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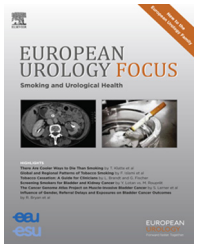

Review – Andrology

Adverse Effects of Common Sports and Recreational Activities on Male Reproduction

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Article info

Article history:
Accepted April 20, 2018

Associate Editor:
Christian Gratzke

Keywords:
Bicycling
Cell phones
Electromagnetic waves
Erectile dysfunction
Hypogonadism
Male infertility
Sauna
Sports
Testicular temperature
Traumatic brain injury

Abstract

Context: Male factor infertility plays a significant role in infertility. Many factors have been associated with male infertility; however, the link between many sports and recreational factors and male reproduction remains poorly characterized.
Objective: To evaluate the current literature regarding the impact of many common sports and recreational factors on male reproduction.
Evidence acquisition: A comprehensive PubMed and Embase search for relevant articles published between 1970?and 2017?was performed by combining the following search terms: *male, sports (including individual sports), traumatic brain injury, sauna, hot tub, fertility, erectile dysfunction, varicocele, environment*, *cell phone*, and *laptop computer*.
Evidence synthesis: Hypogonadism and erectile dysfunction can be associated with sports with high rates of head injuries, such as American football. Although early reports linked other sports, such as bicycling, to erectile dysfunction, subsequent studies isolated these associations to sports cycling rather than recreational cycling. Certain sports (football, basketball, handball, and volleyball) were linked to increasing prevalence and severity of varicocele, offering a potential link to male infertility. In addition, recreational activities such as sauna, hot tubs, Jacuzzis, heated car seats, and laptop use were associated with high testicular temperature, which can impair spermatogenesis. Radio frequency electromagnetic waves from cell phones and laptops have also been shown to have deleterious effects on sperm viability and motility.
Conclusions: Many common sports and daily activities represent potential sources of male infertility. Clinicians should be aware of these associations in explaining idiopathic infertility in males.
Patient summary: Male infertility is an often overlooked component of a couple's inability to conceive. We outline many common and often overlooked sports and recreational exposures that have been associated with male infertility.

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1. Introduction

Healthy male reproductive function relies upon contributions from three main physiological processes: normal semen parameters, erectile function, and ejaculation. Disruption of any of these three processes can result in male reproductive dysfunction. Approximately one in six couples are infertile, and male factor infertility can be found in roughly one-third of these couples [1]. The World Health Organization defines male infertility as semen parameters

https://doi.org/10.1016/j.euf.2018.04.013
2405-4569/

below their normal values, with sperm count being implicated in 90% of cases [2,3]. Erectile dysfunction (ED), defined as the inability to attain or maintain an erection of sufficient rigidity for satisfactory sexual intercourse, is estimated to have a prevalence of 5–20% worldwide [4]. Ejaculatory dysfunction, thought to be the most prevalent of all types of reproductive dysfunction, occurs in roughly 30% of men in the US [5].

Activities and recreational factors considered to be benign or even healthful can be found among risk factors for disruption of the physiological processes necessary for male reproductive health. In this review, we evaluate the effect of sports and recreational activities on male reproductive function.

2. Evidence acquisition

A systematic search of electronic databases PubMed and Embase for relevant articles published between 1970 and 2017 was performed by combining the following terms: *male, sports (including individual sports such as football, basketball, soccer, hockey, and bicycling), traumatic brain injury (TBI), sauna, hot tub, cell phone, fertility, erectile dysfunction, varicocele, environment*, and *laptop computer*. Only articles published in English were selected. In addition, sources in the reference sections of the identified publications were also added to the list. Evidence was not limited to human data; data from animal studies were also included in the review. Each article title and abstract was reviewed for relevance and appropriateness with regard to the relationship between recreational factors and sports activities to male reproduction.

3. Evidence synthesis

Methodological and clinical heterogeneity of the included studies meant that meta-analysis was inappropriate. Therefore, a narrative synthesis of the data was performed and ranges are provided for data where applicable (Table 1).

3.1. Adverse effects of sports

3.1.1. Head trauma

The deleterious effects of sports-related concussions and TBI to contact sports, particularly American football, has been an important and popular topic of conversation and research in recent years. Sports-related head trauma potentially alters male reproductive function, which relies upon contributions from centers within the brain itself as well as the hypothalamus and pituitary. In fact, an intact hypothalamic-pituitary-gonadal (HPG) axis is essential for male reproductive function. The hypothalamus releases gonadotropin-releasing hormone, which stimulates the anterior pituitary to release luteinizing hormone and follicle-stimulating hormone, which in turn stimulate Leydig and Sertoli cells, respectively, within the testes. Leydig cells release most of the body's testosterone and Sertoli cells release androgen-binding protein, which is necessary for spermatogenesis. Therefore, disruptions in this HPG axis can cause impaired reproductive function via a reduction in testosterone, creating a form of secondary hypogonadism.

