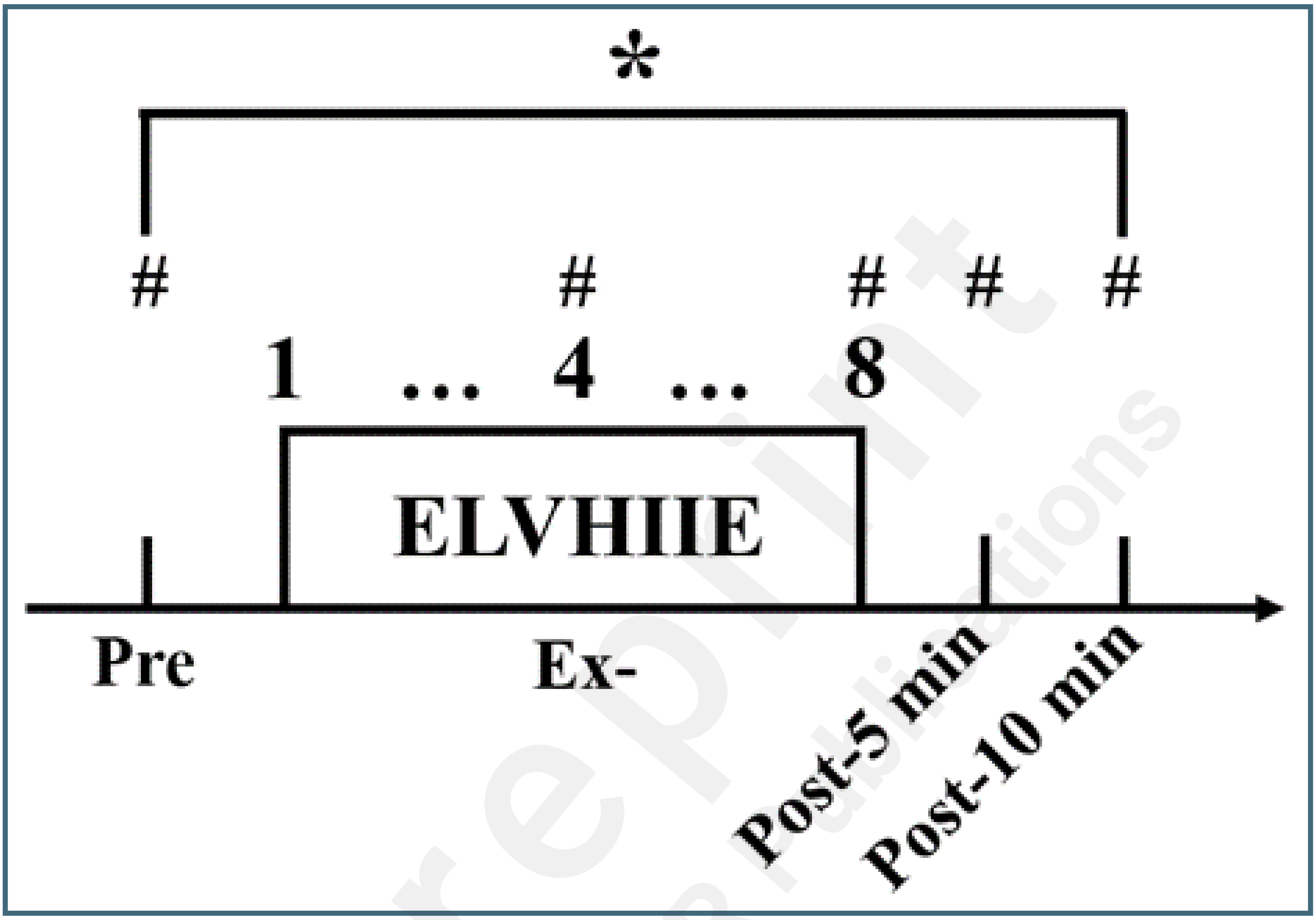
Supplementary Files

Figures

