Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Short-term Effects of Oxygenated Nanobubble-Infused Drinks vs Placebo Drinks on Performance and Fatigue Among Endurance Runners: A Crossover Trial

Dr. G. Arun Maiya

arun.maiya@manipal.edu

Manipal Academy of Higher Education

Pragathi N

Manipal Academy of Higher Education

Anupama Harihar

Manipal Academy of Higher Education

Ramyashree Kalmadi

Manipal Academy of Higher Education

Dr. Mukesh Sinha

Manipal Academy of Higher Education

Dr. Bhaskaran Chandrashekaran

Manipal Academy of Higher Education

Research Article

Keywords: Oxygenated nanobubble drinks, ergogenic aid, aerobic performance, endurance runners, fatigue index, anaerobic performance

Posted Date: March 16th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8840472/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Sport Sciences for Health on July 23rd, 2026. See the published version at https://doi.org/10.1007/s11332-026-01825-3.

Abstract

Purpose

The study aims to check the short-term effects of oxygenated nanobubble-infused drinks on aerobic and anaerobic performance and fatigue among endurance runners. Oxygenated nanobubble beverages have recently gained a lot of attention as an ergogenic aid due to their potential to increase exercise performance and oxygen availability. The primary research question was whether acute consumption of oxygenated nanobubble beverages enhances aerobic performance, anaerobic performance and fatigue resistance compared to a placebo among endurance runners.

Methods

A randomized, double blind, placebo-controlled crossover trial was conducted by including twenty recreational endurance runners aged 18–30 years. Participants underwent aerobic fitness testing using the Modified Bruce Protocol Test to assess peak oxygen uptake VO_2peak. Anaerobic capacity and Fatigue index were measured using the Wingate Anaerobic Test. Each participant consumed both oxygenated nanobubble-infused drinks and placebo drinks with 48hours of washout period. Performance results were compared between conditions.

Results

Consumption of oxygenated nanobubble-infused drinks showed an improvement in aerobic performance, with a mean VO_2peak of 68.5 ± 9.48 ml/kg/min. Anaerobic capacity also increased from 540 ± 113 watts to 582 ± 138 watts, while fatigue index decreased from 45.3 ± 10.03% placebo to 41 ± 10.30%, indicating improved resistance to fatigue compared to the placebo drink.

Conclusion

Oxygenated nanobubble-infused drinks may provide ergogenic benefits by enhancing aerobic and anaerobic performance and reducing fatigue in endurance runners; however, larger trials are needed to validate effectiveness and underlying mechanisms.

Introduction

Athletic performance has driven a continuous innovation in sports, particularly in terms of ergogenic aid. Oxygen plays an important role in endurance performance, and athletes have many ways to enhance oxygen delivery during training or competition(1). Oxygen availability is a key role in aerobic metabolism, which makes it a primary determinant of sustained exercise capacity and an important factor in delaying fatigue, as it controls adenosine triphosphate (ATP) resynthesis and mitochondrial oxidative

phosphorylation during prolonged physical activity(2). Several studies have examined the physiological advantages of increased oxygen availability during exercise. These studies found that improved performance is a result of several factors, including increased VO_2max, decreased submaximal heart rate, and blood lactate concentrations(3, 4). Aerobic performance reflects the combined capacity of circulatory, pulmonary and muscular systems to deliver and consume oxygen during exercise. A key factor in determining performance in endurance athletes, especially long-distance runners, is peak oxygen uptake(VO_2peak), reflecting both central oxygen delivery and peripheral oxygen extraction(5).

High-intensity and long-term exercises are known to interfere with oxygen homeostasis; even in normoxic settings, strenuous work has been shown to lower the arterial oxygen saturation (SpO_2). Experimental studies have shown that exercise-induced haemoglobin desaturation and decreases in peripheral SpO_2 occur during cycling and other endurance sports(6). It has been demonstrated that hyperoxic therapies, such as additional oxygen inhalation, decrease the blood lactate accumulation, lower the heart rate and increase exercise tolerance. However, these methods are not feasible to use because it requires such specialized equipment, regulated conditions or face masks9(7–11).