Decreased pituitary function, also known as hypopituitarism, is a relatively common phenomenon following TBI [7]. Several studies have further established the connection between TBI, hypopituitarism, and hypogonadism [8–10]. In fact, the HPG axis appears to be one of the most frequently affected axes in hypopituitarism secondary to TBI [11,12]. A 2015 review of hypothalamic-pituitary axis dysfunction following moderate to severe TBI reported findings of low testosterone in the acute phase following TBI, suggesting that HPG axis suppression occurs immediately following TBI.

Several studies have reported cases of specifically sports-related TBI inducing HPG axis suppression. One study reported hypogonadotropic hypogonadism in a kickboxer aged 20 yr who complained of decreased libido and impotence following a kickboxing match [14]. Another study reported the prevalence of hypogonadism to be 10% among National Football League retirees; however, this study did not clearly establish football-related head injuries as the cause of hypogonadism. Other studies have described different variations of hypopituitarism caused by sports-related TBI, such as growth hormone deficiency and central diabetes insipidus [15–17]. All the sports discussed in these studies involve head trauma, thus all presenting a risk to the HPG axis. The sports most frequently implicated in sports-related TBI include soccer, boxing, rugby, American football, ice hockey, martial arts, roller skating, motor racing, cycling, skiing, and equestrian [18]. Additionally, the degree of hypopituitarism appears greater in those who participate in the sports over many years and in those who sustain repeated head injuries [18]. This dose-dependent relationship between contact sports with a high prevalence of head injuries and pituitary dysfunction suggests that these sports are a clinically relevant factor in HPG axis suppression resulting in ED and infertility. We were unable to find literature linking sports-related head trauma to ejaculatory dysfunction or abnormal semen parameters.

3.1.2. Other

In addition to brain-related injuries, sports (even noncontact sports) have been associated with an increased prevalence of varicocele, which are present in approximately 40% of men presenting with infertility and have been associated with a progressive decline in fertility [19–21].

In a study of over 1000 males, Radojevic et al [23] showed that varicocele prevalence was higher in males playing basketball, football, handball, and volleyball (BFHV, $n = 305$) than in sport-inactive controls ($n = 644$, 17.05% vs 12.35%). They proposed that these sports necessitated body movement against gravity, which led to the development of varicocele. The researchers also had a third group that consisted of water polo players ($n = 44$) and found that the prevalence of varicocele in that group was even lower than that in the controls. The authors proposed that the external water pressure acting on the genitals of water polo players provided a beneficial effect similar to a suspensory treatment used for varicocele. In a prospective arm of the

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Table 1 – Outline of included studies.

