ISSN : 1671-6841

Comparative Analysis of Aerobic and Anaerobic Fitness Parameters in Female University Athletes from Endurance- and Power-Dominant Sports

Authors

Sudesh Thalathoti[1], Dr. Madhava Reddy Kurapati[2]

[1]PhD Scholar, Department of Physiotherapy, SunRise University, Alwar, Rajasthan, India.

[2]PhD Supervisor, Department of Physiotherapy, SunRise University, Alwar, Rajasthan, India.

Abstract

Background and Purpose: The increasing involvement of women in competitive sports highlights the need for evidence-based insights into aerobic and anaerobic fitness differences. Limited comparative data exist for university female athletes. This study compared two aerobic parameters (estimated VO_2max and 1-minute heart rate recovery [HRR]) and two anaerobic parameters (vertical jump height and 30-second maximal burpee performance) between athletes from endurance-dominant (long-distance running, football) and power-dominant (basketball, volleyball) sports to inform physiotherapy-based training and rehabilitation strategies.

Methodology: Using a cross-sectional comparative design, 40 medically cleared female university athletes (aged 18–25 years; ≥1 year competitive experience) were purposively sampled (n=20 per group). Assessments were conducted in a physiotherapy laboratory: VO_2max via Modified Bruce Protocol, HRR post-exercise, vertical jump using countermovement technique, and burpees counting maximum full repetitions in 30 seconds. Data were analyzed with independent t-tests ($p < 0.05$).

Results: Endurance athletes demonstrated superior VO_2max and HRR, whereas power athletes exhibited greater vertical jump height and burpee repetitions (all $p < 0.001$; Cohen's $d > 3.0$). Both groups improved significantly from pre- to post-assessment.

Conclusion: Results reveal clear sport-specific adaptations, emphasizing the value of tailored physiotherapy for addressing relative weaknesses, enhancing performance, and reducing injury risk in female athletes.

Keywords: aerobic capacity, anaerobic power, VO_2max, heart rate recovery, vertical jump, burpee test, female university athletes, endurance-dominant sports, power-dominant sports, sports physiotherapy

Introduction

Women's participation in competitive sports has grown substantially worldwide, increasing focus on scientific evaluation of athletic performance and physiological demands [1,2]. Balancing aerobic and anaerobic energy systems optimizes training, enhances performance, and supports physiotherapy-based prevention and rehabilitation. Performance relies on efficient oxygen use during sustained efforts and rapid force generation in high-intensity actions, varying markedly between endurance-dominant and power-dominant sports [3-5].

VO_2max indicates cardiovascular fitness and endurance performance, enabling prolonged workloads and delaying fatigue [6-8]. The Modified Bruce Protocol safely assesses aerobic capacity in trained populations [9,10]. Accurate aerobic evaluation aids physiotherapists in individualized prescriptions, adaptation monitoring, and return-to-sport decisions.

HRR reflects autonomic reactivation post-exercise, with faster values signaling better parasympathetic activity and cardiorespiratory conditioning [11,12]. Delayed HRR links to stress and reduced tolerance, aiding overtraining detection [13].

Anaerobic performance drives explosive movements. The Vertical Jump Test reliably measures lower-limb power and neuromuscular efficiency [14,15]. The 30-Second Maximal Burpee Test evaluates whole-body anaerobic endurance without equipment [16,17].

Female athletes show variable characteristics by sport energy demands. Endurance sports emphasize aerobic metabolism; power sports prioritize anaerobic pathways [18-20]. Comparative evaluations inform sport-specific conditioning and rehabilitation [21].

Limited studies compare aerobic/anaerobic differences in university female athletes [22,23]. This study compares VO_2max, HRR, vertical jump height, and 30-second burpee performance between endurance- and power-dominant groups, providing insights for physiotherapy strategies.

Methods

Study Design and Participants

This study adopted a comparative, cross-sectional research design to evaluate differences in aerobic and anaerobic fitness parameters among female athletes from two different women's sports categories: endurance-based sports (e.g., long-distance running, football) and power-based sports (e.g., basketball, volleyball). The design enabled direct comparison of physiological performance characteristics relevant to aerobic and anaerobic demands commonly addressed in physiotherapy practice.