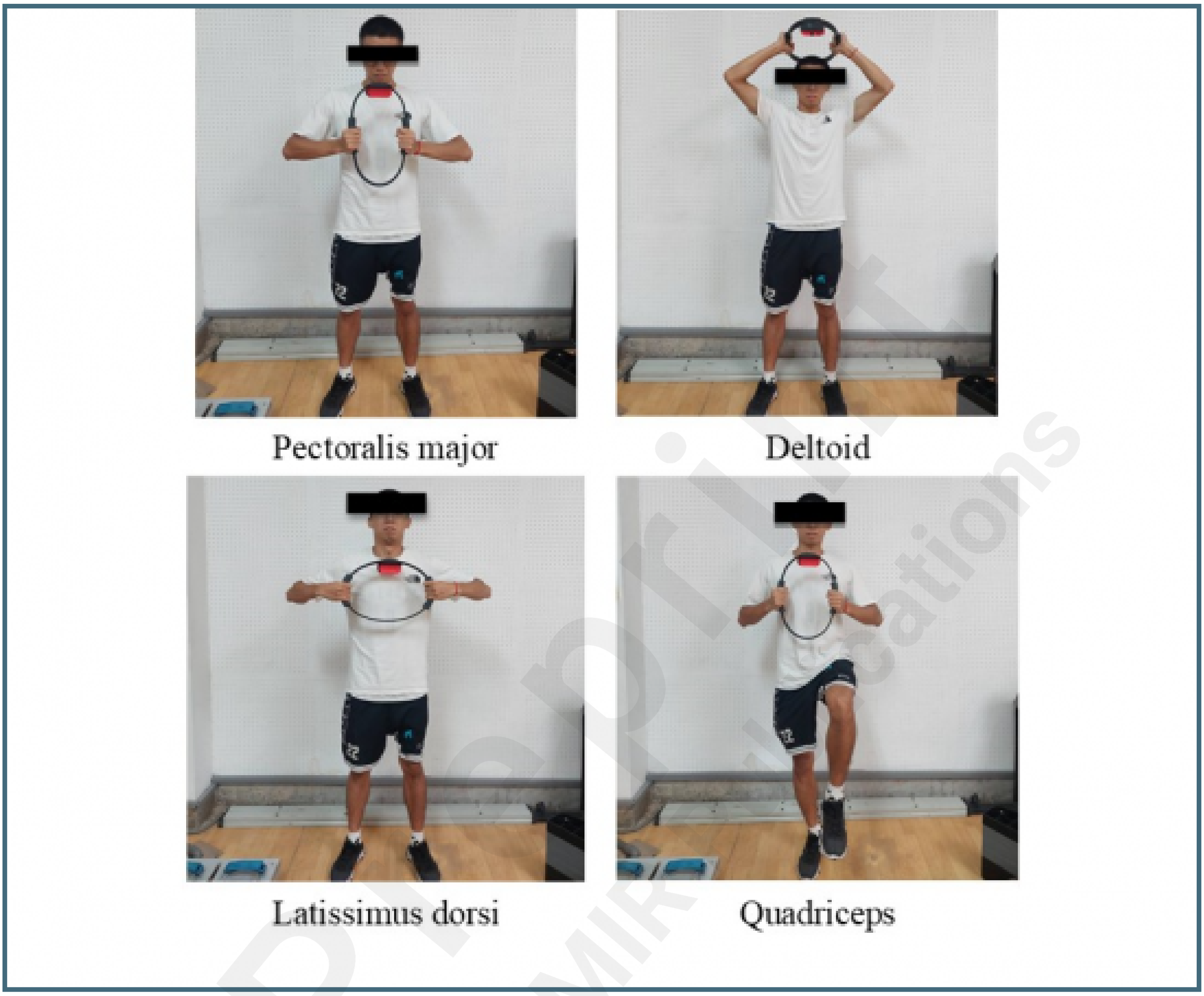
CONSORT and Experimental Procedure Diagram.



