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The Impact of Intense Exercise on Semen Quality

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Abstract

With expanding knowledge on the health benefits of exercise, there is an increasing demand for information on the andrological consequences of participating in sports. These consequences are especially important in the context of infertility problems worldwide. The so-called "male factor" is reported in up to 50% of couples having trouble with conception. The answer to the question, "Is physical activity good for male reproductive health?" is not straightforward. A number of studies have suggested that significant changes in semen parameters may occur due to sports training of certain types, intensities, and durations. The changes to these parameters vary in scope, direction, and magnitude. Findings in recreational athletes have also differed from those in professional athletes. This review of the current literature suggests that intense physical activity may affect the semen concentration, as well as the number of motile and morphologically normal spermatozoa. Training at higher intensities and with increased loads seems to be associated with more profound changes in semen quality. In recreational athletes, exercise has either a positive or neutral effect on semen parameters. Due to many limitations (e.g., global sperm count trends, concerns about the quality control of sperm evaluations, and new standards for semen analysis), comparisons among historical data and their interpretation are difficult.

Keywords

andrology, male reproductive health, exercise

Introduction

Disturbances of reproduction are frequent in humans and the so-called "male factor" may be the cause of infertility in 50% of cases (Brugh & Lipshultz, 2004). At the same time, sports and leisure exercise have become extremely popular in the modern era. People engage in various sports for entertainment and health, and some types of exercise (e.g., football, running, tai chi, cricket, and table tennis) are performed by millions.

In this context, it is important to be aware of the impact of sports on the quality of semen. Despite the proven benefits of regular exercise, there is evidence that spermatogenesis may be hindered in physically active individuals (Gebreegziabher, Marcos, McKinon, & Rogers, 2004; Safarinejad, Azma, & Kolahi, 2009).

Exercise and Spermatogenesis

Apart from congenital, permanent reasons, spermatogenesis may be affected by testicular heat stress, oxidative stress, endocrine pathology, improper nutrition, drug side effects, or irradiation. Testes function properly at a temperature that is optimally 2 °C lower than that of the core body (Durairajanayagam, Agarwal, & Ong, 2015; Mieusset & Bujan, 1995). Inactivity, obesity, occupational exposure to heat (as experienced by metallurgists, bakers, and drivers), and laptop use have been associated with elevated scrotal temperatures. Heat stress induces germ cells apoptosis, autophagy, DNA damage, testicular germinal atrophy, spermatogenic arrest, decreased levels of inhibin B, and increased production of reactive oxygen species. Epididimal spermatozoa present alterations of motility and viability and functions of Sertoli and Leydig cells are compromised under such conditions (Durairajanayagam et al., 2015). With regard to sports, elevated scrotal temperatures that might be expected in motor sports, cycling, or horseback riding, were indeed observed in car drivers (Bujan, Daudin, Charlet, Thonneau, & Mieusset, 2000) and to some degree in cyclists (Jung, Strauss, Lindner, & Schuppe, 2008). In men participating in these activities, spermatogenesis may

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be altered and even completely inhibited after the core body temperature is reached. Differences in the impacts of tight- versus loose-fitting underwear should be addressed, as higher scrotal temperatures have been reported in men wearing tight clothing (Jung & Schuppe, 2007).

The effects of a prolonged period of a moderately increased scrotal temperature are similar to those of a relatively large increase in scrotal temperature over a shorter period of time (Hjollund, Bonde, Jensen, & Olsen, 2000). On the other hand, studies performed on men seated for sustained periods of time (or those wearing tight underwear) have concluded that a reduced sperm count does not have a substantial impact on fertility (Stoy, Hjollund, Mortensen, Burr, & Bonde, 2004). Some results even question the hypothesis that higher scrotal temperatures cause alterations in spermatogenesis (Jung & Schuppe, 2007; Wang et al., 1997).

