



Published in final edited form as:

Rev Andal Med Deport. 2017 June ; 10(2): 79–93. doi:10.1016/j.ramd.2016.11.017.

Impact of physical activity and exercise on male reproductive potential: a new assessment questionnaire

D. Vaamonde^{a,b,*}, J.M. Garcia-Manso^{b,c}, and A.C. Hackney^{b,d}

^aDepartment of Morphological Sciences, School of Medicine, University of Cordoba, Cordoba, Spain

^bInternational Network on Physical Exercise and Fertility, Spain

^cDepartment of Physical Education, Universidad de Las Palmas de Gran Canaria, Santa María de Guía, Canary Islands 35017, Spain

^dDepartment of Nutrition-Gillings School of Global Public Health, Department of Exercise & Sport Science, University of North Carolina, Chapel Hill, NC 27599, USA

Abstract

Male athletes in general are subjected to the same causes of infertility as the general population, but sports practice itself may be possibly an additional infertility factor or, at least an aggravating factor for a previously existing fertility condition; on the contrary, being physically active has been hypothesized to favor hormonal and seminological processes and could be beneficial for fertility. In this relationship, the different inherent parameters of physical activity-exercise (training volume, intensity, objective, organization and frequency) are of paramount importance. Therefore, this review discusses both the negative and positive impact of physical exercise on the male reproductive potential. Clear knowledge is lacking on this topic as incongruences exist due to the fact that studies lack standardization in assessment tools or research protocols. So that future studies can reveal more information regarding exercising male fertility, we introduce a unique questionnaire developed with the intent to help standardize future studies on male fertility and exercise.

Keywords

Exercise; Training; Semen; Hormone; Fertility; Stress; Questionnaire

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

*Corresponding author: fivresearch@yahoo.com (D. Vaamonde).

Conflicts of interest

The authors have no conflicts of interest to declare.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Introduction

Physical activity programs improve health and the quality of life, but excessive or exhaustive exercise exposure can lead to negative side effects, with one of the most recently recognized being possible fertility issues in both females and males when training load is elevated and intense, though this is not universally recognized. Physical activity (exercise) could exert beneficial or detrimental effects depending on the several inherent exercise regimen parameters: type, intensity, volume, objective, or organization. Regrettably, there is still lack of consensus on these effects.¹ Extensive and important work has been done assessing female athletes in this regard but this reviewed is delimited to males only.

In males where results seem more controversial, it has been observed that prolonged intensive exercise (and training) may lead to adverse effects on physiological systems, particularly, the reproductive system and fertility with alterations in reproductive hormone levels,^{2–12} atrophy of the testicular germinal epithelium and adverse effects on spermatogenesis,^{13–15} changes in semen parameters including abnormal sperm morphology,^{2,3,7,10,11,16} and reduced sperm motility.¹⁶

Nevertheless, there are still many discrepancies in studies regarding the effect of exercise and physical activity on male fertility. Therefore, the aim of the present article is to review the impact of physical exercise on reproductive performance and fertility as well as to introduce a unique questionnaire that may help standardize future studies on male fertility and exercise.

Exercise male reproductive performance and fertility

Hormonal alterations – endurance training

Negative effect—While there is no clear consensus, acute and chronic exercise is associated with suppressed endocrine functions at the hypothalamic and testicular levels; specifically, suppression of both gonadotropin-releasing hormone (GnRH) and serum testosterone.¹⁷ Taking testosterone (T) as a major regulator of the hypothalamic-pituitary-testicular (HPT) axis, available studies can be included into three categories: those that do not show changes in either T (free [fT] or total [tT] T) or any of the other HPT hormones,^{18–20} those that show no changes in testosterone (fT or tT) but show changes for the other HPT hormones,^{7,21,22} and those that show changes in fT or tT but there could or could not be changes, for the other HPT hormones.^{2,3,10,23–28}

