

Review Article

Effects of Exercise Type on Testosterone Levels in Female Athletes: A Systematic Review

Pengaruh Jenis Latihan terhadap Kadar Testosteron pada Atlet Perempuan: Sebuah Tinjauan Sistematis

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Abstract

Testosterone is a hormone that plays an important role in stimulating muscle development and regulating fat metabolism. While exercise influences testosterone levels, females generally experience smaller increases in testosterone levels after exercise than males. This has led some female athletes to misuse testosterone, posing potential health risks and altering physiological functions. This systematic review aims to examine the effects of different exercise modalities on testosterone levels in female athletes, providing insights into optimal training approaches. A comprehensive literature search was conducted using PubMed, Google Scholar, Medline, and PEDro, with keywords including "Endurance Exercise," "Resistance Exercise," and "Testosterone Levels in Female Athletes". Of the 45 studies screened, six met the inclusion criteria. The findings suggest that endurance exercises are associated with reduced testosterone levels, whereas resistance training, such as weightlifting and bench pressing, is linked to increased testosterone production. High-intensity resistance training may lower estrogen while elevating testosterone, enhancing muscle strength and lean body mass in female athletes. However, excessive testosterone levels may disrupt menstrual function, despite its beneficial effects on bone health. These findings suggest that resistance training can elevate testosterone levels in female athletes, whereas endurance training tends to decrease them.

Keywords: testosterone level; endurance exercise; resistance exercise; female athletes

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Abstrak

Testosteron adalah hormon yang berperan penting dalam merangsang perkembangan otot dan mengatur metabolisme lemak. Olahraga dapat memengaruhi kadar testosteron, namun pada perempuan umumnya mengalami peningkatan kadar testosteron yang lebih kecil setelah berolahraga dibandingkan laki-laki. Hal ini menyebabkan beberapa atlet perempuan menyalahgunakan testosteron, yang dapat menimbulkan risiko kesehatan dan mengubah fungsi fisiologis. Tinjauan sistematis ini bertujuan untuk mengkaji pengaruh berbagai jenis latihan terhadap kadar testosteron pada atlet perempuan, serta memberikan wawasan mengenai pendekatan pelatihan yang optimal. Pencarian literatur dilakukan secara menyeluruh melalui PubMed, Google Scholar, Medline dan PEDro dengan kata kunci seperti "*Endurance Exercise*," "*Resistance Exercise*," dan "*Testosterone Levels in Female Athletes*." Dari 45 studi yang disaring, enam memenuhi kriteria inklusi. Hasil penelitian menunjukkan bahwa latihan daya tahan dikaitkan dengan penurunan kadar testosteron, sementara latihan resistensi seperti angkat beban dan *bench press* meningkatkan produksi testosteron. Latihan resistensi dengan intensitas tinggi dapat menurunkan estrogen sambil meningkatkan testosteron, yang berpotensi meningkatkan kekuatan otot dan massa tubuh tanpa lemak pada atlet perempuan. Namun, kadar testosteron yang berlebihan dapat mengganggu fungsi menstruasi, meskipun memiliki efek positif terhadap kesehatan tulang. Temuan ini menunjukkan bahwa latihan resistensi dapat meningkatkan kadar testosteron pada atlet perempuan, sedangkan latihan daya tahan cenderung menurunkannya.

Kata kunci: kadar testosteron; latihan daya tahan; latihan resistensi; atlet perempuan

Introduction

Androgens are hormones responsible for developing and maintaining masculine traits in reproductive tissues while contributing to the anabolic functions of non-reproductive tissues.¹ They are synthesized in the adrenal glands and ovaries in response to adrenocorticotrophic and luteinizing hormones and can also be produced through the conversion of precursors in peripheral tissues.² In woman, circulating androgens include dehydroepiandrosterone, androstenedione, and testosterone.³

Testosterone, along with other androgens in women, plays a pivotal role in metabolic processes. It exerts physiological effects on both reproductive and non-reproductive tissues. Testosterone concentration in women is influenced by sexual function, and numerous studies indicate that testosterone therapy can ameliorate sexual dysfunction in females.⁴ Before puberty, testosterone levels in boys and girls are comparable. However, during puberty, the testes produce testosterone at a rate 20 times higher, resulting in a testosterone concentration in males that is approximately 15 times higher than in females of the same age.⁵