In animal models, mechanisms leading to heat-related disturbances in spermatogenesis involve the increased expression of hypoxia-inducible factor 1 alpha mRNA (HIF1A), heme oxygenase 1, and the antioxidant enzymes glutathione peroxidase 1 and glutathione S-transferase alpha, translocation of the HIF1A protein into germ cell nuclei, increased expression of the effector caspase and cleaved caspase 3, and reduced expression of the inhibitor of caspase-activated DNase protein. The changes are consistent with a strong oxidative stress response, germ cell death and an increased rate of DNA fragmentation (Paul, Teng, & Saunders, 2009). In men, a commonly diagnosed problem of varicocoele leads not only to alterations of spermatogenesis through generation of reactive oxygen species but also testicular heat stress and local ischaemia (Agarwal, Hamada, & Esteves, 2012). Changes in the hormonal hypothalamo–pituitary–gonadal axis may affect spermatogenesis as well. Exercise leads to fluctuations in the secretion of gonadotropins and androgens. It is assumed that testosterone concentration is elevated after bouts of resistance exercise (Vingren et al., 2010). To the contrary, prolonged endurance training (of 60 weeks duration) was associated with a tendency toward reduced testosterone concentrations and hypogonadotropic hypogonadism (Safarinejad et al., 2009). The effects of systematic physical activity on the hypothalamo–pituitary–gonadal axis are still debatable. Hypothetically, secretion of androgens in athletes may be reduced due to suppressed release of gonadotropins and direct/indirect effects of increased corticotropin-releasing hormone, corticotropin, cortisol, catecholamines, or prolactin (Jozkow & Medras, 2012). So-called functional hypogonadotropic hypogonadism that occurs in patients with endocrine pathologies (leasions of the pituitary and the hypothalamus, hyperprolactinemia, therapy with sex steroids, glucocorticoids, or GnRH analogues), brain injuries, severe chronic illnesses, eating disorders and malnutrition, metabolic states (obesity, metabolic syndrome, diabetes mellitus), is also diagnosed in athletes after strenuous exercise (Lenzi et al., 2009). Other factors affecting the quality of semen are discussed further.

Active Lifestyle and Semen

It has been suggested that physical inactivity may be associated with reduced semen quality (Stoy et al., 2004) and indeed sedentarism/obesity turned out to be correlated with a lower sperm count (Magnusdottir, Thorsteinsson, Thorsteinsdottir, Heimisdottir, & Olafsdottir, 2005). In addition, television watching appears to be inversely associated with the sperm concentration and total sperm count (Gaskins et al., 2015).

The association between physical activity and semen quality is not so obvious; this lack of an apparent association may be explained by several potential factors. The results of andrological investigations are difficult to compare due to their heterogeneity. Studies are often conducted on populations that are subfertile or infertile (Gaskins et al., 2014; Wise, Cramer, Hornstein, Ashby, & Missmer, 2011), and doubts are regularly raised about the quality control of semen analysis techniques. In addition, physical activity (as a variable) cannot be easily quantified using the currently available tools.

Observational Studies

Some authors have suggested that the level of physical activity is not related to semen quality; however, data relevant to this topic are contradictory (Table 1).

Semen parameters did not correlate with regular exercise in a study of 2,261 men attending fertility clinics in the United States (Wise et al., 2011). Furthermore, no relationship was detected between exercise (i.e., frequency, type, and duration) and sperm parameters in detailed semen analysis (Wogatzky et al., 2012). Findings of relatively large cohort studies conducted on general populations in America and student populations in Europe have also failed to provide evidence of such an association (Eisenberg et al., 2014; Minguez-Alarcon et al., 2014).

Interestingly, physically active subjects from Spain have been reported to have higher numbers of motile spermatozoa and spermatozoa with normal morphology than sedentary controls (Vaamonde et al., 2012). Moreover, a higher level of physical effort has been associated with an increased sperm count and concentration among American students (Gaskins et al., 2015). In addition, the sperm concentration was reported to be 43% higher in men who engaged in moderate/vigorous exercise among a population of 231 men seeking infertility treatment (Gaskins et al., 2014).

