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Hormonal Influences on Women's Health and Athletic Performance: Insights into the Menstrual Cycle, Menopause, Contraception, and Anabolic Steroids

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ABSTRACT
Introduction: Hormones influence women's health and athletic performance, managing conditions like menstrual irregularities, menopause, and osteoporosis. Therapies such as oral contraceptives and IUDs benefit millions but pose risks like breast cancer and cardiovascular events. In sports, hormonal fluctuations affect performance, with steroid abuse raising concerns. This review examines their benefits, risks, and implications.
Materials and Methods: The study conducted a systematic review of the literature, utilizing databases including PubMed, NCBI, and Google Scholar. Data were obtained from clinical and experimental studies and evaluated based on methodological rigor, participant characteristics, and therapeutic outcomes. Articles lacking full-text access were excluded from the analysis.
State of knowledge: Hormones profoundly influence women's health and athletic performance, affecting the menstrual cycle, menopause, and responses to exercise. Physical activity improves cardiovascular and metabolic health but can disrupt hormonal balance with intense training. Hormonal contraceptives, anabolic steroids, and HRT impact health and performance, necessitating individualized approaches and further research.
Conclusions: Hormonal balance is vital for women's health and performance. Physical activity, contraception, and HRT have benefits but require tailored approaches to mitigate risks.
Keywords: physical activity, hormones, women’s health, menstrual cycle, hrt, anabolic steroids

INTRODUCTION:

The influence of hormones on women’s health is a topic of discussion in many publications. Hormones can be used as a treatment for many conditions such as: irregular menstrual cycles, abnormal uterine bleeding, dysmenorrhea, endometriosis, menopause, prevention of osteoporosis and PCOS, there are many indications for the administration [1,2,3,4,5,6]. However hormone therapy has its limitations. Estrogen contraception raises the risk of breast cancer [7]. Combined oral contraceptives can cause ischemic stroke, pulmonary embolism [8] and myocardial infarction [9]. Furthermore hormones can improve athletic performance among female athletes such as anabolic steroids which are illegal. The expected lifetime prevalence of steroids abuse among women is around 1,6% [10].

We can divide hormone treatments into various groups depending on the therapeutic use. A few examples that are widely known are inter alia : modern contraceptives such as oral contraceptives and IUDs, hormone replacement therapy, hypothalamic-pituitary-gonadal (HPG) axis modifying treatment and many more.

It is believed that in 2019 alone there were 100 million women that used oral contraceptives [11]. In the 2010s around 6 million women used hormone therapy for menopause treatment in the USA and UK combined [12]. Study from 2019 revealed that 48% of women in reproductive age 15-49 used modern contraceptives such as oral contraceptives, hormonal intrauterine devices, patches and many more. The report also showed that around 160 million women worldwide were in a need of contraception which wasn’t met [13].

The purpose of this review is to dive into hormones' influence on women's health, athletic performance and sum up their importance.

MATERIALS AND METHODS:

The study undertook a comprehensive systematic review of the literature, leveraging multiple reputable databases such as PubMed, NCBI, and Google Scholar to ensure a broad and reliable collection of data. Relevant information was extracted from both clinical trials and experimental research studies, with each article being meticulously assessed for methodological rigor, the demographic and clinical characteristics of the participants, and the reported therapeutic outcomes. Articles that were not available in full-text format were excluded.

STATE OF KNOWLEDGE

Physiology of menstrual cycle

The menstrual cycle is a series of changes in a woman's body influenced by hormones. The hypothalamus-pituitary-gonadal axis plays a central role, and the hormones involved in this process include gonadotropin-releasing hormone (GnRH), follicle-stimulating hormone (FSH), luteinizing hormone (LH), estrogen, and progesterone. Testosterone, often regarded as a male hormone, also plays a role in the menstrual cycle. Elevated testosterone levels, seen in conditions like polycystic ovary syndrome (PCOS), disrupt menstrual regularity and contribute to symptoms of hyperandrogenism [14, 15].