To overcome these challenges, a new class of dietary supplements, which includes rich oxygen beverages, has emerged. Initial study on traditional oxygenated water, produced by simply dissolving oxygen into a liquid, has failed to demonstrate a performance benefit, mainly due to poor stability of the dissolved oxygen, which tends to dissipate rapidly over time. Currently, there is the development of a novel technology: oxygen nanobubble water (NBO2W). This technology encapsulates oxygen molecules within nanometer-sized bubbles, which are significantly more stable and resistant to buoyancy and gas diffusion (12). Furthermore, oxygenated nanobubble water enhances hypoxic areas in tumors; when taken orally, it transports the nanobubble structure to intended organs without disintegrating(13). This innovation presents a potentially more effective and practical method for delivering supplemental oxygen to athletes.

Therefore, the present study aims to evaluate the short-term effects of oxygenated nanobubble-infused drinks on aerobic performance, assessed as VO_2 peak using the Modified Bruce Protocol Test, anaerobic performance, assessed as anaerobic capacity and fatigue resistance assessed as fatigue index using the Wingate Anaerobic test among healthy recreational endurance runners.

Methods

Study Design

Institutional Research and Ethics Committee approval was obtained (IEC1: 437/2024), and the study was registered with CTRI/2025/03/082772. This was a randomized, placebo-controlled crossover study that was conducted from February 2025 to July 2025. A crossover design was chosen to allow for within-subject comparisons by having each participant serve as their own control.

Eligibility criteria

Inclusion criteria include young adults aged between 18 to 30 years of both genders, recreational endurance runners and individuals who have participated in at least three institutional-level running events representing institutions were included in the study. Exclusion criteria includes, individuals with history of chronic disease that may limit physical activity, any fluid imbalance disorders or allergies to citrus resulting from oxygenated nanobubble infused soft drinks, presence of systemic vascular or autoimmune disorders affecting fluid balance, any known hypertensive or cardiovascular disorders that may be exacerbated with fluid infusions. Out of the 38 screened patients, 20 met the eligibility criteria and completed the trial.

Procedure

A total of 38 participants were screened, and 20 were included in this study. The reasons for excluding 18 participants were: ankle sprains (5), chronic conditions (4), autoimmune diseases (4), and recent fractures (5). After baseline assessment, the participants were randomly assigned to either the placebo group or the nanobubble drink group. The participants consumed a 250 ml of IOTA oxygenated nanobubble-infused drink or placebo drink and immediately performed their assigned tests. After a 48-hour washout period, they were crossed over to receive the other drink, and the remaining test was performed.

(1) Baseline assessment

Body composition was assessed using bioelectrical impedance analysis (BIA). Skeletal muscle mass, visceral fat level and body fat percentage were recorded(14, 15). Waist circumference was measured using a tape while the participant stood upright with arms relaxed at their sides, feet together, and abdomen relaxed. A horizontal measurement was taken at the narrowest point of the torso, which is situated above the umbilicus and below the xiphoid process(16). Flexibility was assessed using a sit-to-reach test (for hamstring/lower back flexibility). Participants were asked to sit on the floor with legs fully extended and heels placed against the box. They were instructed to reach forward slowly, without bending the knees, and held the maximal position for two seconds. The best of three attempts was documented(17). 1-Repetition Maximum (1RM) Strength Testing- Maximal strength of the upper and lower limbs was assessed using a body-solid bench press and a leg press machine, respectively. Participants completed a familiarization session before testing. A standard warm-up consisting of several submaximal repetitions of the respective exercise was performed before initiating the assessment. Each participant performed up to four attempts with 3-5minutes of rest between trials. The initial load was set at approximately 50-7-% of the participant’s perceived maximal capacity. Resistance progressively increased by 5–10% for upper limb and 10–20% for lower limb exercises after each successful lift until a failed attempt occurred. The heaviest successfully lifted load was recorded as the absolute 1RM (or multiple RM), and the 1RM value was estimated using Epley’s Eq. (18,19). Muscular

endurance was assessed using a field-based push-up test for the upper limb and squat test for the lower limb, performed to volitional fatigue without rest. For push-ups, participants started in the standard prone position with their hands placed under the shoulders, a straight back, and toes as the pivot point. Repetitions were counted only if participants fully extended their elbows and returned to the starting position without allowing the abdomen to contact the mat. The maximum number of continuous repetitions was recorded(20).