Comparisons of semen samples from sport professionals, recreational athletes, and sedentary controls from Iran have revealed physical activity–dependent differences in semen

Table 1. Recent Observational Studies of the Overall Relationship Between Physical Activity and Semen Quality.

Author	Subjects	Effects of physical activity on semen parameters
Gaskins et al. (2015)	University students (n = 189)	↑ Concentration, count
Gaskins et al. (2014)	Men treated for infertility (n = 231)	↑ Concentration
Eisenberg et al. (2014)	General population (n = 468)	No effects
Minguez-Alarcon, Chavarro, Mendiola, Gaskins, and Torres-Cantero (2014)	University students (n = 215)	No effects
Hajizadeh Maleki, Tartibian, Eghbali, and Asri-Rezaei (2012)	Elite athletes (n = 56), recreationally active men (n = 52), sedentary controls (n = 53)	Recreationally active men had ↑ volume, , count, motility, and normal morphology
Tartibian and Maleki (2012)	Elite athletes (n = 56) versus recreationally active men (n = 52)	↓ Volume, count, motility, and normal morphology
Vaamonde, Da Silva-Grigoletto, Garcia-Manso, Barrera, and Vaamonde-Lemos (2012)	Physically active men (n = 16) versus sedentary controls (n = 15)	↑ Motility and normal morphology
Wogatzky et al. (2012)	Men treated for infertility (n = 1,683)	No effects
Wise et al. (2011)	Men treated for infertility (n = 2,261)	No effects (apart from those in men who cycled for >5 hours/week)

status similar to those cited above. The sperm volume, number, as well as the percentages of motile and morphologically normal spermatozoa, were the highest among recreational athletes (Hajizadeh Maleki et al., 2012). Further analysis of the same population has suggested that intense training (as with elite sportsmen) is correlated with decreases in the volume and number of spermatozoa, the sperm concentration, and the percentages of motile and morphologically normal spermatozoa (Tartibian & Maleki, 2012).

Intervention Studies

Sports pose discipline-specific burdens. There are considerable differences in the outcomes of the workouts of a skier in the winter and a football player in the summer, even if the duration and intensity are equal. Nevertheless, investigations with controlled training/exercise stimuli can provide some common observations.

For example, recent studies have reported evidence of decreased sperm concentrations in cyclists and mountain trekkers after periods of intense physical effort (Hajizadeh Maleki et al., 2012; Hajizadeh Maleki & Tartibian, 2015; Maleki, Tartibian, & Vaamonde, 2014). Semen volume tends to increase after training (Denham, O'Brien, Harvey, & Charchar, 2015; Maeshima, Tanaka, Matsuda, & Harada, 2012). Furthermore, the sperm count tends to increase after 4 weeks of training (30 minutes per session three times a week for 1 month, at 40% or 80% of the participants maximum heart rate; Maeshima et al., 2012) but to decrease after 60 weeks of high (compared with moderate) intensity training (80% vs. 60% maximal oxygen uptake; Safarinejad et al., 2009). The percentage of normal morphology spermatozoa (Hajizadeh Maleki & Tartibian, 2015; Maleki et al., 2014) and their motility may also be reduced in athletes undergoing intensive cycling training for 16 weeks (Hajizadeh Maleki & Tartibian, 2015), running on a treadmill five times a week, for 120 minutes, at 60% to 80% of maximal oxygen uptake, for 60 weeks (Safarinejad et al., 2009), or trekking in the high mountains for 6 to 8 hours a day for 5 days (Verratti et al., 2016; Table 2).

Earlier studies have reported that the sperm concentration is decreased by different types of training continued for 14 to 33 days (Aitken, Buckingham, Richardson, Gardiner, & Irvine, 2000; Vaamonde, Da Silva, Poblador, & Lancho, 2006; Verratti et al., 2008). Sperm motility has been demonstrated to be lower than that at baseline in men who participate in cycling (Hajizadeh Maleki et al., 2012), in those exposed to high altitudes (Verratti et al., 2008), and in those who participate in diving (Aitken et al., 2000). Exercise has also been related to a decreased proportion of morphologically normal spermatozoa in several studies (Hajizadeh Maleki et al., 2012; Vaamonde et al., 2006; Verratti et al., 2008).