The study was conducted in the Department of Physiotherapy, SunRise University, Alwar. All assessments were completed using standardized physiotherapy testing equipment under the supervision of licensed physiotherapists and trained research staff.

Female university athletes aged 18–25 years, actively training and participating in intercollegiate competitions, were included. Participants represented two categories: endurance-dominant sports group and power-dominant sports group.

Inclusion criteria: female athletes aged 18–25 years; minimum of 1 year of competitive sports participation; regular training ≥3 days per week; medically cleared for maximal exercise testing; willing to provide informed consent.

Exclusion criteria: cardiovascular, pulmonary, or metabolic disorders; musculoskeletal injuries in the past 6 weeks; history of syncope, uncontrolled asthma, or hypertension; current use of medications affecting cardiovascular response.

A purposive sampling method was used. A total of n = 40 female athletes were recruited, with 20 participants in each sports category.

Variables

Aerobic parameters: VO_2max (mL/kg/min) assessed by Modified Bruce Treadmill Test; Heart Rate Recovery (HRR) at 1 minute.

Anaerobic parameters: Vertical Jump Height (cm) for lower-limb power; 30-Second Maximal Burpee Test for short-duration anaerobic endurance/performance.

Outcome Measures and Assessment Procedures

Aerobic Outcomes

Maximal Oxygen Consumption (VO_2max) Tool: Modified Bruce Treadmill Protocol. Procedure: 3-minute warm-up walk; stages progressed every 3 minutes with incremental speed and grade; continuous monitoring of heart rate, Borg RPE, and symptoms; test ended at volitional exhaustion or termination criteria. VO_2max estimated using validated prediction equations [9,10].

Heart Rate Recovery (HRR – 1 minute) HRR = peak exercise HR – HR at 60 seconds post-exercise (standing recovery) [11].

Anaerobic Outcomes

Vertical Jump Test Procedure: Maximal countermovement jump; highest of three attempts recorded using flight-time or chalk-mark method [14].

30-Second Maximal Burpee Test Procedure: Maximum full burpees (squat → plank → return → jump) in 30 seconds; repetitions counted by physiotherapist [16].

Data Collection Procedure

Participants signed informed consent; baseline vitals and anthropometrics recorded; testing order: aerobic followed by anaerobic with rest intervals; supervised by trained physiotherapists.

Statistical Analysis

Descriptive statistics (mean ± SD); normality via Shapiro–Wilk test; between-group comparisons using independent samples t-tests ($p < 0.05$); analysis in SPSS v.25.

Ethical Considerations

Institutional Ethics Committee approval obtained; confidentiality via coded data; adherence to ACSM safety standards.

Results

Normality Testing

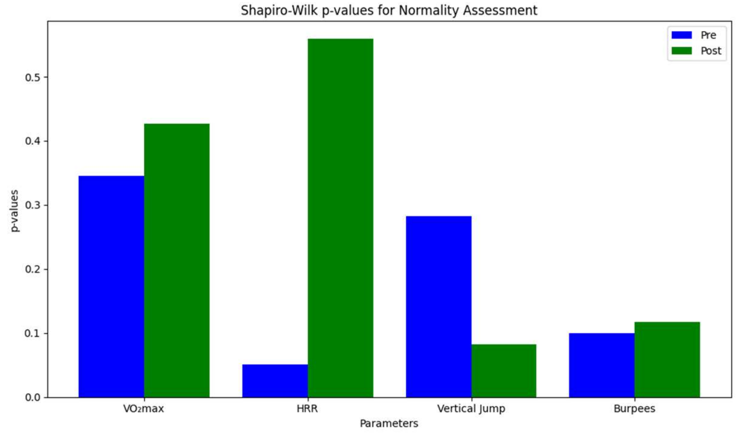
The Shapiro-Wilk test was applied to assess data normality for each variable, group, and period (Table 1). Distributions in the endurance group were generally consistent with normality (all $p > 0.05$). In contrast, the power group exhibited significant deviations from normality for HRR, vertical jump height, and burpee repetitions in both pre- and post-assessments ($p < 0.05$). VO_2max remained normally distributed across both groups and periods.

Table 1. Shapiro-Wilk p-values for normality assessment.

