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# SECULAR DECLINE IN TESTOSTERONE LEVELS IN HEALTHY MEN: EVIDENCE AND POTENTIAL EFFECTS OF PHYSICAL ACTIVITY, DIET, AND ENDOCRINE DISRUPTORS (2021–2026)

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**ABSTRACT**

**Background.** Adequate testosterone levels are essential for maintaining physical, metabolic, and mental health. We are currently facing a problem related to a widespread decline in testosterone levels among healthy men, which has been observed across generations.
**Aim.** The aim of this article is to review the literature from 2021 to 2026 that reports on factors that may lower total testosterone levels in healthy men, as well as which of these factors can play a crucial role.
**Material and methods.** A review of the literature was conducted using the PubMed and Google Scholar databases. Meta-analyses and systematic reviews published between 2021 and 2026 were included in the analysis.
**Results.** Among the reviewed factors, obesity, sedentary behaviour, sleep disorders, reduced physical activity, alcohol overconsumption, and endocrine disruptors demonstrated the most consistent association with lower testosterone levels. Disruptions in the gut microbiota and diet are also likely to contribute to the secular decline in testosterone levels. Radio waves, COVID-19 and pornography have no significant impact on the decline in testosterone levels, or their influence remains unclear.
**Conclusions.** The secular decline in testosterone levels among healthy men appears to be a multifactorial phenomenon associated mainly with modern lifestyle, metabolic disturbances, and environmental exposures. Importantly, much of the current evidence is based on acute or observational data, limiting causal interpretation. Further long-term studies are needed to determine the relative contribution of individual factors to the population-wide decline in testosterone concentrations.

**KEYWORDS**

Testosterone, Secular Decline, Men, Lifestyle Factors, Obesity, Diet, Physical Activity, Sleep, Endocrine Disruptors, Environmental Exposure

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## 1. Introduction

Testosterone is the principal androgen in men and a key regulator of male physiology. It is responsible for the development of secondary sexual characteristics, influences libido, regulates spermatogenesis and bone mineral density, and plays an essential role in the maintenance of mental health. [1, 2] The reference range of testosterone concentration is age-dependent. It generally peaks in early adulthood and gradually declines with age. [3]

In recent years, the scientific community has raised concerns about a secular decline in testosterone levels among young, healthy men. In a study published in 2025, researchers demonstrated a consistent downward trend in overall testosterone levels within this population between 1971 and 2024. Male cohort studies also indicate that this trend persists regardless of BMI, changes in lifestyle or the occurrence of chronic diseases. [4, 5, 6]

The aim of this article is to review the latest literature containing reports on factors with the potential to lower total testosterone levels in men, as well as to identify which of these may play a key role in secular testosterone decline in male population.

## 2. The results of the researchers' study

### 2. 1. Lifestyle and Metabolic Health

According to the WHO, 59% of adults are overweight or obese, and in 50 of the 53 countries within the European Region, more than half of the adult population falls into these categories [7].

Between 1990 and 2021, the prevalence of overweight and obesity increased globally, regionally, and across all countries. It is estimated that in 2021, 1.11 billion adult women and 1.00 billion adult men worldwide were overweight or obese. Compared with 1990, the global prevalence of overweight and obesity increased by 155.1% among men and by 104.9% among women [8].

Across the WHO European Region, as well as in most individual countries, overweight and obesity are more prevalent among men (63%) than among women (54%). In several countries, the prevalence among men has reached or exceeded 70% [9].

If current trends continue, the global number of overweight and obese adults is projected to reach 3.80 billion by 2050, accounting for more than half of the projected worldwide adult population [8].

Obesity has a complex impact on testosterone synthesis and metabolism. Chronic inflammation, combined with hormone secretion by adipose tissue, disrupts the hypothalamic–pituitary–gonadal axis, leading to reduced testosterone production. Studies have demonstrated decreased testosterone levels in obese men, suggesting a possible association between obesity and lower testosterone levels [10].

### 2.2. Sleep Disorders and Stress

#### 2.2.1. Sleep deprivation

Both quantitative and qualitative sleep disturbances have a significant impact on testosterone levels. Full sleep deprivation (lasting 24 hours or more) causes a decrease in male testosterone levels. On the other hand, incomplete short-term sleep deprivation does not significantly affect serum testosterone levels in men [11].