Category	Source	Sample/study description	Purpose	Conclusion
TBI and pituitary dysfunction	Kelly et al [11]	International Index of Erectile Function scores were obtained from NFL retirees with and without hormone deficiency.	To assess the relationship between mild TBI and pituitary function in retired football players.	The prevalence of hypogonadism among NFL retirees is roughly 10%. It is unclear if this hypogonadism can be attributed to recurrent mild TBI secondary to football.
TBI and pituitary dysfunction	Javed et al [18]	Review	To explore the evidence of the incidence of pituitary dysfunction following TBI	High-contact sports have been shown to be associated in pituitary dysfunction in many studies.
TBI and pituitary dysfunction	Tanriverdi et al [16]	Case report	To report a case of transient hypogonadism in an amateur kickboxer	Head trauma related to combat sports like kickboxing can lead to acute-onset, transient hypopituitarism.
TBI and pituitary dysfunction	Foley et al [15]	Case report	To report a case of hypopituitarism in an athlete following head trauma.	Hypopituitarism in the form of central diabetes insipidus can be seen following sports-related head trauma.
Cycling and ED	Marceau et al [35]	Community population of 1700 men aged 40–70 yr	Identify if a correlation between ED and bicycling exists	Those who bicycled for >3 h/wk were at greater risk of developing moderate to severe ED (OR = 1.72).
Cycling and ED	Hollingworth et al [33]	Cross-sectional study of over 5200 cyclists in the UK	To evaluate the association between cycling and ED, fertility, and PSA levels	There was no association between cycling time and ED and infertility. There was, however, a graded increase in prostate cancer risk for men aged >50 yr who bicycled >3.75 h/wk.
Cycling and ED	Taylor et al [34]	Internet-based survey of 688 men	To evaluate if cycling is a hazard to the sexual health of men	The overall prevalence of ED in cyclists does not seem to be higher than that in controls.
Cycling and sexual and urinary dysfunction	Awad et al [36]	Cross-sectional survey of nearly 4000 men aged 40–70 yr	To identify a correlation between bicycling and sexual and urinary dysfunction	There was no significant difference in sexual and urinary dysfunction between cyclists and swimmers/runners. Low intensity cyclists were, however, at higher risk of developing urethral strictures.
Sports and varicoceles	Radojevic et al [23]	1013 young males were divided into groups of: (1) BVHF players, (2) water-polo players, and (3) sports-inactive controls	To test the hypothesis that sports cessation would reduce varicocele prevalence in young athletes	Men in the BFHV group had significantly higher prevalence of varicoceles. Furthermore, a 6-mo sports cessation of men in the BFHV group led to improvement in every semen parameter.
Sports and varicoceles	Di Luigi et al [24]	60 healthy men and 60 men with varicoceles provided semen parameters	To identify the influence of physical exercise on seminal parameters	Athletes with varicoceles had significantly lower progressive forward motility normal spermatozoa ($p < 0.5$). They also had significantly lower left testis volume than contralateral testis ($p < 0.5$).
Recreation and scrotal temperature	Bujan et al [38]	9 volunteers drove a car for 160 min and scrotal temperature was measured	To evaluate the impact of driving position on scrotal temperature	Scrotal temperature was significantly increased after driving for 2 h ($p < 0.0001$).
Recreation and scrotal temperature	Shefi et al [40]	11 men who were exposed to wet heat for 30 min/wk underwent a period of wet heat abstinence for 3 mo	To evaluate the impact of wet heat on spermatogenesis	Elimination of heat exposure led to a return in semen parameters to baseline.
Recreation and scrotal temperature	Jung et al [53]	30 volunteers performed 90 min sitting in a heated and unheated car seat in a randomized order	To evaluate the impact of heated car seats on scrotal temperature	Sitting in a heated car seat for 60 min can significantly increase scrotal temperature, reaching values that may impair spermatogenesis.
Laptop computer and scrotal temperature	Sheynkin et al [42]	Left and right scrotal temperature was measured in 29 volunteers while working with laptops and without laptops.	To evaluate the impact of laptop use on scrotal temperature	Scrotal temperature was significantly higher with working laptops
RF-EMR and spermatogenesis	Adams et al [43]	Meta-analysis of studies looking at radio frequency electromagnetic waves and the impact on spermatogenesis	To evaluate the impact of cell phones on sperm quality	Exposure to phones was significantly associated with reduced sperm motility and viability. They concluded that cell phone use decreases sperm quality in general.

BFHV = basketball, football, handball, and volleyball; ED = erectile dysfunction; NFL = National Football League; OR = odds ratio; PSA = prostate-specific antigen; RF-EMR = radio frequency electromagnetic radiation; TBI = traumatic brain injury.

study, the researchers showed that a 6-mo cessation of all sporting activity among those with varicocele who played BFHV ($n = 50$) led to a statistically significant improvement in sperm count and progressive motility [23].

While it has not been studied whether sports are the direct cause of new cases of varicocele, it has been shown that sports serve as an aggravating factor for cases of pre-existing pathology. Athletes were found to have

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significantly worse varicocele than nonathletes, specifically with lower progressive forward motility and smaller left testis size [24]. The impact of sports on varicoceles can, thus, play a significant factor in causing male infertility.

3.1.3. Bicycling

Bicycling is one the most common forms of transportation, exercise, sport, and recreation among people of all age groups. While there are well-established cardiovascular benefits from this form of aerobic exercise, bicycling is also the most common source of injuries affecting the genitourinary system [25].

The prevalence of genitourinary symptoms varies in the literature, but some have estimated that genital numbness and ED exist in 61% and 24% of male cyclists, respectively [26]. It is believed that bicycling leads to excessive perineal pressures, which can compress the pudendal nerve and artery causing nerve entrapment and transient ischemic hypoxia [27,28]. With this in mind, specific saddles have been created to avoid compression of perineal arteries and preserve penile perfusion [29].

Multiple reports have described ED following cycling activities [30–32]. However, many recent studies have failed to find associations between moderate cycling and ED after controlling for other variables such as age and comorbidities [33,34]. In a large cross-sectional survey, Marceau et al [35] seem to isolate the association of ED and cycling to sports cyclists (cycling more than 3 h/wk) and show a protective effect of cycling on ED in moderate cyclists (cycling less than 3 h/wk). Following up to see impacts on recreational bicycling, Awad et al [36] conducted a large cross-sectional study of almost 4000 men, evaluating the impact of bicycling on sexual function. The researchers found no significant difference in sexual function, including ED, in bicyclists compared with the control athletic group of swimmers and runners. While small studies and case reports explored a link between ED and bicycling, these more robust studies have shown a questionable link in recreational users.