(2) Cardiopulmonary fitness testing-Modified Bruce treadmill test

Cardiopulmonary fitness was evaluated using a treadmill test based on the Modified Bruce Protocol. The procedure was explained to all the participants, and written informed consent was obtained prior to testing. Participants were ensured to be dressed in comfortable exercise clothing and suitable footwear. Baseline physiological parameters, including heart rate (HR), oxygen saturation (SpO_2), blood pressure (BP), and Borg Rating of Perceived Exertion (RPE) were monitored throughout the test. The VO_2 peak was calculated using the ACSM Treadmill Running Equation. The modified Bruce protocol was employed, which begins at a lower speed and incline and progresses with smaller workload increments compared to the standard Bruce protocol. The test comprises multiple 3-minute stages, with both treadmill speed and incline increased at each stage to progressively elevate cardiovascular demand. Heart rate (HR), peripheral oxygen saturation (SPO2) and blood pressure (BP) were measured at the end of each stage. Borg Rating of Perceived Exertion (RPE) was recorded at each stage. Throughout testing, participants were closely monitored for any signs of discomfort, fatigue, or adverse symptoms such as dizziness or chest pain(21, 22).

Termination criteria:

- Achievement of the target HR (usually 85% of the age-predicted max HR) or the VO_2 max plateau.
- The participants were asked to stop due to fatigue
- Development of adverse symptoms (e.g., angina, severe breathlessness, ECG abnormalities, dangerous BP changes)
- Clinical decision making by supervising examiner

Post-Test Procedure:

The treadmill was returned to 0% inclined at low speed for active recovery. Monitoring of HR, BP, and SpO_2 was continued immediately and at 1 minute and 3 minutes posttest. The test duration, HR, BP, and RPE are documented, and the VO2 peak is calculated.

VO2 peak estimation was performed via the ACSM Treadmill Running Equation:

VO2 peak (ml/kg/min) = (0.1 × S) + (1.8 × S × G) + 3.5

where:

- S = Speed in meters per minute (1 mph ≈ 26.8 m/min)
- G = treadmill grade as a decimal (e.g., 10% = 0.10)
- 3.5 = resting oxygen consumption

(3) Wingate anaerobic test

The Wingate Anaerobic Test is a short-duration, high-intensity cycling test designed to measure anaerobic power, anaerobic capacity, and the fatigue index. It is one of the most widely used laboratory protocols to assess performance in the ATP-PC and glycolytic energy systems. Equipment requirements: Monark cycle ergometer, calibrated load weights, and stopwatch.

The test procedure was explained, and familiarization of the equipment was done to the participants. Participants' body mass was measured and recorded to determine the resistance load. The cycle seat and handlebars were adjusted to the participant's comfort. A 5–10 min warm-up with light pedalling and 2–3 short sprints was performed to prepare the muscles for maximal effort. A standard load = 0.075 × body mass (kg) was set and the resistance was applied instantly at the start of the test. The participant begins pedaling at the maximal speed with no resistance for 5–10 seconds. At the command "Go", the predetermined resistance is applied instantly to the flywheel. The participant pedals all-out for 30 seconds against the fixed load. Strong verbal encouragement is given to maintain maximal cadence throughout(23, 24).

Measurements and calculations:

Peak power (PP) = highest 5-second power output during the test.

Anaerobic capacity (AC) = average power over the full 30 seconds.

Fatigue Index (FI) = percentage drop from peak to lowest 5-second power output

The peak power and anaerobic capacity were calculated and recorded in watts (W) and watts per kilogram body weight (W/kg − 1); the FI was calculated as a percentage

- Peak power output = force (kg)* distance (m) ÷ time (s)
- Distance = number of revolutions during the 5-seconds* distance per revolution (m)
- Fatigue index = ((peak power – lowest power) ÷ (peak power))* 100
- Anaerobic capacity = average peak power output

Data analysis

Data analysis was performed via Jamovi 2.4.11 software. Descriptive statistics were used to summarize the demographic and baseline characteristics of the participants. Means and standard deviations (mean ± SD) are reported for continuous variables. The Shapiro–Wilk test was used to test for normality. A paired t test was used to compare the effects of the nanobubble drink and placebo drink within and

between the groups. P values less than 0.05 were considered significant between the pre- and post-intervention data.