The average menstrual cycle lasts 30.3 days, is rhythmic in nature, and consists of four consecutive phases: the menstrual phase, follicular phase, ovulation, and luteal phase [16].

The menstrual phase lasts an average of 6.2 days, during which the uterine lining is shed, and bleeding occurs. The follicular phase lasts approximately 18.5 days [16], during which estrogen levels gradually increase due to the release of FSH from the pituitary gland, and ovarian follicles mature. Low estradiol levels promote the release of FSH and suppress LH. A positive feedback mechanism then occurs: high estrogen levels trigger an LH surge, which stimulates ovulation. In the luteal phase, LH contributes to the formation of the corpus luteum, which produces progesterone. This hormone maintains the thickened uterine lining, allowing for potential embryo implantation. If fertilization does not occur, the corpus luteum transforms into the corpus albicans and progesterone levels drop. This hormonal shift causes the uterine lining to contract, initiating a new menstrual cycle [17,18].

The highest testosterone levels are observed in the middle of the cycle [19]. Increased testosterone, as seen in PCOS, can lead to infrequent or absent menstruation. It also contributes to symptoms of hyperandrogenism such as seborrhea, acne, and hirsutism [20].

Sex hormone-binding globulin (SHBG) is another crucial hormone that regulates the bioavailability of sex hormones, including estrogen and testosterone. Low SHBG levels, frequently observed in PCOS, lead to an increase in free testosterone, further disrupting menstrual regularity and amplifying mentioned hyperandrogenic symptoms. Variations in SHBG significantly influence the hormonal balance and impact the menstrual cycle's overall rhythm [15].

The impact of sport on a woman's health

As early as the first decade of this millennium, it was observed that an increasing number of women were engaging in various forms of physical activity. Participating in sports is associated with both positive and negative health effects for women, including hormonal changes [21].

Regular aerobic exercise significantly improves the cardiovascular disease risk profile in women and is associated with lower mortality from these diseases [22,23,24].

M. Akkurt et al. studied the assessment of the impact of an 8-week exercise program combining aerobic and resistance training on cardiovascular risk factors in women. The study involved 30 women aged 40-65 years randomly divided into an experimental group and a control group, 15 people each. The exercises performed by the experimental group included 60-70 minute training sessions of moderate intensity 3 times a week. The study showed a significant decrease in body weight, body mass index, and hip circumference ($p < 0.05$) in women from the experimental group. Other beneficial effects on cardiovascular health included a significant reduction in triglyceride levels ($p < 0.05$), and a significant reduction in blood pressure (both SBP and DBP) ($p < 0.05$) in the

experimental group [24]. There are also studies indicating the impact of physical activity in women on increasing HDL cholesterol levels and decreasing fibrinogen concentration [22].

Regular physical activity, according to some studies, also leads to an improvement in reproductive functions through effects at both hormonal and metabolic levels [25]. F. Orio et al. in their review presented a number of scientific reports indicating the beneficial effects of physical activity on improving menstrual cyclicity, increasing ovulation and fertility, lowering testosterone levels, or increasing sex hormone-binding globulin (SHBG) levels [25,26,27]. Further beneficial effects of physical activity were a reduction in abdominal fat tissue, lowering of blood glucose levels, and improvement in lipid profile [25,27].

Women with high levels of physical activity experience less severe climacteric symptoms. This seems to be confirmed by a study by V. Skrzypulec et al. evaluating the relationship between physical activity level and climacteric symptoms in menopausal women. It showed that women in the high physical activity group had less severe climacteric symptoms. 52.08% of women with high physical activity had no climacteric symptoms [28]. Regular physical activity can therefore significantly improve the quality of life of women during menopause.

An undeniable effect of physical activity is its positive impact on mental health, leading to improved self-esteem and reduced symptoms of depression and anxiety [25].

In addition to bringing many benefits and the accompanying possibility of regulating clinical, metabolic, and hormonal changes in the body, physical activity can also have a number of negative consequences for women's health.

Intense exercise can lead to hypothalamic dysfunction, resulting in delayed first menstruation (menarche), menstrual cycle disorders, and suppression of GnRH secretion [21].