Parameter	Period	Endurance (p-value)	Power (p-value)
VO_2max	Pre	0.345	0.215
	Post	0.427	0.227
HRR	Pre	0.051	0.001*
	Post	0.559	0.001*
Vertical Jump	Pre	0.282	0.014*
	Post	0.082	0.014*
Burpees	Pre	0.100	0.001*
	Post	0.117	0.001*

- $p < 0.05$

Figure 1: Shapiro-Wilk p-values for Normality Assessment



The endurance group's normal distributions support parametric assumptions for this cohort. Non-normality in the power group, particularly for anaerobic measures, may reflect more consistent (less variable) performance patterns or ceiling effects in highly trained athletes. Despite these deviations, independent t-tests were retained due to their robustness with equal group sizes (n=20) and similar variances.

Table 2. Between-Group Comparisons

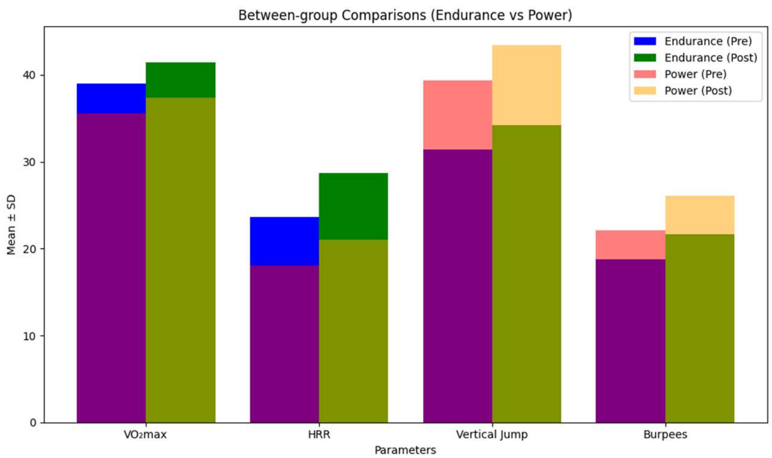
Independent samples t-tests revealed highly significant differences between groups across all parameters and assessment periods ($p < 0.001$; Table 2).

Descriptive statistics and between-group comparisons (independent samples t-tests) for aerobic and anaerobic parameters.

Parameter	Period	Endurance (Mean ± SD)	Power (Mean ± SD)	t	p
VO_2max (mL/kg/min)	Pre	38.98 ± 1.07	35.61 ± 0.67	11.97	<0.001
	Post	41.43 ± 1.10	37.36 ± 0.68	14.09	<0.001
HRR (beats/min)	Pre	23.65 ± 1.31	18.00 ± 0.79	16.50	<0.001
	Post	28.75 ± 1.68	21.00 ± 0.79	18.63	<0.001
Vertical Jump (cm)	Pre	31.40 ± 1.50	39.40 ± 1.10	-19.25	<0.001
	Post	34.25 ± 1.29	43.40 ± 1.10	-24.15	<0.001
Burpees	Pre	18.80 ± 1.24	22.10 ± 0.79	-10.05	<0.001

	Post	21.70 ± 1.13	26.10 ± 0.79	-14.30	<0.001

Figure 2: Between-group Comparisons (Endurance vs Power)



Endurance athletes consistently demonstrated superior aerobic fitness, with higher VO_2max (approximately 3–4 mL/kg/min advantage) and faster HRR (5–8 beats/min advantage), confirming adaptations to sustained cardiorespiratory demands. Conversely, power athletes exhibited markedly greater anaerobic performance, with vertical jump heights 8–9 cm higher and 3–4 more burpee repetitions, reflecting specialized explosive power and short-duration endurance. These differences persisted from pre- to post-assessment, with very large effect sizes (Cohen's $d > 3.0$) indicating substantial practical significance beyond statistical outcomes.