Results

A total of twenty participants were included in the study. Baseline characteristics, including age, body mass index (BMI), waist circumference (WC), skeletal muscle mass (SMM), body fat percentage and visceral fat level, were assessed (Table 1). All twenty participants completed the study with no adverse events or protocol violations.

Table 1
Baseline characteristics of the participants (n = 20)

Variable	Mean ± SD
Age (yrs)	22.6 ± 2.36
BMI (kg/m2)	24.1 ± 4.13
WC (cm)	88.4 ± 8.93
Skeletal muscle mass (kg)	32.1 ± 4.06
Percentage body fat (%)	20.6 ± 8.77
Visceral fat level	5.95 ± 4.21

As shown above, the participants had a healthy body composition, which justifies their selection for this study.

Table 2
Musculoskeletal examinations of the participants (n = 20)

Variable	Mean ± SD
Flexibility (cm)	7.67 ± 2.16
UL endurance (repetitions)	25.3 ± 7.5
LL endurance (repetitions)	91.1 ± 44.6
UL 1RM (lbs)	125.8 ± 30.5
LL 1 RM (lbs)	239.2 ± 48.2

The musculoskeletal profile of the endurance runners revealed a disparity between upper and lower body strength and endurance, which is consistent with the adaptations of endurance runners.

Table 3
Mean VO_2 peak following the treadmill test: Placebo vs. the Nanobubble drink

VO_2 peak (ml/kg/min)	Mean ± SD	df	*p* value
Placebo drink	64.3 ± 7.55	19	0.001
Nanobubble drink	68.5 ± 9.48		

Table 3 summarizes the cardiorespiratory fitness outcomes following the Modified Bruce protocol treadmill test. The VO_2 peak is increased by 6.5%. After the consumption of oxygenated nanobubble-infused drink, indicating a positive trend in aerobic performance.

Table 4
Mean anaerobic capacity following the Wingate test: Placebo vs nanobubble drink

Wingate test: Anaerobic capacity (watts)	Mean ± SD	df	*p* value
Placebo drink	540 ± 113	19	0.009
Nanobubble drink	582 ± 138		

Table 4 summarizes the anaerobic capacity, measured through the Wingate anaerobic test, which is increased by 7.7% with consumption of the oxygenated nanobubble-infused drink as compared to placebo drink.

Table 5
The mean Fatigue index following the Wingate test: Placebo vs nanobubble drink

Wingate test: Fatigue Index (%)	Mean ± SD	df	*p* value
Placebo drink	45.3 ± 10.03	19	< 0.001
Nanobubble drink	41 ± 10.30		

Table 5 describes the fatigue index, and it shows that it dropped by 9.5%, indicating better fatigue resistance, reflecting improved resistance to fatigue following oxygenated nanobubble-infused drink consumption.

Discussion

The present study evaluated the effects of an oxygenated nanobubble-infused drink on both aerobic performance during the modified Bruce protocol treadmill test and anaerobic performance during the Wingate anaerobic test, an aspect that has been mostly overlooked in earlier studies. To the best of our knowledge, this is the first study to report performance enhancement through oxygenated nanobubble-

infused drink consumption, demonstrating improvement in both aerobic and anaerobic capacity. This study explored the short-term ergogenic effects of oxygenated nanobubble-infused drinks on aerobic and anaerobic performance as well as fatigue resistance among recreational endurance runners. With a crossover trial design, participants underwent both placebo and nanobubble interventions, allowing for within-subject comparisons. The result showed that drinking a nanobubble drink consistently improved the VO_2 peak, anaerobic capacity, and fatigue index, indicating potential performance benefits from this novel intervention. The result demonstrated that supplementing with oxygen nanobubbles produced quantifiable improvements in these measures when compared to placebo, which aligns with and extends findings from earlier studies on oxygen-rich interventions(25).