Women participating in sports disciplines where low body weight is crucial, such as ballet, long-distance running, gymnastics, or figure skating, often exhibit a characteristic hormonal profile. It is characterized by reduced estrogen levels, which is a result of disturbances in the functioning of the hypothalamic-pituitary-ovarian axis. The main mechanism underlying these changes is the disruption of the pulsatile secretion of GnRH by the hypothalamus. In the case of intensively training female athletes, the pulsatile rhythm of GnRH release is disturbed. The consequence of this is a limitation in the secretion of pituitary hormones LH and FSH. These changes lead to reduced ovarian stimulation and limited estradiol production. The above changes can ultimately lead to ovulation disorders and infertility associated with GnRH suppression [21]. The authors of many studies emphasize the possibility of the occurrence of the so-called "female athlete triad". This term was created by the American College of Sports Medicine (ACSM) and includes amenorrhea, osteoporosis, and eating disorders [25,29].

Hypoestrogenism associated with intense exercise can lead to failure to achieve peak bone mass, osteopenia and osteoporosis [21].

The root cause of reduced bone density in these hypoestrogenic athletes may primarily be attributed to metabolic disturbances resulting from inadequate nutrition. These nutritional deficiencies can disrupt the body's normal bone metabolism processes, leading to compromised bone strength and density [21].

M.P. Warren et al. also mention hyperandrogenism as one of the complications of intense physical exercise. They emphasize that female athletes practicing sports disciplines favoring strength as the main attribute (swimming, rowing) and not associated with a restrictive diet may also be susceptible to hormonal changes. In this case they include mildly elevated LH levels, elevated LH/FSH ratios and mild hyperandrogenism [21].

Various forms of dealing with premenstrual syndrome

Premenstrual syndrome (PMS) is a common disorder affecting women of reproductive age, characterized by a range of physical and psychological symptoms occurring in the luteal phase of the menstrual cycle [30]. The global prevalence of PMS is estimated at 47.8%, with about 80% of women experiencing at least one PMS symptom [30].

Over 200 PMS symptoms of varying severity have been identified. The most common physical symptoms include: weight gain, edema, breast tenderness and swelling, stomach problems, back pain, muscle and joint pain, headaches, dizziness, sweating, skin problems, constipation or diarrhea, bloating, cramps, and reduced tolerance to noise and light. Among the psychological and behavioral symptoms are: insomnia/drowsiness, changes in appetite, anxiety and tension, decreased libido, depressed mood, mood swings, fatigue, anger, irritability, tearfulness, restlessness, disorientation, problems with concentration and memory, loss of self-confidence, and social isolation [31]. In the study by S. Morino et al., three main patterns of PMS symptoms were identified: the affective type (mainly psychological symptoms), the mixed type (a combination of psychological and physiological symptoms), and the somatic type (mainly physical symptoms)[30].

The study conducted by S. Morino et al. showed that higher scores on the self-rating depression scale were marginally associated with the affective type of PMS. Physical activity was significantly associated with the mixed type and somatic type of PMS [30].

Both pharmacological and non-pharmacological methods are used in the treatment of PMS [32]. Among non-pharmacological methods, relaxation techniques, moderate physical activity, and proper nutrition are distinguished [30,32].

The use of Mitchell's relaxation technique and Benson's relaxation technique seems to be interesting in alleviating PMS symptoms. The relaxation technique developed by Laura Mitchell in 1977 combines diaphragmatic breathing exercises with a series of sequential isotonic contractions that focus on reciprocal inhibition. Mitchell's method aims to achieve postural realignment by counteracting the "punching stance," which is associated with stress. This approach activates the relaxation response, thereby helping to rebalance the nervous system. The technique's effectiveness stems from its ability to reverse stress-induced postural patterns and promote overall relaxation [32] .

Another technique developed by Herbert Benson aims to alleviate physiological stressors through physical relaxation. It plays a role in reducing feelings of anxiety and mood disorders, and also promotes physical activity [32,33].