#### 2.2.2 Obstructive sleep apnoea

Recent studies suggest that obstructive sleep apnea (OSA) lowers testosterone levels. The relationship between OSA and testosterone levels has been widely investigated. OSA is negatively associated with serum testosterone levels, regardless of age or BMI. Notably, there is a correlation between the severity of OSA and testosterone levels, with reduced testosterone levels observed in patients with severe sleep apnea [12].

A different meta-analysis from 2023, encompassing 24 controlled studies, confirmed earlier findings. Testosterone levels were substantially reduced in male patients with OSA compared to control patients. However, there was no statistically significant difference between female patients with OSA and control patients [13].

Exposure to moderate- or low-intensity chronic stress may also have a significant influence on testosterone levels in men. In recent years, few studies have described a direct relationship between chronic stress and testosterone levels. Most studies have focused on the correlation and interaction between cortisol and testosterone, thereby indirectly assessing the effect of stress on testosterone levels. Measuring testosterone levels and fluctuations in the overall activity of the hypothalamic–pituitary–gonadal (HPG) axis in response to acute stress in humans is complex, and the findings presented in a comprehensive meta-analysis remain inconclusive. Nevertheless, the most consistent change was observed in testosterone levels, as a considerable number of studies suggested an increase in testosterone concentrations in blood and saliva following exposure to acute stress [14]

### 2.3. Physical activity

Physical activity encompasses multiple exercise modalities. Depending on the intensity, duration and nature of the exercise, its impact on hormone profile may fluctuate. It has been proved that high or mid-intensity exercise may be associated with increased testosterone concentrations, whereas chronic excessive training load, particularly when accompanied by insufficient recovery or low energy availability, may reduce testosterone concentrations, whilst low-intensity exercise has no significant effect on T concentrations [15]. A resistance-based exercise is also connected with higher testosterone levels, whilst endurance training, particularly of extended duration and insufficient recovery, can be linked to lower testosterone and higher cortisol levels. [16]

Among modern forms of physical activity, high-intensity interval training (HIIT) has gained substantial popularity due to its time efficiency and cardiometabolic benefits. [17] It is a type of physical activity characterised by short, intense periods of exercise mixed with periods of recovery. HIIT is a highly effective form of training when it comes to improving athletic outcomes [18, 19]. Available evidence indicates that HIIT induces short-term changes in testosterone and cortisol levels. Immediately following exercise, the levels of both these hormones peak, then begin to drop, returning to initial levels within 24 hours [20]. These findings suggest that short-term, temporary fluctuations in hormone levels following HIIT should not be interpreted as a long-term reduction in these levels.

Considering the lifestyle changes that have taken place in recent years, namely, an increase in the average amount of time spent sitting, a decrease in spontaneous physical activity among adults [21], and a general impairment of metabolic health [22].

It is reasonable to assume that changes in physical activity patterns may represent one of several contributors to declining testosterone levels. Importantly, much of the current evidence is based on acute exercise interventions and may not fully reflect chronic adaptations in baseline testosterone concentrations.

### 2.4. Diet

#### 2.4.1. Energy balance

Recent meta-analyses have examined the impact of dietary interventions on testosterone levels, highlighting the importance of both energy balance and macronutrient composition. Caloric restriction, particularly in men with obesity, appears to increase testosterone concentrations, likely due to reductions in adipose tissue and decreased aromatization of androgens [23, 24]. These findings are further supported by evidence indicating that the magnitude of this effect depends on baseline body mass index [25].

#### 2.4.2. Macronutrient composition

In terms of the qualitative approach to diet, research suggests that a low-carbohydrate diet with a very high protein intake (>4.4 g/kg/day) could lower testosterone levels, possibly due to increased cortisol concentrations and altered energy metabolism [26]. Similar findings have been reported in systematic reviews, suggesting that low-carbohydrate diets combined with high protein intake may reduce testosterone levels, whereas moderate protein intake does not appear to exert the same effect [27]. Notably, the definition of “high” versus “moderate” protein intake varies across studies, which limits direct comparisons.