The participants' mean age was 22.6 ± 2.37 years, and their BMI was 24.1 ± 4.12 kg/m². The mean waist circumference in this study was 88.4 ± 8.93, which was in the low to high-risk category. Adequate skeletal muscle mass and endurance in this population indicated that they are a moderately trained population. The proportion of body fat percentage and skeletal muscle mass (32.1 ± 4.06 and 20.6 ± 8.77, respectively) in recreational endurance runners may represent adaptations linked to regular endurance activity(26). The average sit-and-reach flexibility score among participants in our study was approximately 7.7cm, which indicates that they have good flexibility levels. According to Mayorga-Vega D et al. (2024), the normative values for adults range from + 6 to + 16 cm. Both male and female individuals have adequate flexibility for endurance performance, as indicated by the average score(27). Upper-body strength in the study participants was relatively low, wity mean 1RM bench press value of 125.8 ± 30.5 lb and strength to bodyweight ratio of 0.79. These values fall below reported normative values for recreationally trained young adults. These findings reflect the sports-specific training profile of endurance runners, who more likely prioritise aerobic capacity and lower limb strength than upper-body strength. Previous literature indicates that endurance athletes often demonstrate lower absolute and relative upper-body strength compared with strength and power trained individuals(28). Lower-body strength, on other hand, was significantly higher (239.2 ± 48.2lb), which is indicative of metabolic and biomechanical demands of endurance runners, they need the repetitive production of force from the lower extremities. This difference in strength between upper and lower body is in line with normal physiological changes which seen in populations that have received endurance training(29).

The aerobic capacity (VO_2 peak) of participants improved from 64.3 ± 7.55ml/kg/min (placebo) to 68.5 ± 9.4855ml/kg/min following oxygenated nanobubble-infused drink consumption. Representing an approximate 6.5% increase that may be of physiological significance for endurance athletes, as even slight improvements can influence competition outcomes. The observed increase in VO_2 peak aligns with the idea that an oxygenated nanobubble-infused drink could enhance oxygen supply to working muscles, hence increasing aerobic capacity during high-intensity endurance efforts. This is in line with other studies on ozone nanobubble water in animal models, where the therapy improved mice's total exercise endurance and oxygen consumption (VO_2)(30).

Similarly, the study revealed a statistically significant improvement in anaerobic capacity among recreational endurance runners after consumption of oxygenated nanobubble-infused drink ($p = 0.009$),

and a significant reduction in fatigue index (p = < 0.001) was observed. This indicates better buffering against metabolic byproducts like lactate, potentially delaying the onset of muscular fatigue. This is consistent with results from a randomized, placebo-controlled study by King et al on competitive cyclists that found that an oxygen nanobubble beverage increased repeated sprint peak power by 7.1% and 16.1-km time trial performance by 2.4% due to increased submaximal and high-intensity efforts(25). The concept of increased exercise tolerance and delayed fatigue was supported by another randomized crossover trial that found that single- nanosized oxygen nanobubble water increased work rate at lactate threshold by 5%(31).

This study has several limitations. The small sample size (n = 20), which restricts the generalizability of the results and raises the risk of statistical errors, especially when assessing small-to moderate effect sizes. Furthermore, long-term safety, efficacy and any physiological changes linked to repeated use of oxygenated nanobubble-infused drinks are yet unknown because only short-term effects were investigated. Another limitation is the lack of physiological and biochemical indicators, including blood lactate, oxygen saturation and respiratory exchange ratio. Further research using these metrics would offer a more in-depth mechanistic understanding of the physiological effects of oxygenated nanobubble supplementation.

Future research should investigate dose-response relationships, long-term supplementation, and underlying physiological mechanisms. Comparative studies with alternative oxygen delivery techniques may further validate the oxygenated nanobubble-infused drink as a non-invasive ergogenic aid.

Conclusions

Oxygenated nanobubble-infused drinks showed the ability to enhance both aerobic and anaerobic performance metrics in recreational endurance runners. Improvement observed in anaerobic capacity and fatigue resistance aligns with earlier findings on oxygen-rich supplementation, which indicate potential ergogenic benefit. With the growing interest in non-pharmacological performance aids, nanobubble technology-based oxygen supplementation represents a novel and practical tool in the athletic population; however, larger trials are needed to validate effectiveness and underlying mechanisms.