Some studies may reflect training stimuli that were not sufficient enough to alter the axis (low or moderate performance level, or low volume used in the study), which could be plausible explanations for studies not detecting changes in T but detecting changes for other hormones (Follicle Stimulating Hormone (FSH) and Luteinizing Hormone (LH)). Among works detecting changes in T the most habitual finding is decrease in T without changes in FSH or LH.^{2,3,10,22,27} Research has focused primarily on distance runners, but studies have been conducted with other endurance sports. For example cyclists, were findings are controversial. One study reported no differences in hormonal profiles of cyclists.¹⁶ Other studies have revealed decreased T values in professional cyclists, during one specific race

(Tour of Spain),^{29,30} researcher found cyclists coming into competition with the greatest training volume had lower T levels than those of other comparative cyclists. This finding is supported by other studies.^{5,31} Likewise, when trained and untrained subjects performing four hours of road bicycling at the highest possible level were compared, it was observed that FSH levels were higher in the trained subjects, suggestive of a compensatory hypogonadism as result of intensive chronic training or Sertoli cell dysfunction.³²

Hypogonadal states have been observed as a result of chronic ultra-endurance-training when running or cycling 10–20 or more hours per week.³³ Triathletes, normally undergoing high volume in the three sports modalities composing this discipline, showed, when compared to cyclists and recreationally active men, significantly lower levels of estradiol and T.¹² However, not all previous studies have observed such differences.¹⁶

Rowing has also assessed the effect of training on HPT. Heavy training seems to result in decreased free Testosterone Cortisol ratio (T/C) when compared to basal levels; though decreases greater than 30% have been reported, but never drop below the threshold value indicating overstrain of 0.35×10^{-3} .³⁴ Urhausen et al.³⁵ observed that T, T/sex hormone – binding globulin (SHBG), and T/C decreased during a 7-week period of training, stopping with recovery of only one week and with two rowers showing normalized values within several weeks of training discontinuation. A 2-week period of high-training volume significantly decreased T 30 min after finishing a long-distance rowing test; such observed changes indicate decreased adaptive ability.³⁶

Such decreased adaptivity was also observed in another study as evidenced by reduced basal fT and fT/C ratio as well as an altered T response to an exercise challenge after a heavy training period of three weeks.³⁷ Similarly Vinther et al.³⁸ found that values, albeit within normal range, were in the lower part of the normal spectrum. Therefore, as reported by some, T and cortisol (C) are altered as a result of changes in training volume, and the values of such hormones appear related to weekly training volume.³⁹

Not only does the volume of training induce hormonal alterations, but in fact, the intensity of the exercise may also exert an influence on hormonal profile alterations. In this regard, Safarinejad and co-workers,¹⁰ compared moderate-intensity exercise (60% Maximal Oxygen Consumption (VO_{2max})) to high-intensity exercise (80% VO_{2max}) for a period of 12 weeks and reported alterations in hormones (returning to normal during recovery) with a decrease in T and blunted response to a Gonadotropin Releasing Hormone (GnRH) stimulation challenge in both groups but alterations being more marked in the high intensity group.

Furthermore, our research group has shown that maximal intensity exercise imposed on physically active subjects during a short period of time results in alterations in FSH, LH, prolactin (PRL), dehydroepiandrosterone and C values but no significant changes in T, progesterone and estradiol; such alterations returned to pre-training values after three days during the recovery period.⁷

In soccer, Grandi and Celani⁴⁰ have observed that the LH response to a GnRH-Thyrotropin Releasing Hormone (TRH) challenge test was less in the professional players as compared to non-professional players; while no significant hormone changes were observed during the

training season, PRL basal levels were increased after a strenuous soccer game. In basketball, an initial transient increase in T was observed to later on decrease, along with a decrease in T/C, from mid-season on.⁴¹

The evidence discussed above points to the hormonal response to exercise being affected by both by intensity and volume of training. Although the complexity in hormone feedback mechanisms and the disparity in results in the available literature demands that a consensus in study design and protocols needs to be reached. The heterogeneity observed in different studies with regards to, but not limited, the type of athlete (sedentary vs. amateur vs. professional), the type of intervention (observational vs. interventional) should be minimized.