Several studies have investigated low-fat and high-fat diets and their influence on testosterone concentrations. Evidence suggests that low-fat diets may lower testosterone levels. Moreover, a stronger effect was observed in subgroups of European and North American men [28]. Comparable findings have been reported in studies investigating ketogenic diets, although the influence of caloric intake and metabolic adaptation complicates interpretation [29].

### 2.5. Chemical endocrine disruptors

#### 2.5.1. BPA (plastics, bottles, packaging)

The findings indicated that post-pubertal BPA exposure negatively affected the weight of reproductive organs, including the testes, seminal vesicles, and epididymis. Moreover, BPA exposure decreased testosterone and superoxide dismutase levels while increasing the serum estradiol-to-testosterone ratio. It also negatively affected semen parameters, including sperm motility, epididymal sperm concentration, and sperm morphology [30].

#### 2.5.2. Phthalates (cosmetics, cleaning products)

Phthalates, which are chemical plasticisers commonly found in plastics, may negatively affect human health and have been associated with lower semen quality, primarily decreased sperm concentration and reduced motility, as well as lower testosterone levels. Two systematic reviews indicated that human exposure to phthalates, particularly DEHP, DINP, and DIBP, is correlated with reduced testosterone levels in adult men. The evidence is weaker for DBP and inconsistent for BBP and DEP [31].

#### 2.5.3. Pesticides

In a meta-analysis involving 766 men, no differences were found in ejaculate volume, leukocyte count, or testosterone, FSH, and LH levels. In contrast, exposure to organophosphate pesticides was associated with deterioration in semen parameters, including reduced sperm concentration, total sperm count, normal morphology, and motility. However, after sensitivity and subgroup analyses, some of these associations were no longer significant, and no effect on progressive motility or sperm count was confirmed [32].

#### 2.5.4. Microplastic

Lingli Sang et al. published a meta-analysis involving 7,506 participants. The results showed that exposure to per- and polyfluoroalkyl substances (PFAS), particularly perfluorooctanoic acid (PFOA) and perfluorononanoic acid (PFNA), was negatively correlated with testosterone concentrations [33].

### 2.6. Medications and other substances

#### 2.6.1. Alcohol

Globally, a rise in alcohol consumption has been reported in recent decades. Studies comparing annual alcohol consumption per person in 1990 and 2017 estimate that consumption was 5.9 litres per person and 6.5 litres per person, respectively [34]. Other sources suggest that consumption has risen over the last two decades and currently reaches its peak in Europe [35]. The above epidemiological data may be relevant when considering the impact of alcohol consumption on serum testosterone levels. A recent meta-analysis demonstrated that chronic alcohol consumption, particularly in the context of excessive intake, is associated with reduced total and free testosterone concentrations in men [35]. Importantly, the results of this study relate strictly to healthy men who chronically consume alcohol but do not have diagnosed diseases or acute alcohol-related disorders. Additionally, chronic alcohol exposure may affect not only testicular function but also the entire hypothalamic-pituitary-gonadal axis [36].

#### 2.6.2. Cannabis

According to the United Nations Office on Drugs and Crime, cannabis is the most widely used illicit drug worldwide [37]. A meta-analysis examining the effects of marijuana usage on fertility indicates an association between cannabis use and the impaired semen quality. Overall, 44.9% of studied men consuming cannabis exhibited impaired semen parameters. Meanwhile, among abstainers, the incidence was 24.5%. However, the same study suggests no consistent association between cannabis usage and testosterone levels, with some studies even reporting an increase in testosterone levels following cannabis use [38].

Furthermore, a cross-sectional study of infertile men aged 18–60 years found that consumption of marijuana was not associated with lower testosterone values in this particular group as well. The study also assessed the effects of this drug on various hormones and reported decreased concentrations of estradiol and increased concentrations of prolactin [39].

#### 2.6.3. Antidepressants

Another factor that may contribute to decreased testosterone levels in men is the use of SSRIs (selective serotonin reuptake inhibitors). In vitro research conducted on human adrenocortical H295R cells examined the impact of these medications on hormonal balance. The effect on the H295R steroidogenic pathway was analyzed for six commonly prescribed drugs in this group: sertraline, fluoxetine, paroxetine, citalopram, escitalopram, and fluvoxamine. All six drugs included in the study caused a decrease in testosterone synthesis and an increase in estrogen levels [40].