Declarations

Conflict of interest

The authors declare no conflict of interest

Ethical approval

The study was conducted in accordance with the Declaration of Helsinki, and the Institutional Ethical Committee's approval was obtained. IEC number: IEC1: 437/2024

Informed consent

Written informed consent was obtained from all the participants

Funding

This study was funded by IOTA Nanotechnology Private Limited

Author Contribution

All authors contributed equally to the present study. Conceptualization was performed by A.M. Methodology was developed by A.M, B.C and M.S. Formal analysis and investigation were carried out by A.M, P.N, R.K, and M.S. Manuscript draft preparation was completed by P.N, R.M and A.H. Testing and data collection were conducted by P.N and R.K. All authors reviewed, edited, and approved the final manuscript.

Acknowledgement

We would like to thank all of the participants for their time and effort during the study. We would also like to acknowledge• Department of Physiotherapy, Center for Podiatry & Diabetic Foot Care and Research, and Department of Exercise and Sports Science from Manipal College of Health Professions, Manipal• IOTA Nanotechnology Pvt. Ltd., for supplying oxygenated nanobubbles and placebo drinks and for their valuable input throughout the project.We would also like to acknowledge the guidance, encouragement, and constructive feedback provided by our colleagues and research assistants, whose expertise greatly enhanced the quality of this work.

References

1. Hirayama H, Yamamoto M. Effects of Canoe Ergometer Training in Normal and Hypoxic Environment in Elite Canadian Canoeists. Journal of Training Science for Exercise and Sport. 2011;23(1):63–75.
2. Ross R, Arena R, Myers J, Kokkinos P, Kaminsky LA. Update to the 2016 American Heart Association cardiorespiratory fitness statement. Prog Cardiovasc Dis. 2024;83:10–5.
3. Piantadosi CA. "Oxygenated" water and athletic performance. Br J Sports Med. 2006;40(9):740–1.
4. Williams JH, Powers SK, Stuart MK. Hemoglobin desaturation in highly trained athletes during heavy exercise. Med Sci Sports Exerc. 1986;18(2):168–73.

5. Hamlin MJ, Draper N, Blackwell G, Shearman JP, Kimber NE. Determination of maximal oxygen uptake using the bruce or a novel athlete-led protocol in a mixed population. J Hum Kinet. 2012;31:97–104.
6. Willmert N, Porcari J, Foster C, Doberstein S, Brice G, Willmert J, et al. The effects of oxygenated water on exercise physiology during incremental exercise and recovery. 2002;5.
7. Mallette MM, Stewart DG, Cheung SS. The Effects of Hyperoxia on Sea-Level Exercise Performance, Training, and Recovery: A Meta-Analysis. Sports Med. 2018;48(1):153–75.
8. Sperlich B, Zinner C, Hauser A, Holmberg HC, Wegrzyk J. The Impact of Hyperoxia on Human Performance and Recovery. Sports Med. 2017;47(3):429–38.
9. Ulrich S, Hasler ED, Müller-Mottet S, Keusch S, Furian M, Latshang TD, et al. Mechanisms of Improved Exercise Performance under Hyperoxia. Respiration. 2017;93(2):90–8.
10. Périard JD, Houtkamp D, Bright F, Daanen H a. M, Abbiss CR, Thompson KG, et al. Hyperoxia enhances self-paced exercise performance to a greater extent in cool than hot conditions. Exp Physiol. 2019;104(9):1398–407.
11. Müller W, Neufurth M, Wang S, Schröder H, Wang X. Polyphosphate Nanoparticles: Balancing Energy Requirements in Tissue Regeneration Processes. SMALL. 2024;20(33).
12. Leon BR, Romary DJ, Landsberger SA, Bradner KN, Ramirez M, Lubitz RM. Risks of ozonated oil and ozonated water on human skin: A systematic review. Int Wound J. 2022;19(7):1901–10.
13. Gombodorj N, Yokobori T, Mutsuki N, Erkhem-Ochir B, Okami H, Asao T, et al. Effects of Ultrafine Single-Nanometer Oxygen Bubbles on Radiation Sensitivity in a Tumor-Bearing Mouse Model. Int J Mol Sci. 2022;23(12):6838.
14. Merrigan J, Stute N, Eckerle J, Mackowski N, Walters J, O'Connor M, et al. Reliability and Validity of Contemporary Bioelectrical Impedance Analysis Devices for Body Composition Assessment: Original Research. JEN [Internet]. 2022 Nov 10 [cited 2026 Feb 10];5(4). Available from: https://www.journalofexerciseandnutrition.com
15. Campa F, Toselli S, Mazzilli M, Gobbo LA, Coratella G. Assessment of Body Composition in Athletes: A Narrative Review of Available Methods with Special Reference to Quantitative and Qualitative Bioimpedance Analysis. Nutrients. 2021;13(5):1620.
16. Rottensteiner M, Mäkelä S, Bogl LH, Törmäkangas T, Kaprio J, Kujala UM. Sport disciplines, types of sports, and waist circumference in young adulthood - a population-based twin study. Eur J Sport Sci. 2017;17(9):1184–93.
17. Mayorga-Vega D, Merino-Marban R, Viciana J. Criterion-Related Validity of Sit-and-Reach Tests for Estimating Hamstring and Lumbar Extensibility: a Meta-Analysis. J Sports Sci Med. 2014;13(1):1–14.
18. Kim PS, Mayhew JL, Peterson DF. A modified YMCA bench press test as a predictor of 1 repetition maximum bench press strength. J Strength Cond Res. 2002;16(3):440–5.
19. Clark NC, Reilly LJ, Davies SC. Intra-rater reliability, measurement precision, and inter-test correlations of 1RM single-leg leg-press, knee-flexion, and knee-extension in uninjured adult agility-