The major limitation of the studies presented above is their small population sizes; authors obtained data using only three (Aitken et al., 2000), eight (Vaamonde et al., 2006), and six subjects (Verratti et al., 2008), respectively. Another limitation was the variable time points used for postexercise sperm evaluations. The samples in the aforementioned studies were collected at 80 and 243 days after exercise; immediately after exercise and after 3 days; and immediately after exercise, after 1 month, and after 3 months, respectively.

Examples of Sport Disciplines

Cycling

Cycling is one of the most troublesome activities for fertility due to the mechanical impact sustained from sitting

Table 2. Most Recent Investigations of the Effects of Physical Activity on Semen Quality.

Author	Subjects	Intervention	Duration	Evaluation	Preexercise vs. postexercise semen evaluations
Verratti et al. (2016)	Mountain trekkers (n = 7)	Expedition to altitude of 900m to 5,895m	5 Days	3 Days after trekking	No difference (apart from reduced forward motility)
Denham et al. (2015)	Healthy men (n = 13), controls (n = 11)	Sprint interval training 2x/week	12 Weeks	After 12 weeks	Healthy (Volume: 4.7 ± 1.4 vs. 5.17 ± 0.87 [mL]; Count: 271 ± 242 vs. 278 ± 282 [× 10^6]) Controls (Volume: 3.95 ± 1.7 vs. 3.97 ± 1.79 [mL]; Count: 315 ± 313 vs. 266 ± 278 [× 10^6]
Hajizadeh Maleki and Tartibian (2015), Maleki et al. (2014)	Cyclists (n = 24)	Intensive cycling training	16 Weeks	After 30 days of recovery	Concentration: 255 ± 36 vs. 45 ± 20 [× 10^6/mL] (p < .008) Motile: 69 ± 17 vs. 65 ± 20 [%] (p < .008) Normal morphology: 16±3 vs. 9 ± 3 [%] (p < .008)
Maeshima et al. (2012)	Healthy men (n = 15)	Ergometer (40% vs. 80% of HRmax), 30 minutes 3x/week	4 Weeks	1 Day after intervention	Volume: 2.2 ± 1.1 vs. 2.7 ± 1.1 [mL] (p < .05) Count: 240 ± 71 vs. 310 ± 100 [× 10^6] (p < .05)
Pelliccione et al. (2011)	Mountain trekkers (n = 7)	Expedition to altitude of 5,900m	46 Days	At sea level, 3 days before and 1 day after expedition	Concentration: 68 vs. 35 [× 10^6/mL] (p < .02)
Safarinejad et al. (2009)	Recreational athletes (n = 246)	High-intensity (80% VO_2 max) versus moderate-intensity exercise (60% VO_2 max), 5 sessions (120 minutes) per week	60 Weeks	Immediately after intervention and at 12, 24, and 36 weeks of recovery	High- versus moderate-intensity exercise led to decreased Count: 106 ± 21 vs. 161 ± 31 [× 10^6] (p = .03) Concentration: 35 ± 4 vs. 57 ± 4 [x 10^6/mL] (p = .02) Motile: 48 ± 3 vs. 54 ± 3 [%] (p = .02)

Note. HRmax = maximum heart rate; VO_2 max = maximal oxygen consumption.

on the saddle, gonadal overheating, wearing tight clothes, and hormonal dysfunction (hypogonadism). In a number of studies (usually focused on road-bikers), cycling has been associated with abnormal spermatozoa morphology and reduced motility (Gebreegziabher et al., 2004; Kipandula & Lampiao, 2015).