Positive effect—Though studies analyzing long term response are scarce, imposed training loads seem to elicit an acute response with an initial increase in androgenic hormones, but when programs are sustained, often surpassing the habitual training levels of the athletes, there may be a decrease in basal levels of these hormones.^{42–45} The loaded used, time of application and type of athletes are key factors for the long-term effects of training. Frequently, exercising subjects present with higher T basal levels than sedentary subjects.^{46,47} Intervention with moderate intensity aerobic exercise resulted in increased serum dihydrotestosterone (DHT),⁴⁸ in fT⁴⁹ and SHBG^{48,49} in sedentary subjects. Also, Vaamonde and colleagues⁵⁰ have recently reported improved values for FSH, LH, T and the T/C ratio when comparing sedentary subjects to physically active subjects.

Hormonal alterations – resistance training

Resistance exercise elicits acute post-exercise hormonal responses whereas prolonged, long-term training has an effect on basal or resting concentrations.^{51–53} Hormonal responses after a resistance training session, depend on the load, the used muscle mass and the impact that the session may impose on the organism. Though not to be discussed here we must be aware that use and abuse of anabolic androgenic steroids may be common feature in resistance training athletes and that these compounds may alter the HPT axis and inhibit endogenous T production, which may be reversible or not depending especially on dose and time of use.

Negative effect—While an increase in the resting levels of T is common feature of chronic response to strength training,⁵ when resistance training becomes excessive, with the athlete coming close to overtraining or with persistent fatigue, T levels may even decrease from baseline.⁵⁴

Yet not fully elucidated such response may involve amino acid deficit and central nervous system alterations,² alterations in neurotransmitters or increase in T-inhibiting hormones, and aging processes.⁵⁴

Positive effect—For male athletic performance, it may be beneficial to alter the levels of circulating anabolic hormones and the anabolic-catabolic ratio as testosterone, among others, is directly involved in muscle adaptation to exercise.

Generally speaking, albeit discrepancies exist, including theories that changes in hormones are not mechanistic, but a result of hemoconcentration or decreased hepatic clearance, adequately applied resistance training provokes an increase in tT and fT levels after one training session,^{51,55} with magnitude of changes depending on different factors such as load (intensity,⁵⁶ volume,⁶ recovery,⁵⁷ amount of muscle mass involved, athlete's age,⁵⁸ experience and performance level.⁵⁸ The magnitude of the load used will determine the time that T levels are elevated after training.⁶

Reproductive function – endurance training

Negative effect—Though controversy, as in hormonal studies, there is evidence that long-term exhaustive exercise seems to negatively affect sperm quality and reproductive potential.¹¹

One study reports that even up to 10% of the assessed runners exhibit severe oligospermia, yet other authors report non-existing or merely subclinical alterations due to exercise training.^{2,19,23,59} Increase in “round cells” has also been reported² indicating a possible infectious and/or inflammatory environment. Arce and colleagues² were able to, retrospectively establish a volume threshold of 100 km/wk for semen alterations to occur, as they found alterations in sperm density, motility, morphology and in vitro sperm penetration of standard cervical mucus in endurance-trained runners when compared to resistance athletes or sedentary subjects. Similarly, Safarinejad et al.¹⁰ observed a negative effect of training on sperm parameters, though reverting during recovery, in high-intensity training athletes when compared to moderate-intensity ones. Conversely, Hall and co-workers⁶⁰ could not find an influence on sperm count, morphology, or motility after a period of six weeks of gradually intensified training followed by two weeks of detraining.