sport athletes: Considerations for right and left unilateral measurements in knee injury control. Phys Ther Sport. 2019;40:128–36.

20. Sedano S, Marín PJ, Cuadrado G, Redondo JC. Concurrent training in elite male runners: the influence of strength versus muscular endurance training on performance outcomes. J Strength Cond Res. 2013;27(9):2433–43.
21. Badawy MM, Muaidi QI. Cardio respiratory response: Validation of new modifications of Bruce protocol for exercise testing and training in elite Saudi triathlon and soccer players. Saudi J Biol Sci. 2019;26(1):105–11.
22. Vilcant V, Zeltser R. Treadmill Stress Testing. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 [cited 2026 Feb 10]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK499903/
23. Ramírez-Vélez R, López-Albán CA, La Rotta-Villamizar DR, Romero-García JA, Alonso-Martinez AM, Izquierdo M. Wingate Anaerobic Test Percentile Norms in Colombian Healthy Adults. The Journal of Strength & Conditioning Research. 2016;30(1):217.
24. Hachana Y, Attia A, Nassib S, Shephard RJ, Chelly MS. Test-retest reliability, criterion-related validity, and minimal detectable change of score on an abbreviated Wingate test for field sport participants. J Strength Cond Res. 2012;26(5):1324–30.
25. King DG, Stride E, Mendis J, Gurton WH, Macrae H, Jones L, et al. A Double-Blind, Randomized, Placebo-Controlled Pilot Study examining an Oxygen Nanobubble Beverage for 16.1-km Time Trial and Repeated Sprint Cycling Performance. J Diet Suppl. 2024;21(2):167–81.
26. Kutac P, Bunc V, Buzga M, Krajcigr M, Sigmund M. The effect of regular running on body weight and fat tissue of individuals aged 18 to 65. J Physiol Anthropol. 2023;42(1):28.
27. Mayorga-Vega D, Merino-Marban R, Viciana J. Criterion-Related Validity of Sit-and-Reach Tests for Estimating Hamstring and Lumbar Extensibility: a Meta-Analysis. J Sports Sci Med. 2014;13(1):1–14.
28. Bazyler CD, Abbott HA, Bellon CR, Taber CB, Stone MH. Strength Training for Endurance Athletes: Theory to Practice. Strength & Conditioning Journal [Internet]. 2015 Apr 1 [cited 2026 Feb 10];37. Available from: https://dc.etsu.edu/etsu-works/3781
29. Vernillo G, Giandolini M, Edwards WB, Morin JB, Samozino P, Horvais N, et al. Biomechanics and Physiology of Uphill and Downhill Running. Sports Med. 2017;47(4):615–29.
30. Tsai CJ, Hsu PC, Kuo M l, Chen YM. Ozone Nanobubble Water as a Sustainable Strategy to Enhance Metabolism, Muscle Function, and Exercise Performance in Mice. Nutrients. 2025;17(17):2821.
31. Muramoto Y, Ishida N, Minaguchi E, Sugai K, Daigo K, Iwasawa Y, et al. Positive effects of single-nanosized oxygen nanobubble water on exercise tolerance: A randomized crossover trial. Current Research in Physiology. 2025;8:100159.