A prospective cohort study conducted in the United States evaluated the association between semen quality and physical activity in a large group of men attending an infertility clinic (n = 2,261, aged 36 ± 3 years). Although regular exercise was not associated with any semen parameters, cycling for ≥5 hours per week was associated with reductions in the sperm concentration and motility (Wise et al., 2011). Another study that examined semen samples from 231 men referred for infertility treatment pointed to a similar trend. Men who reported cycling for 1.5 hours or more per week had sperm concentrations that were 34% lower than those of men who did not ride bicycles (Gaskins et al., 2014). Just recently, a small study identified that young men who cycled as taxi operators had lower than controls: semen volume, concentration, total motility, progressive motility, and higher percentage of abnormal morphology sperm (Kipandula & Lampiao, 2015).

Running

Training in running affects semen as well. It is possibly due to disturbances in the hormonal milieu (e.g., gonadotropins and testosterone), the stress response (e.g., corticotropin-releasing hormone, adrenocorticotropin, cortisol, and beta-endorphins), oxidative stress, and scrotal heating.

Running a minimum mean distance of 108 km/week for 12 months has been associated with reductions in several semen parameters as well as sperm concentration and motility and number of round cells. Semen profiles were not affected in runners who covered only 40 to 56 km/week for a year (M. J. De Souza, Arce, Pescatello, Scherzer, & Luciano, 1994). Conversely, a prospective, 1-year-long study that examined a group of 24 marathon runners identified negative associations between high-intensity training and the sperm count and number of spermatozoa with normal morphology, with sperm count and percentage of morphologically normal spermatozoa significantly lower after about 1 year (Jensen, Wiswedel, McLoughlin, & van der Spuy, 1995).

A study conducted in Iran evaluated the effects of intensive, long-term treadmill running on the hypothalamo–pituitary–testicular axis in a group of 286 subjects (75% of whom had fathered children). The participants were randomized into groups and run at either a moderate (60% of VO_2 max) or high (80% of VO_2 max) intensity for 120 minutes, five times a week, for 60 weeks. This period was followed by a 36-week low-intensity recovery period. Semen samples were collected at the initiation of the exercise regimen and at consecutive visits every 12 weeks. The results of this study suggested that high-intensity exercise was correlated with decreases in sperm density, motility, and morphology after 24 weeks of exercise. Continuing with exercising caused the parameters to worsen, although they were still within the fertile range. Reductions in sperm parameters were also observed in the subjects running at a moderate intensity; however, these changes did not reach statistical significance. Most important, during the recovery period, the semen parameters returned to their preexercise levels (Safarinejad et al., 2009).

Mountaineering

Mountain trekkers should be aware of the potential effects of high altitude on fecundity. Issues of concern for this population include the direct influences of the low-oxygen environment on spermiogenesis and spermiation, epididymal dysfunction, alterations in the hypothalamo–pituitary–gonadal axis, and/or hyperprolactinemia (Pelliccione et al., 2011).

In addition to influencing the sperm concentration, exposure to altitudes higher than 2,000m may result in reductions in sperm motility and the number of spermatozoa with normal morphology (Pelliccione et al., 2011; Verratti et al., 2008).

In six trekkers climbing to an altitude of 5,600 m, the sperm concentrations dropped from 53 ± 18 to 16 ± 16 × 10^6/mL, motility decreased from 57 ± 16 to 37% ± 7%, and the percent of abnormal and immature spermatozoa increased from 32 ± 5 to 47 ± 5% (after 1 month). Notably, these changes were reversible (Verratti et al., 2008). In the most recent study, short (5 days) exposure to hypoxia combined with exercise (trekking to an altitude of 900m to 5,895m above sea level) did not significantly alter sperm parameters, apart from a marked reduction in sperm forward motility (Verratti et al., 2016).

Effects of Doping on Semen Parameters

Anabolic androgenic steroids (AAS) are not only the most commonly used drugs for doping among male athletes but also probably the most dangerous to the reproductive system. Hundreds of thousands of professional and recreational athletes, accounting for 6.4% of men globally, may be exposed to AAS during their lifetimes (Nieschlag & Vorona, 2015).