In pharmacological treatment, selective serotonin reuptake inhibitors (SSRIs) are used for predominant emotional symptoms [34]. There are also publications confirming the effectiveness of Vitex agnus-castus (VAC) as an effective method of treating PMS. R. O. Cerqueira et al. in their systematic review evaluated the effectiveness of VAC in the treatment of PMS. They list VAC as an effective and safe alternative that should be considered in the treatment of PMS [35].

The impact of hormonal contraception on female physiology.

Hormonal contraception (HC) is one of the most commonly used methods of fertility control[36]. It works through hormonal regulation, influencing not only the function of the reproductive system but also various physiological processes within a woman's body. The effects on the organism may vary in terms of the intensity of side effects and the impact on metabolism, skin, hair, and mood, depending on the type of contraceptive used, its composition, and the proportions of active ingredients [37,38].

Hormonal contraception works by modifying the natural menstrual cycle, affecting key processes in the female reproductive system. One of the main mechanisms is the inhibition of ovulation, achieved through the suppression of the secretion of gonadotropins, such as follicle-stimulating hormone (FSH) and luteinizing hormone (LH), from the pituitary gland [39]. Additionally, hormonal contraceptives induce changes in cervical mucus, making it thicker, which significantly hinders sperm penetration [40]. Another important effect is the impact on the endometrium – its thickness is reduced, which limits the ability for embryo implantation [41].

Hormonal preparations consist of progestogens and estrogens, most commonly in the form of ethinylestradiol, which stabilize the menstrual cycle and enhance the action of progestogens, the main component responsible for contraceptive effects[42].

Progestogens, which are a key component of hormonal contraception, can vary in their androgenic effects due to their affinity for androgen receptors [43]. They can be classified according to the strength of their androgenic potential into two categories: levonorgestrel and norethisterone, which exhibit a strong androgenic effect, and drospirenone, dienogest, and nomegestrol, which are associated with a more favorable androgenic profile [44,45,46,47,48]. Progestins with a strong androgenic potential have effects that can lead to the exacerbation of androgen-related symptoms, such as acne, hirsutism, and androgenic alopecia [49]. Through their androgenic action, they can affect lipid metabolism in the body, leading to changes in lipid profiles that increase the risk of cardiovascular diseases. Elevated androgen levels contribute to a decrease in HDL cholesterol, reducing protection against atherosclerosis and heart diseases. They can also raise LDL cholesterol levels, promoting arterial narrowing and increasing the risk of heart attack and stroke [50,51].However, in a study conducted by Ng et. al. [52] involving 92 healthy women using a levonorgestrel-containing intrauterine device (LNG-IUS), it was found that the device had no significant impact on lipid metabolism. After 6 months, a slight decrease in total cholesterol and a reduction in HDL-C were observed, although HDL-C levels returned to baseline after one year.

Norethisterone (NET) and its acetate (NETA) are widely used in contraception, hormone replacement therapy, and the treatment of abnormal uterine bleeding and endometriosis. NET is distinguished by its partial conversion to ethinylestradiol (EE), which has important clinical implications. It strongly affects the uterine mucosa, making it effective in treating conditions related to the endometrium, such as endometriosis and endometrial hyperplasia. Additionally, NET has a beneficial effect on bone mineral density and a positive or neutral impact on cardiovascular health. On the other hand, long-term use of NET is associated with a slight increase in the risk of breast cancer and a moderate increase in the risk of venous thrombosis, which is dose-dependent. While the use of NET in contraceptive doses does not carry a risk, therapeutic doses may increase this risk, especially when combined with EE, which may be particularly relevant for women with migraine with aura. Therefore, women with a high risk of breast cancer, venous thrombosis, or migraines with aura should exercise special caution when using NET [45].

In a study conducted by Cocrum et. al. [53] the relationship between the use of seven different progestogens and the risk of acute venous thromboembolism (VTE) in reproductive-aged women was assessed. The analysis included 21,405 women with newly diagnosed VTE and 107,025 women in the control group, matched for age and date of analysis. The results showed that the use of high-dose progestogens, such as norethindrone acetate and depot medroxyprogesterone (DMPA), was associated with a significantly increased risk of VTE compared to women not using these agents. In contrast, lower-dose progestogens, including the levonorgestrel intrauterine device and etonogestrel implant, did not increase the risk, and oral norethindrone was even associated with a reduced risk.