Figures

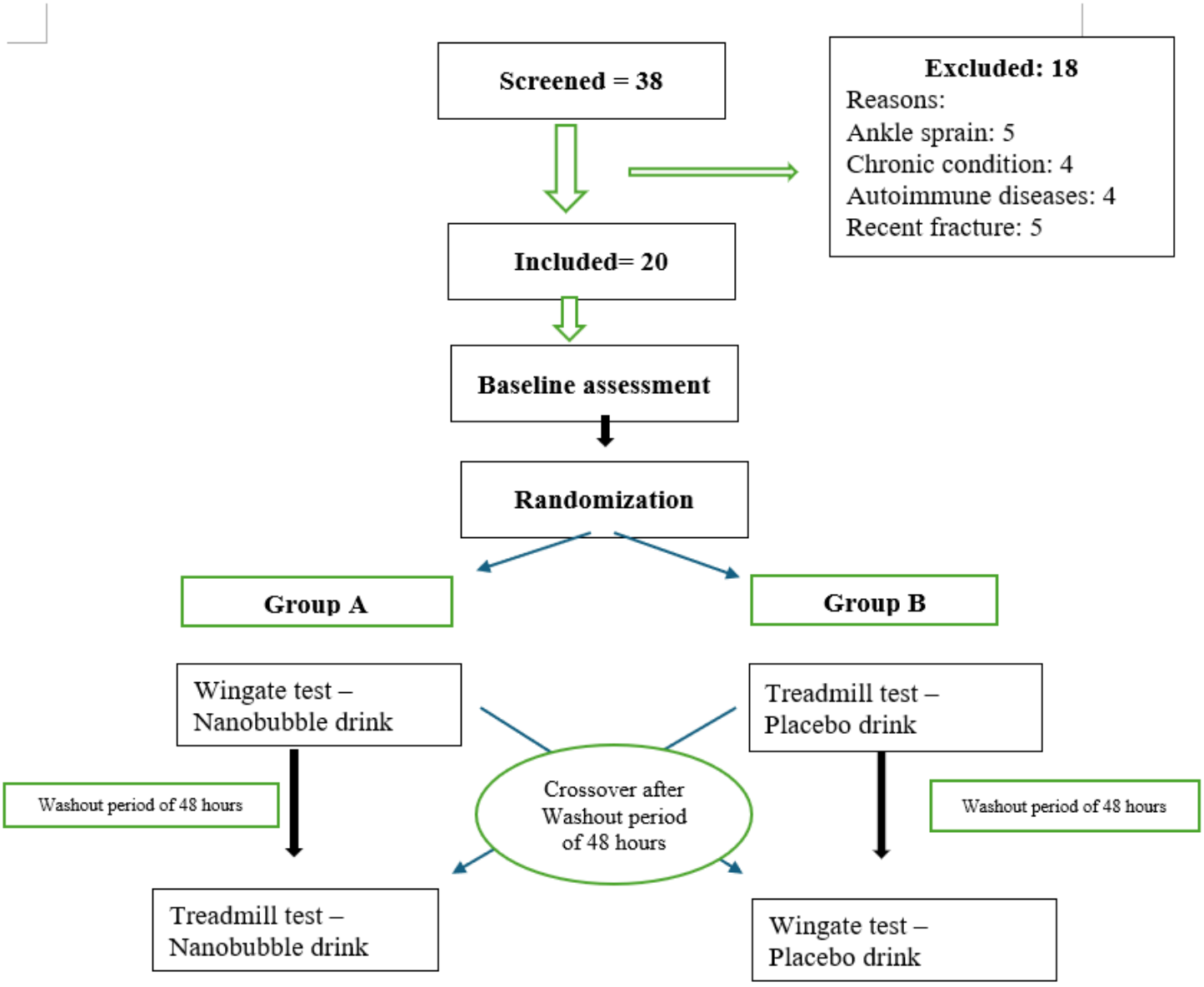


Figure 1

Bioelectrical Impedance Analysis (BIA)