In premenopausal women, testosterone concentrations fluctuate across the menstrual cycle, peaking in mid-cycle and follow a diurnal rhythm with a bigger levels in the morning. Among this population, approximately 25% of testosterone is produced by the ovaries, 25% by the adrenal glands, and the remainder by peripheral tissues.⁶ Testosterone levels in women typically remain below 5 nmol/L, a threshold necessary for exerting masculine effects such as

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muscle growth, height increase, elevated hemoglobin levels, body hair distribution, and voice changes during puberty.⁵

Due to the differing testosterone concentrations between genders, men generally exhibit higher muscle mass, aerobic capacity, and physical performance than women.⁵ Examined the minimal testosterone requirement for muscle size and strength in premenopausal women. Subjects received weekly injections of 25 mg of testosterone, resulting in a rise in testosterone concentrations from 0.9 nmol/L to 7.3 nmol/L over 24 weeks, akin to male puberty levels. This intervention significantly increased muscle size (4.4%) and strength (12%-26%).⁵

Testosterone also influences a woman's response to exercise or sports. Several studies have observed elevated testosterone and estradiol levels in women following physical activity.⁷ Differences in post-exercise hormone concentrations between men and women are largely due to differences in baseline hormone levels. Observed increased free and total testosterone following acute resistance exercise. Kraemer et al.'s study on women undergoing eight weeks of resistance training revealed a modest yet significant rise in testosterone levels by week six compared to week one.⁸ It reported a 40% decrease in free testosterone and a 41% decrease in total testosterone in postmenopausal women with overweight or obese BMIs after 12 weeks of endurance training.⁹

Long-term exercise impacts on testosterone concentrations in women are often studied under conditions of minimal energy availability, as seen in the athlete triad, which can lead to menstrual cycle irregularities and reduced bone density.⁸

Resistance exercise boosts testosterone in women, aiding muscle mass and performance, yet it may disrupt menstrual cycles. Conversely, endurance training may increase body mass while lowering testosterone. Thus, this study aims to recommend appropriate exercises for reproductive-aged women by examining the effects of exercise types on testosterone levels. Although previous studies have investigated the effects of testosterone in female athletes, findings remain inconsistent. This study aims to clarify these inconsistencies by considering age and sports activity type.

Methods

a. Study Strategy and Selection

This systematic review utilizes articles from reputable electronic databases, including PubMed, PEDro, MEDLINE, and Google Scholar. This literature search was conducted using PubMed, Scopus, and Google Scholar with the keywords "Endurance Exercise", "Resistance Exercise and Testosterone in female athletes". Studies published in the last 10 years with experimental methods were prioritized. Inclusion criteria encompassed human studies

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published in English, involving samples of adult females or female athletes, utilizing robust methodologies such as Randomized Controlled Trials (RCTs) and experimental designs, with a publication date spanning over ten years. Only original articles were considered for inclusion, while review articles, conference abstracts, case studies, and review studies were excluded. This review adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines (Figure 1). Initial searches were conducted in September 2023, with an update in January 2024, followed by two reviewers' double screening for eligibility.

b. Study Quality Assessment

Primary research papers encompassing various fields were evaluated using the Standard Quality Assessment Criteria. The PEDro scale, comprising 11 criteria including eligibility criteria specification, random allocation, concealed allocation, baseline comparability, blinding of subjects/therapists/assessors, adequate follow-up, intention-to-treat analysis, between-group statistical comparisons, and point measures with variability measures, assessed the quality of randomized controlled trials for conducting systematic review studies.

c. Data Extraction

Data extraction involved summarizing the included studies' population/subject characteristics, intervention and control/comparison group details, outcome measurements, results, and quality ratings. Four reviewers duplicated this process to ensure accuracy and reliability.