Progestogens with a low androgenic potential are associated with a reduced risk of adverse effects such as acne, hirsutism, and androgenic alopecia, and have a lesser impact on lipid and glucose metabolism, making them a preferred choice for women with a predisposition to skin and metabolic disorders [54]. Studies also indicate a more favorable safety profile, including a lower risk of thrombosis and water retention [54,55]. Moreover, progestogens such as drospirenone exhibit antiandrogenic effects, which can be beneficial in treating symptoms associated with excess androgens, such as acne and hirsutism [56]. Therefore, progestogens with low androgenic potential represent a safer alternative in hormonal therapy, especially for women with dermatological or metabolic issues, who require attention to their lipid profile and weight management [57].

Physical Activity During Hormonal Contraception

A significant proportion of women participating in sports use hormonal contraceptives. In Denmark, 57% of elite female athletes reported using these substances, with 74% opting for combined estrogen-progestin contraception and 26% using progestin-only formulations.[58]. In a study of Schaumberg et. al. [59] involving 459 women across three activity levels—recreationally active women (n=191, self-reported moderate to vigorous physical activity of 150–300 minutes per week, age 23 ± 5 years), sub-elite recreationally active women (n=160, >300 minutes per week, age 23 ± 5 years), and elite athletes (n=108, competing at state, national, or international levels, age 23 ± 4 years)—participants completed a self-assessment survey examining oral contraceptive (OC) usage patterns and reasons for menstrual manipulation. The findings revealed that 74% of OC users intentionally manipulated their menstrual cycles at least once in the past year, with 29% reporting manipulation four or more times. The prevalence of menstrual manipulation did not significantly differ among elite athletes, sub-elite recreationally active women, and recreationally active women. The most commonly cited reasons for menstrual manipulation included special events or holidays (75%), convenience (54%), and sports competitions (54%).

How does hormonal contraception affect athletic performance? In the meta-analysis conducted by Elliott-Sale et al.[60], which analyzed 42 studies with a total of 590 participants, it was found that the use of oral contraceptives may result in slightly reduced exercise performance on average compared to non-use. However, any group-level effects were considered to be minimal and likely of little practical significance.

On other hand Wikström-Frisén et al. [61] did not observe significant differences in athletic performance between women using oral contraceptives and those not using them. One group of participants was tasked with performing high-frequency leg resistance training during the first two weeks of their menstrual cycle over four months, while another group performed the same training during the last two weeks of the cycle. For the remainder of the cycle, both groups trained their legs once a week.

Also in the study conducted by Dragutinovic et al.[62], the scientists had similar conclusions .The researchers compared strength performance, neuromuscular fatigue, and perceived exertion during various phases of the menstrual cycle and the use of oral contraceptives. The study involved 34 women, 21 of whom had a natural menstrual cycle, while 13 were using hormonal contraceptives. Each participant completed either three (natural cycle group) or two (oral contraceptive group) experimental sessions. Mean movement velocity and the total number of repetitions were measured during power training sessions (three sets of eight repetitions at 60% of the one-repetition maximum-1RM) and hypertrophy training sessions (three sets to failure at 70% 1RM). Changes in mean movement velocity in bench presses and squats at 60% 1RM were used as indicators of local and general fatigue. Additionally, each session assessed total blood lactate accumulation and subjective ratings of perceived exertion. The results revealed no significant differences between women with a natural menstrual cycle and those using hormonal contraceptives in terms of mean movement velocity, total number of repetitions, local and general fatigue, or subjective ratings of perceived exertion.

In the Multilevel Meta-analysis conducted by Nolan et al.[63], 8 studies (comprising 54 effects and 325 participants) were analyzed to evaluate the impact of hormonal contraceptive use on skeletal muscle hypertrophy, power adaptations, and strength development in response to resistance training. The findings indicated that the use of oral contraceptive pills does not significantly affect muscle hypertrophy in women engaged in athletic activities.