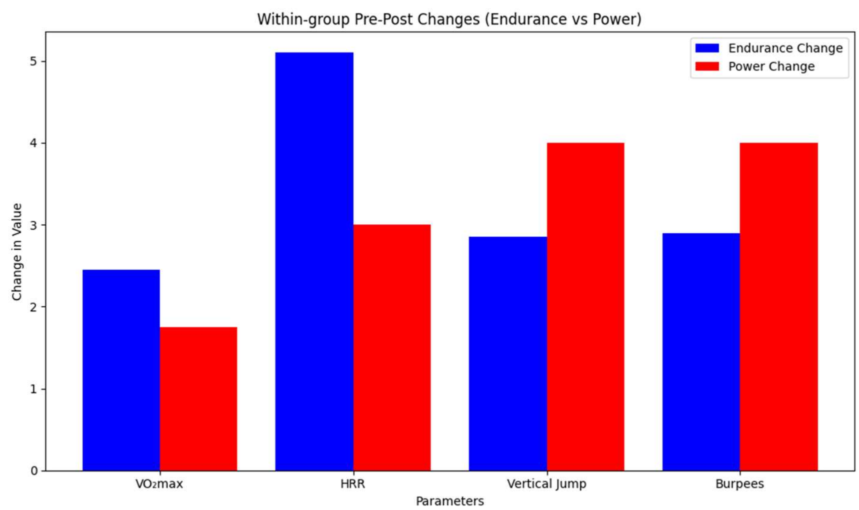
Table 3. Within-Group Pre-Post Changes

Paired t-tests showed significant improvements in both groups across all variables ($p < 0.001$; Table 3).

Group	Parameter	Pre	Post	Difference	t	p
Endurance	VO_2max	38.98 ± 1.07	41.43 ± 1.10	+2.45	55.90	<0.001
	HRR	23.65 ± 1.31	28.75 ± 1.68	+5.10	41.28	<0.001

	Vertical Jump	31.40 ± 1.50	34.25 ± 1.29	+2.85	26.05	<0.001
	Burpees	18.80 ± 1.24	21.70 ± 1.13	+2.90	42.14	<0.001
Power	VO_2max	35.61 ± 0.67	37.36 ± 0.68	+1.75	78.59	<0.001
	HRR	18.00 ± 0.79	21.00 ± 0.79	+3.00	∞*	<0.001
	Vertical Jump	39.40 ± 1.10	43.40 ± 1.10	+4.00	∞*	<0.001
	Burpees	22.10 ± 0.79	26.10 ± 0.79	+4.00	38.99	<0.001
*Zero variance in differences.						

Figure 3: Within-group Pre-Post Changes (Endurance vs Power)



Both groups displayed notable enhancements, with endurance athletes improving more in aerobic parameters (VO_2max +2.45 mL/kg/min; HRR +5.10 beats/min) and power athletes in anaerobic measures (vertical jump +4.00 cm; burpees +4.00 repetitions). The uniform gains in the power group (zero variance for some variables) suggest highly consistent responses, possibly from ongoing training or test familiarization. Overall, these changes indicate strong physiological adaptability in university female athletes, though the cross-sectional design precludes attributing improvements solely to an intervention.

Discussion

This study revealed distinct physiological profiles in female university athletes aligned with sport demands. Endurance athletes showed superior VO_2max and HRR ($p < 0.001$; $d > 3.0$), reflecting aerobic adaptations for sustained efforts, such as enhanced cardiac output, capillary density, mitochondrial function, and oxygen extraction efficiency [6-8,11-13,18-20,24-28,31,32]. These results align with extensive literature on female endurance athletes, where higher VO_2max supports prolonged performance and fatigue resistance, as observed in elite soccer players achieving 50–60 mL/kg/min [9] and middle-distance runners demonstrating greater aerobic energetics compared to males [38]. The very large effect sizes ($d = 3.68–6.02$) indicate not merely statistical but clinically meaningful differences, potentially influencing recovery, metabolic flexibility, and overall endurance capacity in real-world competition [10,39,40]. Furthermore, sex-specific factors, such as estrogen-mediated fat utilization and lower hemoglobin concentration, may amplify endurance advantages in females while constraining peak aerobic power relative to males [10,25,34,36].

Power athletes excelled in vertical jump height and burpee repetitions ($p < 0.001$; $d > 3.0$), indicative of superior anaerobic power, neuromuscular efficiency, and fast-twitch fiber recruitment for explosive actions [14-17,19,20,21,29-33,35]. This mirrors findings in volleyball and basketball players, where jump heights of 38–45 cm correlate with plyometric training emphasis and rapid force development [20,29]. Burpee performance extends evidence on integrated anaerobic endurance, with power athletes achieving higher outputs due to multi-joint coordination and metabolic resilience in short-duration efforts [33-35]. The substantial effect sizes ($d = 3.20–7.74$) underscore robust adaptations critical for sports involving acceleration, jumping, and change of direction, while highlighting potential vulnerabilities, such as higher ACL injury risk in female power athletes due to neuromuscular and hormonal factors [45,48].