In turn, an extensive review focused on the possible negative impact of antidepressants on testosterone levels [41]. Nonetheless, the evidence remains inconclusive. Some studies suggest an increase in testosterone levels, whereas others indicate a decrease. There are also studies showing no effect at all [41].

According to a study conducted in England, sertraline consumption increased by 685% between 2010 and 2023, rising from 2.9 million to 23 million prescriptions, respectively [42]. Taking into account the steadily increasing use of antidepressants, particularly SSRIs, in recent years, SSRIs should be considered a potential factor contributing to the decline in testosterone levels in the male population.

#### 2.6.4. Statins

A 2024 meta-analysis reported a statistically significant decrease of 9.11 ng/dL in the mean total testosterone concentration among patients who started statin therapy. Before the initiation of statin therapy, the average testosterone concentration was 427.83 ng/dL, whereas after starting therapy, it decreased to 416.86 ng/dL. Despite a significant decrease in free testosterone levels during statin therapy, the study authors emphasized that testosterone levels did not fall below the lower limit of the reference range [43].

### 2.7. Gut microbiota

Due to its constant interaction with the metabolism, immune system, and neurosecretory systems of the host, the intestinal microflora may exert an impact on distant organs, extending far beyond the boundaries of the intestine [44, 45]. These findings led to the concept of an "axis" between organs (e.g., the gut-brain axis). Consequently, it was hypothesized that the gut-brain axis may represent an important pathway through which gut microbiota dysbiosis (an imbalance in the composition of gut bacteria) can negatively affect male reproductive function [44, 46].

A positive correlation between the gut microbiome and testosterone levels in men was demonstrated by Cennikon Pakpahan et al., with selected microorganisms potentially influencing androgen production. Among the analyzed microorganisms, Ruminococcus showed the strongest correlation with testosterone levels. Other bacterial genera, including Dorea, Clostridium, Akkermansia, Adlercreutzia, and Parabacteroides, were also associated with testosterone metabolism, highlighting the complex relationship between the gut microbiome and androgen homeostasis [47].

In a cohort of older men, higher testosterone levels were associated with an increased abundance of bacteria belonging to the phylum Firmicutes, particularly Clostridiales, Turicibacter, and Gemella. Moreover, the relationship between Firmicutes abundance and serum testosterone levels remained significant independently of host-related factors, including age, body mass index, triglyceride levels, and total cholesterol [48].

Patients with type 2 diabetes mellitus (T2DM) and testosterone deficiency were found to exhibit distinct gut microbiota profiles compared with patients with T2DM alone. In particular, individuals with low serum testosterone demonstrated an increased abundance of opportunistic pathogens and Gram-negative bacteria, accompanied by reduced microbial diversity and altered relative abundance of bacterial taxa, including Blautia and members of the order Lachnospirales. Furthermore, serum testosterone levels showed significant correlations with several bacterial genera, suggesting that gut dysbiosis and chronic low-grade inflammation may contribute to the development of testosterone deficiency in men with T2DM [49].

### 2.8. Mobile devices

According to the authors, it is worth considering the potential impact of radiofrequency electromagnetic radiation emitted by wireless communication devices on men's hormonal balance and reproductive capacity. Researchers conducting the systematic review reported evidence suggesting possible negative effects of long-term (>6 years) use of devices operating at a frequency of 950 MHz on testosterone levels [51]. While the results of human studies were less conclusive than those observed in animal studies, the widespread daily use of RF-EMR suggests that this exposure could be considered a potential contributing factor to the decline in testicular function within the population [50].

### 2.9. Pornography and sexual habits

Recently published papers have provided new data on sexual behaviour disorders in the context of the male endocrine health crisis. A Chinese study involving more than 500 young, healthy men reported that pornography exposure was associated with specific hormonal profiles. According to the researchers, earlier exposure to pornography appeared to be associated with lower blood levels of prolactin, follicle-stimulating hormone, and progesterone, as well as higher estrogen levels. It was also associated with lower sperm concentration and total sperm count. However, the researchers did not directly refer to changes in testosterone levels [51].