Results

a. Study Selection

The initial search across four databases yielded approximately 45 articles relevant to various exercise modalities using keywords such as "endurance exercise," "resistance exercise," "exercise on women," "hormone on female athletes," and "level of testosterone on female athletes." Following eligibility criteria, only six articles met the inclusion criteria. The study selection process is outlined in Figure 1.

b. Methodological Quality and Risk of Bias

Methodological quality was assessed using the PEDro scale, which evaluates various study design criteria. The PEDro scores for the selected studies ranged from 4 to 10, with two studies scoring 5 for overall quality, while the remaining studies scored 4, 7, 9, and 10. Criteria assessed included eligibility criteria, random allocation of samples, concealed allocation, measurement or critical outcome measures, blinding, comparison analysis, and point

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measurement.

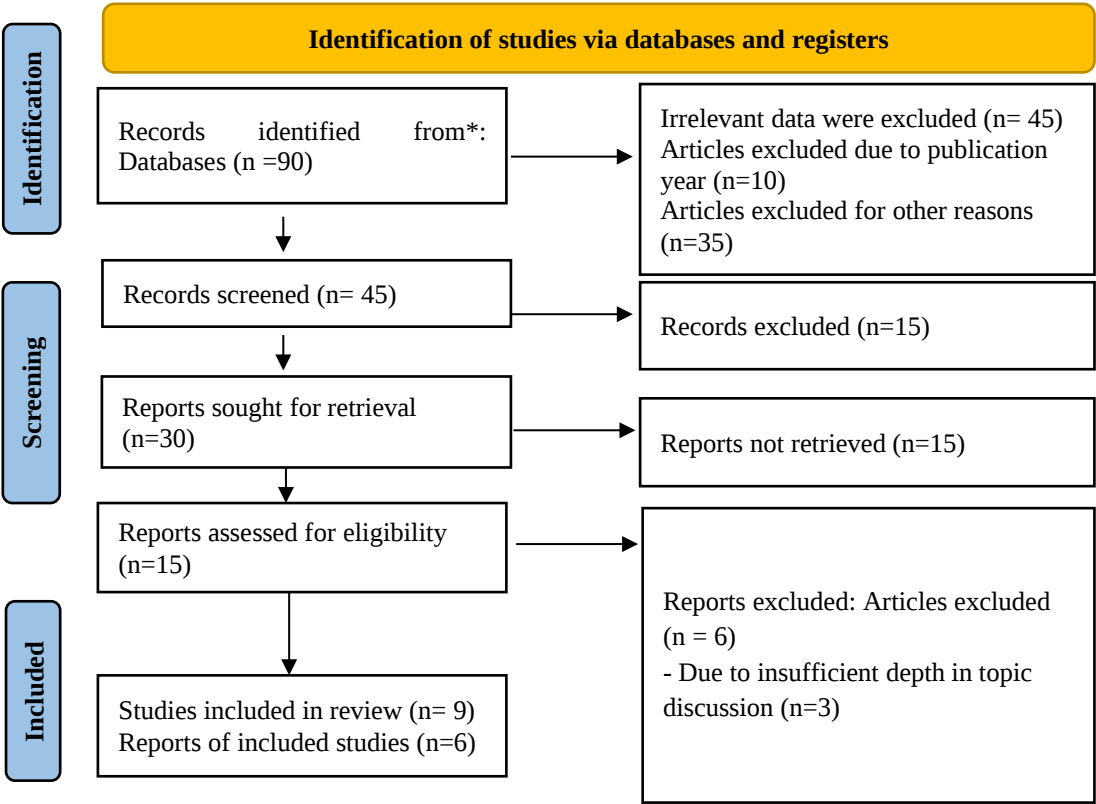


Figure 1 Flow Chart Diagram Study Selection Process

The effects of different types of exercise on testosterone levels in female athletes have been examined in various studies. These studies investigate the impact of endurance training, resistance training, and high-intensity functional training on hormonal responses. A summary of the key findings, including sample characteristics, intervention details, and results, can be seen in Table 1.