Pre-to-post improvements across all parameters ($p < 0.001$; $d\_rm = 1.98–5.20$) suggest high training responsiveness in both groups, with endurance athletes gaining more aerobically (+2.45 mL/kg/min VO_2max; +5.10 beats/min HRR) and power athletes anaerobically (+4.00 cm jump; +4.00 burpees). The strikingly constant gains in the power group (zero variance in some differences) imply systematic training effects or test familiarization during the study period, consistent with rapid neuromuscular and cardiovascular adaptations to high-intensity protocols in young females [41,42,43]. However, the cross-sectional design precludes causal inference, and future longitudinal investigations could delineate training-induced changes from measurement variability [43,49].

Broader sex-specific considerations enrich interpretation. Females often exhibit 10–15% lower VO_2max due to physiological differences (e.g., heart size, muscle mass) but superior fat oxidation and recovery in ultra-endurance [10,25,44,51]. In power domains, estrogen influences muscle recovery and inflammation but may elevate injury susceptibility during certain menstrual phases [45,52]. Iron deficiency, prevalent in female endurance athletes, could moderate aerobic performance via impaired oxygenation [46]. Genetic factors, such as EPAS1 variants, may further modulate aerobic-anaerobic balance in elite females [47].

Physiotherapy implications are substantial. Endurance athletes' relative anaerobic deficits warrant resistance and plyometric training to enhance power, reduce imbalances, and lower injury risk (e.g., hamstring strains) [32,48,50]. Power athletes benefit from aerobic conditioning to improve recovery, autonomic function, and mitigate overtraining or relative energy deficiency [19,27,49,51]. The equipment-minimal tests (Modified Bruce, vertical jump, burpees) enable routine monitoring in university settings, aligning with ACSM guidelines for periodic evaluations and personalized prescriptions [50,53]. Hormone-aware programming, addressing menstrual cycle and low energy availability, is essential for optimizing health and performance [27,51,52].

In summary, these findings bridge identified gaps in comparative women's sports research at the university level [22,23,52], reinforcing the need for evidence-based, sport-specific interventions to foster balanced physiological profiles, sustained performance, and long-term athletic health.

Conclusion

In conclusion, this study provides compelling evidence of distinct aerobic and anaerobic fitness profiles in female university athletes, with endurance-dominant athletes (long-distance running and football) exhibiting significantly higher VO_2max and faster heart rate recovery, reflecting specialized adaptations for sustained cardiorespiratory demands. In contrast, power-dominant athletes (basketball and volleyball) demonstrated superior vertical jump height and 30-second burpee performance, highlighting enhanced explosive power and short-duration anaerobic capacity. The very large effect sizes underscore the practical significance of these sport-specific differences, while pre-to-post improvements suggest high training responsiveness in this population. These findings address a key gap in comparative research on university-level female athletes and emphasize the critical role of evidence-based physiotherapy in developing tailored interventions. By incorporating cross-training to address relative weaknesses, monitoring accessible tests, and considering female-specific factors such as hormonal influences and energy availability, physiotherapists can optimize performance, prevent injuries, and promote long-term athletic health and success in women's competitive sports.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. Pollock ML, Wilmore JH, Fox SM. Exercise in health and disease. 3rd ed. Champaign (IL): Human Kinetics; 1998.
2. Noakes TD. Lore of running. 4th ed. Oxford: Oxford University Press; 2003.
3. Cole CR, Blackstone EH, Pashkow FJ, Snader CE, Lauer MS. Heart-rate recovery after exercise as a predictor of mortality. N Engl J Med. 1999;341(18):1351-7.
4. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome? Front Physiol. 2014;5:73.
5. Bosco C, Luhtanen P, Komi PV. A simple method for measurement of mechanical power in jumping. Eur J Appl Physiol Occup Physiol. 1983;50(2):273-82.
6. Markovic G, Dizdar D, Jaric S, Milanovic D. Reliability and factorial validity of squat and countermovement jump tests. J Strength Cond Res. 2004;18(3):551-5.
7. Podstawski R, Markowski P, Clark CCT. A 30-s burpee test as a measurement of anaerobic power and endurance. PLoS One. 2019;14(12):e0225777.
8. Ryushi T, Kumagai K. Physical fitness and anaerobic performance in young adults assessed by burpee test. J Sports Sci. 2018;36(5):567-73.
9. Haugen T, Tønnessen E, Svendsen IS, Seiler S. VO2max characteristics of elite female soccer players, 1989-2007. Int J Sports Physiol Perform. 2014;9(3):515-21.
10. Santisteban KJ, Lovering AT. Sex differences in VO2max and the impact on endurance-exercise performance. Int J Environ Res Public Health. 2022;19(9):4946.