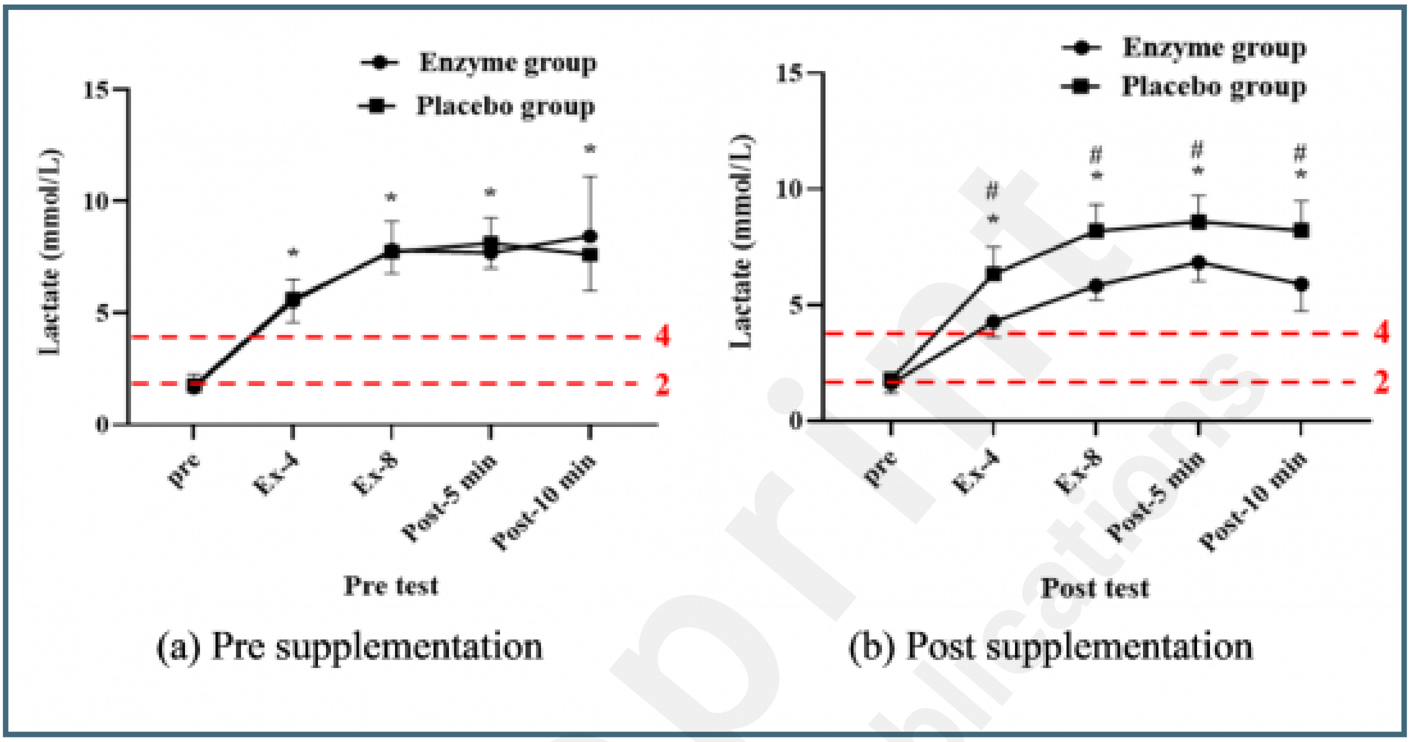
Experimental flowchart. Ex-: bout of HIIE test; Post-5 min: after 5 minutes of HIIE test; Post-10 min: after 10 minutes of HIIE test. Asterisk (*) indicates lactate test. Asterisk (#) indicates test heart rate and RPE.