Based on Table 1, endurance exercises generally lead to a reduction in testosterone levels, while resistance training and high-intensity functional training tend to increase testosterone production. Additionally, long-term and high-volume training, as observed in ballet dancers and volleyball athletes, appears to influence testosterone levels. These variations suggest that exercise type, intensity, and duration play a crucial role in hormonal adaptations among female athletes.

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Table 1 The Impact of Testosterone on Female Athletes' Performance

Author (Year)	Sample	Intervention	Control	Outcome Measurement	Results	Quality
Banitelebi et al. (2018)	40 healthy women (67 y/o)	Endurance & resistance training (3x/week, 12 weeks)	No intervention	Anthropometrics, VO2Max, muscle strength, blood analysis (hormones)	Endurance ↓ testosterone	10
Krishnan et al. (2014)	28 women (42–52 y/o)	Aerobic & resistance training (6x/week, 6 months)	No specific regimen	Lipid profile, insulin sensitivity, steroid hormones (testosterone, DHEA)	No significant testosterone change	9
Arazi et al. (2017)	30 female volleyball athletes (18.5 y/o)	Volleyball + resistance training (8 weeks)	Volleyball only	1RM strength, vertical jump, sprint, hormone analysis	Resistance ↑ testosterone	7
Mangine et al. (2018)	10 (5M/5F)	High-Intensity Functional Training (CrossFit Open, 5 weeks)	None	Salivary testosterone & cortisol	HIFT ↑ testosterone	5
Lagowska & Kapczuk (2015)	31 female athletes, 21 ballet dancers	Sport-specific training (>10h/week)	None	Menstrual status, body composition, hormone panel, nutrition	Ballet dancers ↑ testosterone	4
Roli et al. (2018)	54 female volleyball athletes	Volleyball training	None	Serum testosterone, cortisol, hGH, IGF-1	4-week training altered testosterone levels	5

Discussion

Testosterone, an androgen-containing anabolic steroid, is typically abundant in men, yet women also exhibit significantly elevated levels, particularly in response to vigorous activities like sports.¹⁰ Prolonged or intense exercise can swiftly escalate testosterone levels in women.¹¹ This hormone is pivotal in enhancing muscle mass and reducing body fat. Additionally, testosterone and cortisol influence protein and carbohydrate metabolism.¹² While testosterone offers performance benefits for athletes, its use as a doping agent in competitions presents both advantages and drawbacks.¹³ Athletes have utilized testosterone hormone therapy since the mid-20th century to enhance athletic performance.¹⁴

Earlier research has demonstrated that changes in steroid hormone levels triggered by exercise are influenced by both the intensity of the activity and an individual's fitness level. Building on this, the present study set out to explore how steroid metabolism differs between elite female endurance athletes and women who are not physically active.^{15,16}

Testosterone levels are crucial in women's physiology when within normal limits. However, excessive levels can lead to menstrual cycle disorders and even disorders of sexual

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differentiation (DSD).¹⁷ Compared to men, women typically have testosterone levels that are 20-30 times lower, resulting in lower strength and muscle mass.¹⁸ Nevertheless, women with elevated testosterone levels may experience similar effects. Professional female athletes often exhibit 2-5% higher testosterone levels compared to sedentary women, which can confer competitive advantages and positively impact performance.¹⁹ Testosterone influences muscle formation, particularly by increasing muscle mass through hypertrophy of both type I and II muscle fibers via enhanced satellite cell and myonuclear activity.¹⁸

Female participation in sports has grown significantly over recent decades, but research focused specifically on elite female athletes still lags that of their male counterparts. As a result, findings from studies on men are often generalized to women, despite physiological differences.²⁰ This lack of data tailored to women is particularly concerning because elite female endurance athletes frequently face unique health issues such as poor bone health, low energy availability, and menstrual irregularities, collectively known as the female athlete triad.²¹