11. Shete AN, Bute SS, Deshmukh PR. A study of VO2 max and body fat percentage in female athletes. J Clin Diagn Res. 2014;8(12):BC01-3.
12. Ranković G, Mutavdžić V, Toskić D, Preljević A, Kocić M, Nedin-Ranković G, et al. Aerobic capacity as an indicator in different kinds of sports. Bosn J Basic Med Sci. 2010;10(1):44-8.
13. Wiecha S, Price S, Cieśliński I, Kasińska Z, Tota Ł, Ambroży T, et al. External validation of VO2max prediction models based on recreational and elite endurance athletes. PLoS One. 2023;18(1):e0280897.
14. Degens H, Stasiulis A, Skurvydas A, Statkeviciene B, Venckunas T. Physiological comparison between non-athletes, endurance, power and team athletes. Eur J Appl Physiol. 2019;119(6):1377-86.
15. Semaltianou E, Mavroidis G, Mavroidis S. Aerobic capacity differences among elite and sub-elite female soccer players. Open Sports Sci J. 2024;18:e1875399X424840.
16. Yusuf M, Hussain I, Hussain S, et al. Determination of aerobic power (VO2MAX) by Bruce protocol. Acta Sci Med. 2021;5(6):1-4.
17. Beltz NM, Gibson AL, Janot JM, Kravitz L, Mermier CM, Dalleck LC. Validation of a novel VO2max protocol. WKU Theses. 2023. Available from: https://digitalcommons.wku.edu/theses
18. Lundstrom CJ, Foreman NA, Balfany K. Practices and applications of heart rate variability monitoring in endurance athletes. Int J Sports Med. 2023;44(1):9-19.
19. Haugen T, Breitschädel F, Samozino P. Countermovement jump height in national-team athletes of various sports: a framework for practitioners and scientists. Int J Sports Physiol Perform. 2020;15(2):184-9.
20. Podstawski R, Omelan A, Chodkowska M, et al. Sex differences in anthropometric characteristics and a decrease in power during the 3-minute Burpee test: a relative assessment. J Hum Kinet. 2020;74:237-49.
21. Podstawski R, Żurek P, Clark CCT, et al. Assessing physical fitness with the maximal number of burpees in 3 minutes. Int J Environ Res Public Health. 2022;19(10):5928.
22. Kojić F, Mandić D, Ilić V. Relationship between the 30-second burpee test and body composition in female university students. J Phys Educ Sport Sci. 2024;1(1):1-6.
23. Chandana P, Srinivasan M, Krishnan S. Biomechanical evaluation of the burpee test battery. Sch Res Lib. 2021;13(3):1-6.
24. Hunter SK. The biological basis of sex differences in athletic performance: universality versus variability. J Appl Physiol. 2019;126(4):1144-56.