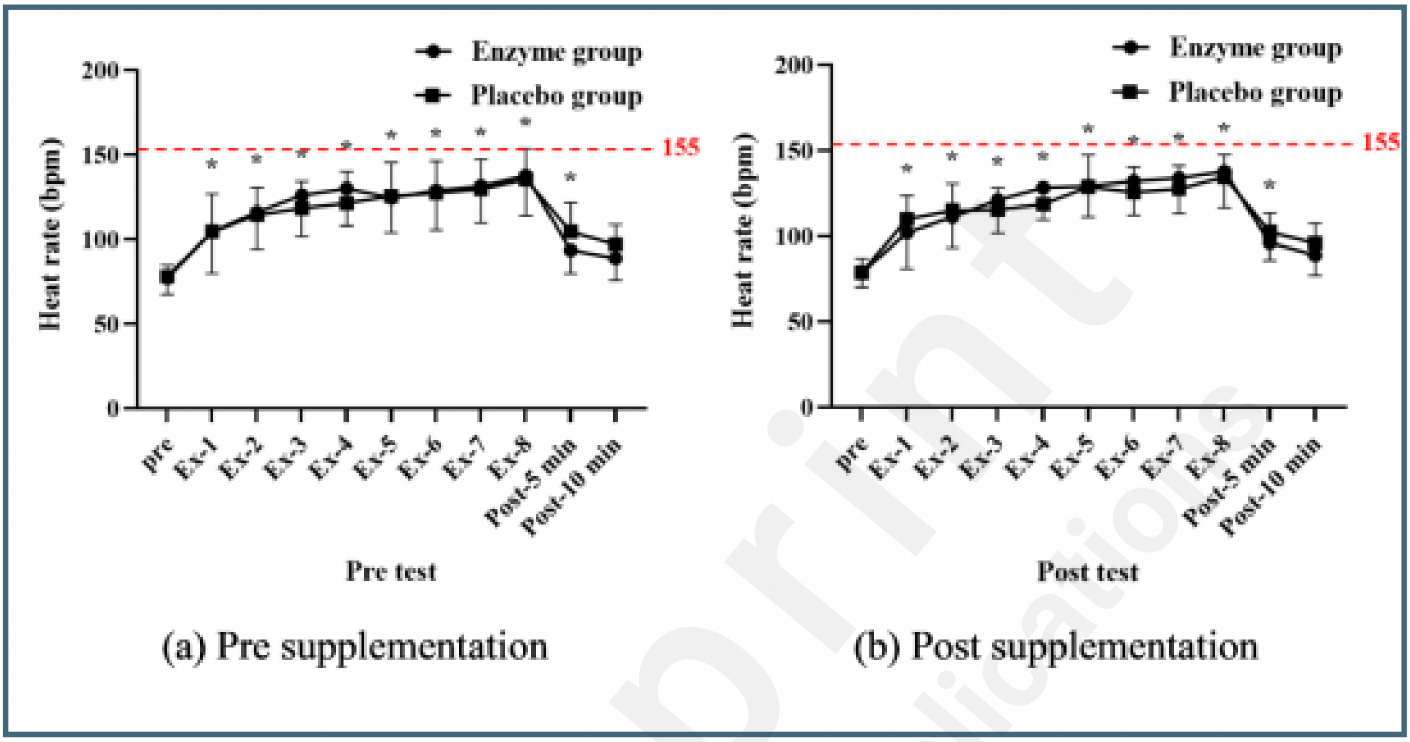
Exercises training model.



Blood lactate response before and after fourteen days of enzyme or placebo supplementation. (a) Pre supplementation. (b) Post supplementation. Data are the means ± standard deviation. Ex-= bout of HIIE test; Post-5 min= after 5 minute of HIIE test; Post-10 min= after 10 minute of HIIE test. Asterisk (*) indicates a significant difference ($p < 0.05$) from the pre-exercise value within the group. Asterisk (#) indicates a significant difference ($p < 0.05$) between the group.