Hypogonadotropic hypogonadism and a dampened semen profile are well-known signs of AAS abuse being sometimes described as anabolic-steroids induced hypogonadism (ASIH). In athletes suffering from ASIH low or normal concentrations of gonadotropins and low concentration of testosterone are usually observed. Symptoms do not necessarily appear abruptly. Furthermore, ASIH may be associated with structural and genetic sperm damage (G. L. de Souza & Hallak, 2011; Salenave, Trabado, Maione, Brailly-Tabard, & Young, 2012). Although ASIH is usually temporal, disturbances in hormone and sperm

production may persist for months after AAS withdrawal (van Breda, Keizer, Kuipers, & Wolffenbuttel, 2003). A Finnish study of male power athletes (exposed to AAS for between 6 months and 13 years) reported that at 6 months after cessation of AAS use (but not after 1.5 months), the sperm count increased from 33 ± 49 to $77 \pm 70 \times 10^6$/mL (Karila, Hovatta, & Seppala, 2004). Athletes who decide to stop taking AAS experience recovery of spermatogenesis (usually after 6-12 months); however, the reduced sperm count is not always reversible (Boregowda, Joels, Stephens, & Price, 2011). Authors of the most recent recommendations on the management of ASIH noted that they were based on the review of the literature and expert opinions as high-quality studies on patients with ASIH were lacking (Rahnema, Lipshultz, Crosnoe, Kovac, & Kim, 2014).

Genital Trauma

Scrotal injuries may occur in men participating in certain sport disciplines, and they represent threats to fertility. The relationship of such injuries with semen quality has not yet been examined.

In a recent survey, 18% of male American students reported that they had suffered from a testicular injury (Bieniek & Sumfest, 2014). In yet another investigation of 755 male athletes aged 12 to 25 years, 20% of emergencies due to genital trauma involved a risk of permanent injury (Congeni, Miller, & Bennett, 2005). Furthermore, in a study of extreme mountain bikers from Austria who were especially prone to genital trauma but who had no history of major incidents, scrotal ultrasound examination revealed abnormalities in 94% of the men (Frauscher et al., 2001).

It can be speculated that microtrauma sustained by testicles or the prostate gland during exercise may affect semen variables. A few authors reported that prostate-specific antigen (PSA) increases after cycling. At the same time, PSA concentration turned out to be inversely related to semen volume, sperm concentration, and progressive motility (Ausmees et al., 2014). Nevertheless, other reports identified that PSA concentration is not influenced by exercise in young subjects (Banfi, Pontillo, Dolci, & Roi, 1997), and levels of PSA and free PSA in elite cyclists are the same as in sedentary controls (Lippi et al., 2005).

Factors That Affect the Quality of Semen

Semen quality is dependent on biological, environmental, and lifestyle factors. There is strong evidence that the perinatal period is related to intact spermatogenesis during adulthood. In many cases, male infertility may be linked to Sertoli-cell-only syndrome, immature, undifferentiated Sertoli cells, microliths, or Leydig cell nodules. Other relevant factors include disorders of sexual development, which may be mild or severe.

Problems with spermatogenesis that arise during development are usually permanent. In contrast, the potentially detrimental effects of the environment, lifestyle, and diet are avoidable.

Both acute and chronic medical conditions may transiently or permanently affect gonadal function. In previous centuries, infectious diseases posed the greatest threat to gonadal function. Currently, altered spermatogenesis is observed in men with liver pathology, those who have received chemotherapy and those with sleep apnea (Hammoud, Carrell, Gibson, Peterson, & Meikle, 2012; Sharpe, 2010).

Medications that are suspected to interfere with semen quality include antidepressants, calcium channel blockers, alpha-adrenergic blockers, antiepileptics, and antiretroviral drugs. In a study of 165 men with idiopathic infertility, the withdrawal of drugs (antihistamines, antibiotics, or antiepileptics) resulted in improvements in semen quality and the conception rate (93% and 85%, respectively) compared with a control group that did not stop treatment (12% and 10%, respectively; Hayashi, Miyata, & Yamada, 2008).

It is also possible that disturbances in spermatogenesis arise as a consequence of exposure to chemicals and environmental contaminants. The following endocrine disruptors have attracted the most attention due to their negative effects on spermatogenesis: bisphenol A, parabens, heavy metal ions, and insecticides. Despite extensive research in this field, such associations remain largely unconfirmed.