The study investigated the response of select androgenic steroid hormones to intensive endurance exercise in female athletes, aiming to determine whether their hormonal patterns mirror those observed in men. Results showed that androgenic hormone levels significantly increased at volitional fatigue and remained elevated 90 minutes into recovery. However, a notable decline was observed in 24 hours post-exercise.²² This pattern, though similar to previous findings in men, is influenced by sex-specific factors such as lower baseline hormone levels in women and contributions from both adrenal and gonadal sources.²³ The 24-hour decline may result from cortisol-induced suppression of androgen production or disrupted endocrine regulation. Elevated cortisol levels may divert precursors, such as pregnenolone, toward cortisol synthesis, thereby reducing androgen output. Statistical analyses ruled out exercise performance (i.e., time to fatigue) as the main driver of hormonal changes, highlighting cortisol's influence. These hormonal shifts may impact recovery and adaptation in female athletes, suggesting that a 24-hour recovery period may be insufficient for endocrine system restoration. The study emphasizes the need for adequate rest following intense endurance exercise and recommends further research on hormonal responses across different menstrual phases and fitness levels to better understand female-specific endocrine adaptations.²⁴

In a study conducted by Banitebe et al., comparing endurance training and resistance training in adult women, it was observed that after 12 weeks of exercise, testosterone levels significantly decreased in the endurance training group, while they increased in the resistance training group.²⁵ Endurance training, characterized by high-volume and repetitive movements, may lead to overtraining and a subsequent decrease in testosterone levels. Conversely, resistance

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training, which focuses on building muscle mass, stimulates testosterone production, contributing to increased serum testosterone levels. This finding aligns with previous studies that have reported an increase in testosterone levels following resistance training lasting 4-10 weeks.²⁵

Another study by Mangine demonstrated an increase in testosterone levels following high-intensity resistance training. Similarly, a previous study by Staron et al. in 1994 reported that 8 weeks of progressive resistance training led to increased testosterone levels in women. Additionally, Arazi *et al.* found a significant increase in testosterone levels among women after undergoing resistance training. Moreover, Huang and Shehzad (2018) reported that athletes engaging in strength, power, and speed training activities exhibited higher testosterone levels compared to those involved in endurance exercises such as marathons. These findings collectively suggest that resistance training, particularly of high intensity, is associated with increased testosterone levels in women.^{26,27,28}

The results of the previously mentioned studies suggest that strength or resistance training is beneficial for increasing testosterone levels in female athletes, providing advantages during competition and promoting physiological and psychological benefits for the muscles.²⁹ Conversely, endurance training tends to reduce testosterone levels in female athletes. Nutrition and the age of the athlete are additional influential factors in this regard.³⁰

In contrast to endurance training, resistance training consistently demonstrated positive effects on testosterone levels across multiple studies. Banitalebi et al. observed a significant increase in testosterone levels in the resistance training group, with mean increases of approximately 20-25% from baseline after 12 weeks of training.²⁵ Similarly, Arazi et al. found that female volleyball athletes who underwent additional resistance training showed significantly higher testosterone levels compared to the control group that performed only sport-specific training.²⁷

The mechanisms underlying testosterone elevation following resistance training include: direct stimulation of Leydig cells in the ovaries, increased luteinizing hormone release, and enhanced steroidogenesis. The anabolic nature of resistance exercise creates a favorable hormonal environment for testosterone production, particularly when training intensity and volume are appropriately managed.

Mangine et al. demonstrated an increase in testosterone levels following high-intensity functional training (HIFT), which incorporates resistance-based movements.²⁸ The study showed that HIFT participants experienced acute testosterone elevations that were sustained throughout the 5-week training period. This finding aligns with previous studies by Staron et al. (1994), who

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reported that 8 weeks of progressive resistance training led to increased testosterone levels in women.

The study by Krishnan et al. presents an interesting contrast, reporting no significant testosterone changes in women who underwent combined aerobic and resistance training for 6 months.³¹ This finding suggests that when endurance and resistance training are combined, the testosterone-suppressing effects of endurance exercise may counteract the testosterone-enhancing effects of resistance training. The 6-month duration and high training frequency (6 times per week) may have contributed to overtraining adaptations, resulting in hormonal suppression rather than enhancement.

The classification of ballet dancing and volleyball requires careful consideration. Ballet dancing, as examined by Lagowska & Kapczuk, involves primarily endurance-type activities with some anaerobic power components.³² Despite being classified as an endurance activity, ballet dancers in this study showed increased testosterone levels, possibly due to the explosive movements and strength requirements inherent in ballet technique. The high training volume (>10 hours/week) and the combination of aerobic endurance with power movements may create a unique hormonal response profile.