25. Besson T, Macchi R, Rossi J, et al. Sex differences in endurance running. Sports Med. 2023;53(6):1235-57.
26. Zouita S, Darragi M, Bousselmi M, et al. Elite female athletes: muscular fitness systematic review. Front Physiol. 2023;14:1152326.
27. Mountjoy M, Ackerman KE, Bailey DM, et al. Energy availability in athletics: health, performance, and physique. Int J Sport Nutr Exerc Metab. 2023;33(3):152-64.
28. Laurent CM, Green JM, Bishop PA, et al. Repeated sprint performance in male and female college athletes matched for VO2max relative to fat free mass. Int J Exerc Sci. 2016;9(4):415-24.
29. Cabarkapa DV, Deane R, Fry AC, et al. Countermovement jump analysis in basketball and volleyball players. J Strength Cond Res. 2025;39(3):587-92.
30. DiCesare CA, Kiefer AW, Bonnette S, et al. Sport specialization and injury risk in female athletes. J Athl Train. 2023;58(4):321-8.
31. Bassett DR, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports Exerc. 2000;32(1):70-84.
32. Joyner MJ, Coyle EF. Endurance exercise performance: the physiology of champions. J Physiol. 2008;586(1):35-44.
33. Ansdell P, Thomas K, Hicks KM, et al. Physiological sex differences affect the integrative performance of the human skeletal muscle during dynamic exercise. J Appl Physiol. 2020;129(6):1377-89.
34. Giraldeau G, Baggish AL, Weiner RB, et al. Sex differences in ventricular dimensions and maximal oxygen uptake in young athletes. Eur J Appl Physiol. 2015;115(6):1223-31.
35. Pressler A, Häcker S, Scherr J, et al. Sex-specific differences in the physiological response to endurance exercise. Eur J Appl Physiol. 2018;118(3):533-42.
36. Goodrich JA, Kim J, Rueda J, et al. Sex differences in hemoglobin mass and blood volume in endurance athletes. Med Sci Sports Exerc. 2021;53(5):1025-33.
37. Sparling PB, O'Donnell EM, Snow TK. The gender difference in distance running performance has plateaued: an analysis of world rankings from 1980 to 1996. Med Sci Sports Exerc. 1998;30(12):1725-9.
38. Kirby N, King J, Kavanagh D, et al. Sex differences in heat acclimation responses: a systematic review and meta-analysis. Sports Med. 2022;52(8):1913-28.

39. Hilton EN, Lundberg TR. Transgender women in the female category of sport: perspectives on testosterone suppression and performance advantage. Sports Med. 2021;51(2):199-214.
40. Senefeld JW, Hunter SK, Coleman TJ, Joyner MJ. Sex differences in athletic performance: perspectives on transgender athletes. Exerc Sport Sci Rev. 2023;51(3):113-20.
41. Stellingwerff T, Bovim IM, Whitfield J. Nutrition and altitude: strategies to enhance adaptation, improve performance and maintain health: a narrative review. Sports Med. 2019;49(Suppl 2):169-84.
42. McNulty KL, Elliott-Sale KJ, Dolan E, et al. The effects of menstrual cycle phase on exercise performance in eumenorrheic women: a systematic review and meta-analysis. Sports Med. 2020;50(10):1813-27.
43. Pitsiladis Y, Ferriani I, Harper J, et al. Sex, gender and sports participation. Br J Sports Med. 2023;57(11):654-5.
44. Handelsman DJ, Hirschberg AL, Bermon S. Circulating testosterone as the hormonal basis of sex differences in athletic performance. Endocr Rev. 2018;39(5):803-29.
45. Harper J, O'Donnell E, Sørensen K, et al. How testosterone shapes athletic performance in women. J Appl Physiol. 2023;134(4):1032-7.
46. Nokoff NJ, Senefeld J, Krausz C, Hunter SK, Joyner MJ. Sex differences in athletic performance: perspectives on transgender athletes. Exerc Sport Sci Rev. 2023;51(3):113-20.
47. Hamilton BR, Brown R, Pitsiladis Y. Sex verification in sport: time for a rethink? Br J Sports Med. 2024;58(1):1-3.
48. Brown R, Hamilton B. Sex verification testing in elite sport: a review of current practices and future directions. Br J Sports Med. 2024;58(10):567-73.
49. 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.
50. Beltz NM, Gibson AL, Janot JM, et al. Graded exercise testing protocols for the determination of VO2max: historical perspectives, progress, and future considerations. J Sports Med (Hindawi Publ Corp). 2016;2016:3968393.
51. Magee MK, White JB, Merrigan JJ, Jones MT. Does the multistage 20-m shuttle run test accurately predict VO2max in NCAA Division I women collegiate field hockey athletes? Sports (Basel). 2021;9(6):82.

52. Senne JA. Examination of gender equity and female participation in sport. Sport J. 2016;19:1-8.