3.2. Adverse effects of recreational activities

3.2.1. High testicular temperature

Testicular thermoregulation is an important part in normal spermatogenesis and sperm function. Increased temperature impedes differentiation and maturation of spermatocytes, leading to alteration of sperm parameters and apoptosis [37,38]. In addition to varicoceles, many daily activities, such as saunas, Jacuzzis, hot tubs, and heated car seats, are associated with increased intratesticular temperature and, consequently, infertility.

The sauna is largely used in Nordic countries and gained popularity all around the world. Sauna exposure was studied by Garolla et al [39] in normozoospermic men who underwent two sauna sessions per week for 3 mo. They found a transient decrease in sperm count and motility along with impaired mitochondrial function and sperm DNA packaging when compared with baseline. However, after 6 mo from the end of sauna sessions, semen parameters returned to normal.

Jacuzzis and hot tubs have also been associated with abnormal serum parameters. Shefi et al [40] evaluated male semen parameters with a known history of Jacuzzi, hot tub, and whirlpool bath exposure for $\geq$30 min/wk during $\geq$3 mo prior to study enrollment. Similar to the findings seen in Garolla et al [39], this study found that cessation of heat exposure led to a return of baseline semen parameters. However, this study is limited by its weak inclusion criteria that may play a significant role in its end point.

In addition to clear cases of heat exposures such as saunas and hot tubs, other, less obvious activities have been implicated in increasing testicular temperature. For example, sitting in a vehicle for extended periods of time has been shown to increase testicular temperature. Bujan et al [38] demonstrated that scrotal temperature was increased by 1.7–2.2 °C after participants sat in a car for 2 h, ultimately leading to an increased risk factor for sperm parameter alterations. More recently, the use of heated car seats has been proposed to affect semen parameters in drivers who have long journeys. A clinical trial by Jung et al [41] evaluated the influence of heated versus unheated car seats on the scrotal temperature in patients with a normal andrological evaluation and no history of infertility. They found that sitting for up to 60 min in a heated car seat is associated with an increase of 0.5–0.6 °C above the increase found in unheated car seats, reaching values that may impair spermatogenesis.

Nowadays, many have raised concerns about the significant increase in laptop computer usage and an association with male infertility. Sheynkin et al [42] found that scrotal temperature was increased by 1 °C among the people who had the laptops placed on their lap in a sitting position compared with those who did not have laptops placed on their lap but were in the same sitting position. Male patients should be wary of this potential association.

3.2.2. Radio frequency electromagnetic waves

Cell phones and laptop computers have been adopted worldwide. Radio frequency electromagnetic radiation (RF-EMR) emitted from these devices are a potential risk factor for sperm development and function [43]. Despite efforts to control EMR emission by limiting frequencies, many adverse effects such as headache [44], increased resting blood pressure [45], and electroencephalographic activity disturbance during sleep [46] have been reported.

Given the concern of RF-EMR emitted from cell phones, Adams et al [43] performed a meta-analysis of in vivo and in vitro studies to determine whether exposure to RF-EMR emitted from cell phones would affect human sperm quality. Interestingly, they found that exposure to cell phones was associated with reduced sperm motility in six of nine studies. Regarding viability, four of five studies revealed a significant negative association between cell phone exposure and sperm viability by 9.1%. However, there was no significant effect of EMR on sperm concentration. Furthermore, RF-EMR is proposed to increase the production of reactive oxygen species (ROS), leading to DNA damage. In this scenario, in vitro models revealed increased mitochondrial ROS production and DNA fragmentation, leading to

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decreased sperm motility and viability [47]. Moreover, Avenda et al [48] used an in vitro model where sperm were incubated at room temperature and placed under a laptop computer that was working actively (uploading and downloading information) throughout the period of exposure. These groups also found a significant decrease in sperm motility and a significantly higher proportion of sperm with DNA fragmentation when samples were incubated for 4 h. Considering the ubiquitous use of cell phones, men should be increasingly wary of the effect on RF-EMR as a potential cause of impaired spermatogenesis.

4. Conclusions

Many studies have looked at the impact of sports and recreational factors on male reproduction. While much of the literature is mixed and plagued with inadequate samples or cofounders, clinicians and the general public should be aware of the many ubiquitous activities that can be associated with idiopathic male infertility.

Author contributions: Kush Panara had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Ramasamy.
Acquisition of data: Panara, Masteron, Savio.
Analysis and interpretation of data: Panara, Masteron, Savio.
Drafting of the manuscript: Panara, Masteron, Savio.
Critical revision of the manuscript for important intellectual content: all authors.
Statistical analysis: None.
Obtaining funding: None.
Administrative, technical, or material support: Ramasamy.
Supervision: Ramasamy.
Other: None.

Financial disclosures: Kush Panara certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: None.

Funding/Support and role of the sponsor: None.

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