Volleyball, studied by both Roli et al and Arazi et al., represents a mixed-modal sport combining endurance, power, and strength components.^{12 34} The volleyball training alone showed altered testosterone levels over 4 weeks, while the addition of specific resistance training resulted in more pronounced testosterone increases. This suggests that while sport-specific training may modulate hormone levels, targeted resistance training provides more substantial hormonal benefits.

However, it's important to note several weaknesses in this study. Firstly, the selected articles lacked data on the optimal dosage of resistance training for female athletes. Additionally, variations in study designs and a lack of data analysis using forest plots hindered the ability to conduct a meta-analysis of the data. These limitations suggest the need for further research to address these gaps and provide more comprehensive insights into the effects of different types of training on testosterone levels in female athletes.

In addition to the findings discussed above, it is imperative to highlight avenues for future research in this field. Firstly, future studies should aim to elucidate the optimal dosage and duration of resistance training needed to maximize testosterone levels in female athletes. Moreover, investigating the potential interactions between resistance training intensity, volume, and frequency on testosterone responses could provide valuable insights into designing effective training programs for female athletes. Additionally, exploring the impact of nutritional

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interventions on testosterone levels in conjunction with resistance training could further enhance our understanding of the factors influencing hormonal adaptations in women athletes.

The findings from this study have significant implications for coaches, trainers, and athletes alike. Understanding the differential effects of endurance and resistance training on testosterone levels can inform the development of tailored training programs to optimize athletic performance in female athletes. Coaches and trainers can use this knowledge to design training regimens that leverage the anabolic properties of resistance exercise while minimizing the potential negative impacts of endurance training on hormonal balance. Moreover, athletes can make informed decisions about their training protocols based on the desired outcomes and performance goals.

In terms of generalizability, while the findings of this study offer valuable insights into the effects of different training modalities on testosterone levels in female athletes, caution should be exercised when extrapolating the results to broader populations. The study sample predominantly comprised adult women engaged in regular athletic training, and the findings may not be directly applicable to other demographic groups or athletic populations. Therefore, future research with larger and more diverse samples is needed to corroborate these findings and enhance the generalizability of the results across different populations and contexts.

Overall, this study underscores the importance of considering the nuanced effects of training modalities on testosterone levels in female athletes. By elucidating the mechanisms underlying hormonal adaptations to exercise, future research can contribute to the development of evidence-based training strategies aimed at optimizing athletic performance and promoting overall health and well-being in female athletes.

Conclusion

The findings of the study highlight the significant impact of different exercise modalities on testosterone levels in female athletes. Endurance training tends to decrease testosterone levels, potentially due to overtraining and the repetitive nature of endurance exercises. Conversely, resistance training, particularly high intensity, increases testosterone levels by stimulating muscle mass development. These results emphasize the importance of tailoring training programs to optimize hormonal responses and athletic performance in female athletes.

Moreover, the study underscores the need for further research to explore optimal training protocols, including dosage, intensity, and frequency, to maximize the beneficial effects of exercise on testosterone levels in female athletes. Additionally, investigating the role of nutrition and other lifestyle factors in modulating hormonal responses to exercise could provide valuable

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insights into comprehensive strategies for enhancing athletic performance and overall well-being in female athletes.

In conclusion, this systematic review demonstrates that different exercise modalities distinctly affect testosterone levels in female athletes. Resistance training, particularly at high intensity, is associated with increased testosterone production, promoting greater muscle mass, strength, and athletic performance. In contrast, endurance training tends to lower testosterone levels, which may negatively impact muscle development and overall performance.

These findings suggest that resistance training should be emphasized as part of optimal training strategies for female athletes aiming to enhance performance through hormonal balance. However, training programs must also consider individual factors such as age, nutrition, and menstrual health to prevent potential adverse effects. Future research is needed to refine specific resistance training protocols that maximize benefits while maintaining female athletes' physiological health.

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