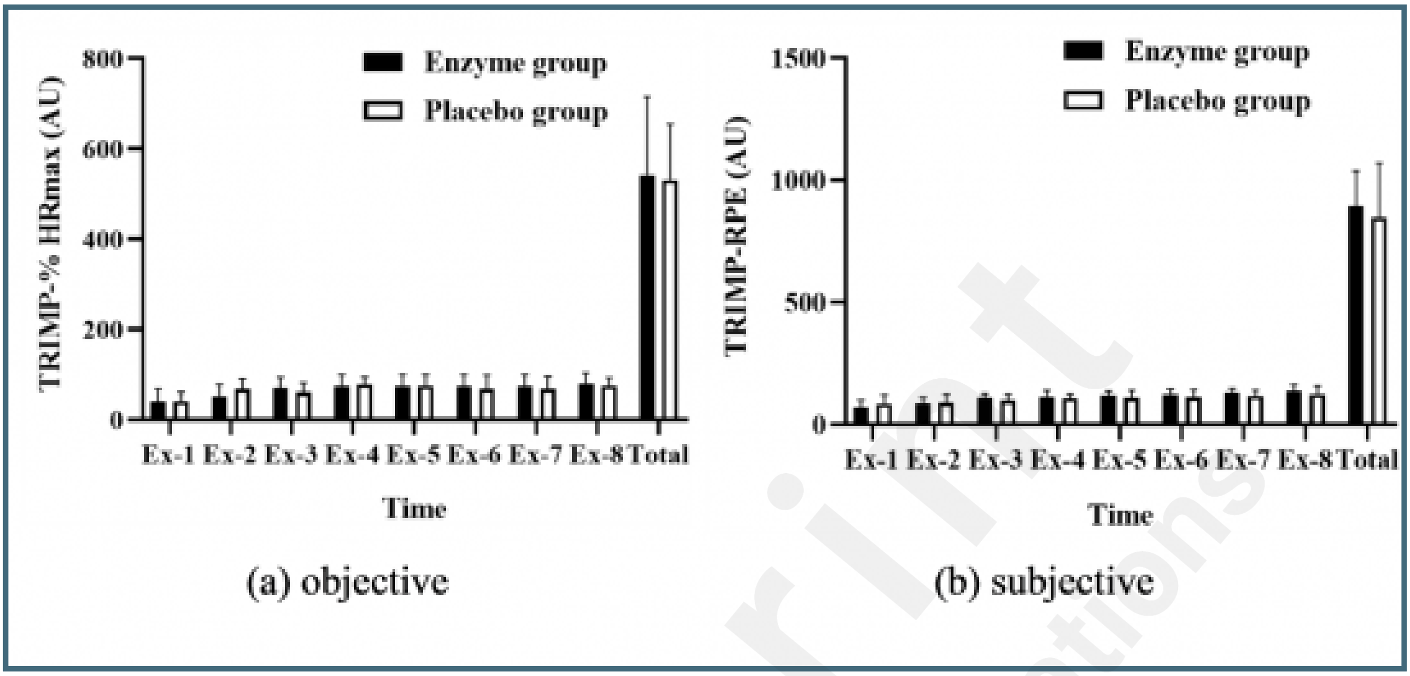


Heat rate response before and after fourteen days of enzyme or placebo supplementation. (a) Pre supplementation. (b) Post supplementation. Data are the means ± standard deviation. Ex-= bout of HIIE test; Post-5 min= after 5 minute of HIIE test; Post-10 min= after 10 minute of HIIE test. Asterisk (*) indicates a significant difference ($p < 0.05$) from the pre-exercise value within the group.



(a) Pre supplementation (b) Post supplementation

Comparison of training impulse between enzyme and placebo groups after supplementation during HIIE with exergaming. Data are the means ± standard deviation. Ex-= bout of HIIE test.



Multimedia Appendixes

The Edwards' block TRIMP calculation method.
URL: http://asset.jmir.pub/assets/699618268fe133c797b38c8e4c0c0989.docx

Borg's CR-10 RPE.
URL: http://asset.jmir.pub/assets/cd22310300b97460732778951e3d1b62.docx

Participants' baseline characteristics.
URL: http://asset.jmir.pub/assets/bbf7411e2c82433a8439de425e6ce546.docx

CONSORT (or other) checklists

CONSORT-EHEALTH (V 1.6.1) -Submission/Publication Form.
URL: http://asset.jmir.pub/assets/d8b175a9125a4ee490052e5860c12f34.pdf