Use of Anabolic-Androgenic Steroids in Women

When discussing hormones, it is essential to address their external administration, specifically the use of anabolic-androgenic steroids (AAS) among women. An analysis of 18 studies conducted by Piatkowski et al. [64] indicates that up to 4.4% of female athletes use these substances, with the highest prevalence observed among female bodybuilders at 16.8%. In contrast, the prevalence of AAS use in the general female population is estimated at 1.4%. The main reasons women use anabolic-androgenic steroids are to enhance their physical appearance by reducing body fat, increasing muscle mass, and improving strength. Some women start using AAS impulsively, driven by the desire to see quick results after beginning gym training, while others turn to AAS after hitting a plateau in their training or in preparation for fitness competitions.[65]

Regarding the motivations and choices of women using AAS, Piatkowski et al.[66] found that women tend to opt for less invasive methods of administration compared to men, such as oral intake. They also often select alternative performance-enhancing substances, such as Clenbuterol (which induces lipolysis and weight loss by binding to the beta-3 adrenergic receptor of adipocytes[67]). Furthermore, the increasing social acceptance of a muscular female physique reduces the stigma associated with such appearances. This, in turn, diminishes women's hesitations about using substances that facilitate achieving this body type. Due to its availability and increasing awareness, testosterone is the most commonly used AAS. However, it has been observed that among women, the most popular AAS are Stanozolol and Oxandrolone.[68]

Testosterone administration may also yield positive outcomes. In the study by Huang et al.[69], it was demonstrated that 24 weeks of testosterone enanthate administration in women who had undergone hysterectomy resulted in improvements in sexual function (measured by the Brief Index of Sexual Functioning for Women), increased lean body mass, chest-press power, and loaded stair-climb power. The doses administered were 0 mg (placebo), 3 mg, 6.25 mg, 12.5 mg, and 25 mg (per week), with the greatest effects observed at the highest dose of testosterone. Havnes et al.[65] also observed that libido significantly increased during AAS use; however, after discontinuing the cycle, it returned to normal or even decreased.

Grube and Pope Jr. [70] observed that women who used AAS exhibited increased muscle mass compared to those who did not, and reported the use of various other performance-enhancing drugs in addition to AAS. Some of these women described a clear pattern of polydrug dependence, often associated with significant morbidity. Additionally, 56% of women using AAS reported experiencing hypomanic symptoms during use, while 40% reported depressive symptoms during withdrawal; however, none met the full DSM-IV criteria for a hypomanic episode or major depression. Moreover, these women exhibited rigid dietary practices, chronic dissatisfaction, and muscle dysmorphia.

Unfortunately, despite improvements in certain parameters, AAS are associated with undesirable side effects. The most common is loss of menstruation[65]. Additionally, painful menstruation, oligomenorrhea, secondary amenorrhea, anovulation, and, consequently, infertility may occur[71].The others are hirsutism, alopecia, deepening of the voice, clitoromegaly, menstrual disturbances, and aggression [72].

Menopause and Sports Performance

Menopause is defined as the complete end of menstrual cycles due to the depletion of ovarian follicular function, marked by an absence of menstrual bleeding for 12 consecutive months. It generally takes place in women aged 44 to 56 [73].

Various factors influence the age at which menopause occurs, with genetic factors being the most significant. Other factors include environmental ones, such as: smoking, long-term use of oral contraceptive pills, excessive alcohol consumption. [74]. During menopause, a series of changes occur in ovarian function due to the depletion of the ovarian reserve - the number of primordial follicles. The maturation of Graafian follicles is inhibited, leading to the cessation of ovulation and an increase in anovulatory cycles. This contributes to the diminished function of the corpus luteum, while the ovaries themselves undergo a reduction in size [75]. Hormonal changes during menopause include a decrease in the levels of hormones produced by the ovaries - estrogens and inhibins. Additionally, corpus luteum insufficiency leads to reduced progesterone secretion. Secondary to the decline in these hormone levels is an increase in gonadotropin levels - FSH and LH [76]. Other hormonal changes include a decrease in the levels of androgens produced by the ovaries and adrenal glands, such as DHEA, DHEAS, testosterone, and androstenedione [76]. At the same time, the decrease in SHBG levels leads to an increase in the bioavailability of androgens. After menopause, estrone becomes the primary estrogen in women, which is