Other factors that interfere with male fertility include smoking and alcohol consumption. Interestingly, the effect of maternal smoking (during pregnancy) on spermatogenesis in male offspring is stronger than that of active smoking by men. Heavy smokers have a 19% lower mean sperm concentration and a 29% lower total sperm count than nonsmokers (Ramlau-Hansen et al., 2007). In contrast with the detrimental effects of heavy drinking, moderate alcohol consumption has a moderate impact on sperm and thus fertility (Alvarez, 2015).

Obesity is often associated with altered sperm parameters. Azoospermia and oligozoospermia occur more frequently in obese and overweight subjects (Sermondade et al., 2013). An increased body mass index is associated with a reduced blood testosterone concentration and an increased estradiol concentration (Rohrmann et al., 2011). The frequency of obesity in infertile men is higher than in those with a normal sperm count (Sharpe, 2010). One may assume that the negative effect of obesity on male fertility is small to moderate.

The quality of human semen may also vary seasonally, although it is not as evident in humans as it is in animals. Semen volume, sperm concentration, and the percentage of spermatozoa with normal morphology are all lower during the summer than during other periods of the year. The sperm count may decrease by up to 30% during the summer months (Jorgensen et al., 2001).

Sperm motility at temperatures of 10 °C to 20 °C (during the winter and spring) is higher than that during warmer seasons, and the percentage of spermatozoa with head defects is lower during the winter (Zhang et al., 2013). These findings are consistent with observations made in individuals working outdoors, which is a typical environment for many sports. Seasonal changes in sperm parameters are also present in subjects working in air-conditioned spaces (Levine et al., 1992). The latter should be considered in athletes exercising in sport halls.

The effects of socioeconomic and psychological influences on the semen profile and male fecundity are less clear (Jozkow & Medras, 2012; Li, Lin, & Cao, 2011).

Discussion and Conclusions

The authors are aware of the potential pitfalls of the current review. Most recent studies on this topic were performed on small numbers of subjects: between 7 and 246 in intervention trials and between 16 and 2,261 in cross-sectional designs. Furthermore, a few studies might have been biased by inclusion of infertile/subfertile men (Wise et al., 2011; Wogatzky et al., 2012). In addition, it cannot be ruled out that associations between physical activity and semen quality vary in populations of different genetic backgrounds. Also, the methodology of the semen analysis (time of semen acquisition, time of evaluation, laboratory technique), the range of evaluated parameters, and the laboratory quality control might have affected the outcomes of specific investigations. To this regard, semen samples were assessed as soon as 1 day after intervention (Maeshima et al., 2012; Pelliccione et al., 2011), and as late as after 36 weeks of recovery after an intervention (Safarinejad et al., 2009). In some studies, it was not possible to evaluate sperm motility. At the same time, it is not straightforward to compare studies in which strenuous physical activity lasted from 5 days (Verratti et al., 2016) to 60 weeks (Safarinejad et al., 2009). The intensity of applied exercise/training and the sport level of enrolled subjects differed considerably across the studies. Moreover, control groups were not always recruited. Another shortcoming is the fact that popular sports disciplines were under- and less popular (mountaineering) overrepresented in the current analysis.

Generally, the review of the literature supports the evidence that sports practice affects semen quality. In recreational athletes, exercise seems to be mainly associated with positive or neutral effects, while professionals should be aware of potential risks. The parameters that are most often reduced by intense training are the sperm concentration, percentage of motile spermatozoa, and percentage of morphologically normal spermatozoa. The impacts of these factors on fecundity are unknown. Future studies should clarify the direction and magnitude of the effects on semen in men participating in the most popular sport disciplines.

At this time, it seems prudent to advise all active men to minimize scrotal heating, to maintain a proper body mass, to avoid smoking, alcohol consumption, doping, and environmental toxins and to address sleep apnea (if present). These measures will have beneficial effects on spermatogenesis and should result in healthy offspring.

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