Another study by Burkardt et al. suggested that problematic pornography use may be associated with the testosterone-to-cortisol ratio, highlighting the potential role of interactions between gonadal and stress-related hormonal systems. Nevertheless, current evidence regarding pornography exposure remains limited and inconsistent. Existing studies mainly focus on reproductive hormones and semen quality rather than direct long-term changes in testosterone concentrations [52].

### 2.10. COVID-19

During the COVID-19 pandemic, in addition to the classic manifestations of severe viral lower respiratory tract infection, several cases of orchitis and epididymitis were also reported [53]. These findings encourage further assessment of the impact of SARS-CoV-2 infection on male reproductive function and hormonal balance.

For this purpose, 1,250 patients with active or recent (within 80 days) COVID-19 infection were examined. The study suggested a link between SARS-CoV-2 infection and primary testicular tissue damage, manifested by changes in steroidogenesis and impaired spermatogenesis. A significant decrease in total sperm count, sperm concentration, and overall sperm motility was observed in patients compared with the control group. Patients also exhibited lower total testosterone levels than the control group [54].

The findings of this study should encourage further research into the long-term consequences of the COVID-19 pandemic on male sexual health.

## 3. Discussion

Latest available data suggest that the secular decline in testosterone levels among healthy men is likely driven by a combination of metabolic, lifestyle, and environmental factors. However, these factors do not appear to contribute equally, and their relative importance depends on both the quality and consistency of the available evidence.

The strongest and most consistent associations are linked to metabolic health, particularly obesity. Excess adipose tissue increases the conversion of androgens to estrogens, while chronic low-grade inflammation associated with metabolic dysfunction may suppress the HPG axis. Given the worldwide rise in overweight and obesity over recent decades, these factors are likely among the main contributors to declining testosterone levels in the general male population.

Lifestyle-related factors also seem to play a meaningful role, although the evidence is more variable. Sleep deprivation and obstructive sleep apnoea are consistently associated with reduced testosterone levels. The relationship between physical activity and testosterone appears to be more complex. Moderate exercise and resistance training are generally beneficial, whereas excessive training loads may have the opposite effect. Diet may also influence testosterone levels through energy balance and macronutrient composition, although these effects appear to depend heavily on baseline metabolic status and overall dietary patterns. The condition of the gut microbiota may also be relevant. Reduced microbial diversity or an increased abundance of opportunistic bacteria may contribute to chronic inflammation, which can indirectly lead to testosterone deficiency.

Environmental and exogenous influences, including endocrine-disrupting chemicals, alcohol consumption, and certain medications, may additionally contribute to hormonal dysregulation. Chronic alcohol use and exposure to endocrine disruptors have been associated with adverse effects on the HPG axis, although the strength of evidence varies across studies. For some proposed factors, such as radiofrequency electromagnetic radiation, pornography use, or the consequences of COVID-19, current findings remain limited and inconsistent.

Several important limitations should also be considered. Many studies rely on single, short-term testosterone measurements or include patients with comorbidities, which may not accurately reflect long-term hormonal status. In addition, differences in study design, population characteristics, and exposure definitions make it difficult to establish causality or directly compare effect sizes across studies.

Overall, the decline in testosterone levels is unlikely to result from a single dominant cause. Instead, it probably reflects the combined influence of multiple metabolic, behavioural, and environmental factors acting together over time. Future research should focus on clarifying the relative contribution of these factors and distinguishing temporary hormonal fluctuations from sustained long-term changes in baseline testosterone levels.

## 4. Conclusions

The secular decline in testosterone levels among healthy men appears to be a multifactorial phenomenon associated mainly with modern lifestyle, metabolic disturbances, and environmental exposures.

Importantly, much of the current evidence is based on acute or observational data, limiting causal interpretation. Further long-term studies are needed to determine the relative contribution of individual factors to the population-wide decline in testosterone concentrations.

### Author Contributions

Conceptualization: GR, PS, RG, KG, KS, BB, RJ, JC, EB, BK
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Investigation: GR, PS, RG, RJ, JC
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Drafting: KG, KS
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