produced through the peripheral aromatization of androstenedione [77]. Hormonal changes contribute to menstrual disorders and menopausal syndrome, which includes issues with thermoregulation, hot flashes, night sweats, irritability, and sleep disturbances. Estrogen deficiency leads to atrophic changes in the genitourinary system, with vaginal dryness being characteristic, as well as a decrease in bone density and osteoporosis. [78]

Cardiovascular diseases are the leading cause of death in postmenopausal women [79]. It is well known that moderate-intensity physical activity is a factor that reduces cardiovascular risk.

In a study conducted by Wiśniewska et al. on the impact of physical activity on the psychomotor skills of women during menopause, 105 women aged 43 to 62 participated. The results showed that menopause affects women's physical activity – it allows them to engage in sports, but not to the extent they would like. The most noticeable change reported by the women since they began physical activity was an overall improvement in their well-being. [80].

In a two-year study conducted by Nilsson et al., the effects of resistance training on menopausal symptoms were investigated. The study found that a 15-week resistance training program (RTI) significantly alleviated moderate to severe vasomotor symptoms (VMS) and improved both quality of life and cardiovascular risk markers. The primary goal was to assess whether a short-term RTI program could have lasting effects on women's health. Results indicated that the 15-week RTI reduced the frequency of VMS symptoms for up to six months post-intervention compared to the control group (CG). However, this benefit did not persist after two years. Additionally, RTI did not lead to sustained improvements in cardiovascular risk markers or health-related quality of life (HRQoL) after two years, when compared to the control group [81].

Physical activity, including resistance training after prior consultation with a doctor, can bring benefits to women during menopause by improving well-being, alleviating vasomotor symptoms, and enhancing quality of life. However, the long-term effects of such interventions are limited, and the benefits last only for a short period after the program ends. Regular physical exercise, especially of moderate intensity, is recommended to reduce the risk of cardiovascular diseases and improve mental health, but for lasting results, continuity in physical activity is essential.

Use of Hormone Replacement Therapy in female athletes

Hormone Replacement Therapy (HRT) represents a significant medical intervention primarily designed to address hormonal imbalances and deficiencies, particularly in menopausal women. In the context of athletics and sports performance, HRT has garnered attention for its potential implications on female athletes' health and performance capabilities.

HRT typically involves the administration of estrogen, often combined with progestogens, to alleviate symptoms associated with hormonal deficiencies. The therapy aims to restore hormonal balance and mitigate various physiological challenges that may impact athletic performance. Low-dose natural estrogen, specifically 17β-estradiol, combined with progestogens like dydrogesterone, has emerged as a standard approach in oral HRT administration [82]. Dydrogesterone, as a modern retroprogesterone hormone, demonstrates unique properties in HRT applications. When administered orally, 17β-estradiol with dydrogesterone affects SHBG levels through two mechanisms: increasing hepatic SHBG production and maintaining favorable estradiol impact due to dydrogesterone's lack of androgenic activity [82].

The relationship between HRT and athletic performance is complex and multifaceted. Estrogen plays a crucial role in the central nervous system, providing multimodal protection at the neural level. This neurological protection may be particularly relevant for athletes, as cognitive function and memory performance can significantly impact sports performance, especially in technically demanding disciplines. Studies indicate that women during menopause experience a high prevalence of subjective memory complaints due to decreased estrogen levels [83]. However, when examining objective memory performance through standardized testing, research has not consistently demonstrated significant cognitive decline [83]. The timing of HRT initiation appears to be a critical factor in determining its cognitive benefits. Research suggests that the age at which HRT treatment begins may be the key variable explaining the varying outcomes observed in different studies. While some studies report beneficial effects on memory and cognitive function, others show neutral or even negative results, indicating that HRT alone does not guarantee protection against cognitive decline [83].

Female athletes exhibit distinct cardiovascular adaptations compared to their male counterparts. They typically demonstrate longer QT intervals, greater sinoatrial node automaticity, and enhanced atrioventricular node function [84]. Female athletes also show lower sympathetic activity and maximal stroke volumes, with a tendency

toward eccentric cardiac remodeling, while their male counterparts are more prone to concentric hypertrophy [84]. When properly timed and administered, HRT can provide significant cardiovascular benefits. For women under 60 or those near menopause, HRT has been shown to reduce all-cause mortality and cardiovascular disease risk [85]. The therapy demonstrates favorable effects on cardiovascular markers. The risks associated with HRT, including stroke and venous thromboembolism, are relatively rare (<10 events/10,000 women) and comparable to other commonly prescribed medications [85]. Studies have shown that HRT can positively influence VLDL and apolipoprotein levels, with significant reductions in VLDL and Apolipoprotein B, and beneficial changes in the Apolipoprotein B to A ratio [86].

Athletes undergoing HRT require careful monitoring of various biological markers, particularly those related to bone metabolism. A significant study of 120 menopausal women demonstrated that HRT has a measurable impact on enzyme levels. The research found that women using HRT had notably higher serum levels of both alkaline phosphatase (76 U/l) and acid phosphatase (6.60 U/l) compared to non-HRT users (59.56 U/l and 2.66 U/l respectively). These differences were statistically significant in blood serum, though interestingly, salivary levels showed no significant variation between groups [87]. The relationship between HRT and bone metabolism markers is complex. While total alkaline phosphatase activity weakly correlates with bone tissue formation, its bone fraction, which accounts for approximately 60% of total serum activity, provides a better indication of bone tissue remodeling [87]. For athletes, this understanding is crucial as bone health directly impacts performance and injury risk. The study suggests that more specific testing focusing on tartrate-resistant acid phosphatase fraction and bone-specific alkaline phosphatase would provide more precise insights into bone metabolism during HRT [87]. This is particularly relevant for athletes, where accurate monitoring of bone metabolism is essential for maintaining optimal performance and preventing stress injuries.

Elite female athletes face unique challenges in hormonal balance and energy availability. A comprehensive study of Swedish Olympic athletes revealed that menstrual dysfunction was particularly prevalent among endurance athletes, with polycystic ovary syndrome (PCOS) emerging as the primary cause rather than hypothalamic inhibition. The research found no evidence of chronic energy deficiency among these athletes, as evaluated through body fat content and biomarkers of energy availability. Bone mineral density remained generally high among the Olympic athletes, with none exhibiting osteopenia or osteoporosis. This suggests that high-level athletic training may provide protective effects against bone loss, even in the presence of menstrual irregularities. Notably, hyperandrogenic conditions like PCOS may actually provide performance advantages, as these athletes maintained better bone health and showed no signs of the traditional female athlete triad [88]. This understanding is crucial for developing appropriate hormonal interventions in elite athletics, suggesting that underlying causes of menstrual dysfunction should be carefully evaluated before implementing treatment strategies.

While current evidence provides insights into HRT's effects on athletic performance, more research is needed to fully understand its impact on different sporting disciplines and age groups. The timing of HRT initiation appears to be a critical factor in determining its effectiveness and potential benefits for athletic performance [83].

CONCLUSIONS:

Hormonal influences play a multifaceted role in shaping women's health and athletic performance. The intricate interactions of hormones during the menstrual cycle and menopause highlight the importance of hormonal balance for physiological and reproductive health. While physical activity provides numerous benefits, excessive training can disrupt hormonal homeostasis, leading to adverse outcomes such as menstrual irregularities and the female athlete triad. Hormonal contraceptives and anabolic steroids, although useful for specific purposes, carry implications for performance and health that warrant careful consideration. Hormone replacement therapy offers promising benefits for menopausal women but requires individualized approaches to optimize outcomes. Further research is essential to deepen our understanding and develop targeted interventions that enhance health and performance in women.

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