High-level athletes have been typically training for many years, making it difficult to establish a potential harmful training threshold (volume and/or intensity) as they normally start training at pre-or peri-pubertal years. Nevertheless, high volume cycle training seems to correlate with sperm morphology anomalies.⁶¹ In fact, in triathletes, a cycling volume of 300 km/wk correlates with serious degree of morphology abnormalities and possibly leading to fertility impairment. Also, ultra-endurance athletes when compared to other athletes show significantly different values for the various sperm parameters with morphology showing the greatest difference, with clinical relevance (<5% normal forms).¹¹

In animal models decreased number of cells from the spermatogenic lineage at different stages of development has been observed with training,^{14,15} some of these studies also revealed decreased levels of serum hormones, enzymes and antioxidant agents.^{14,15} Vaamonde et al.⁶² have reported exercise-related alterations in sperm which may be prevented with antioxidant agents. Vaamonde et al.⁶³ also recently reported that, similarly to sperm morphology, cycling volume positively correlates to sperm deoxyribonucleic acid (DNA) fragmentation, also observing high correlation between training volume, sperm DNA fragmentation, percentage of morphological abnormalities and TUNEL(+) cells (unpublished data Vaamonde).

Regarding reproductive tract abnormalities, it has been reported that a soccer player exhibited testicular mal-development;⁶⁴ as the athlete had cryptorchidism it is hard to establish a relationship to sports practice, however, with greater training load all other symptoms worsened. In this regard, continuous strenuous exercise has also been linked to erectile dysfunction or impotence⁶⁵ as tiredness and fatigue may lead to reduced libido, especially in bicycling exercise^{64,66} due to microtrauma and compression on the genital area. In rats, decreased testicular, epididymal, prostatic, and seminal vesicles somatic indices have been reported as a result of exercise.¹⁵

Positive effect—Far less studied is the positive effect of exercise or physical activity on seminal parameters. Vaamonde et al.⁵⁰ reported improved semen parameters in physically active men when compared to sedentary people, such findings being supported by hormonal differences. Other studies with endurance-trained men report that average semen parameters values are usually within normal limits¹⁶ or show subclinical alterations.^{2,3,19} In this regard, significant alterations, even if subclinical, have been reported to require a certain “training volume-threshold” (~100 km/wk) before occurring.³ Also in animals similar results have been reported, not only on sperm parameters but also on testicular health.^{67,68}

Training load affects oxidative stress; as such, superoxide dismutase (SOD) capacity has been reported to be increased in elite athletes⁶⁹ which can affect the testicular environment. Physically active men, in comparison to higher level athletes, have been shown to have higher levels of seminal antioxidant compounds and lower levels of seminal reactive oxygen species (ROS), oxidative stress and sperm DNA fragmentation.⁷⁰ Erectile dysfunction has also been reported to be less common in physically active subjects (non-athletes) than in sedentary; moreover, this condition has been seen to improve as a result of unhealthy lifestyle modification like becoming physically active (minimum energy expenditure of 200 kcal/day).⁷¹

Also in animal models it has been observed that exercise reduces markers of oxidative stress and increases antioxidant-related enzymes,⁶⁸ decreasing age-related damage, especially if exercise practice begins earlier in life,⁷² and also decreasing DNA damage.⁷³ Moreover, testicular atrophy, inflammation and degeneration, related to aging, is decreased in animals submitted to exercise.⁶⁸

Reproductive function – resistance training

Negative effect—Resistance training is many times intimately related to androgenic anabolic steroid (AAS) use and regrettably little is known, if any on sperm quality as a result of resistance training without steroid use. It has been observed that the HPT axis and its hormones are altered by supraphysiologic levels of exogenous AAS and that these changes may lead to semen alterations like azoospermia, oligospermia, teratozoospermia (mainly head and mid-piece), and oftentimes testicular atrophy^{74,75} as evidenced by alterations in germinal epithelium, Leydig cells, among others.⁷⁶

Positive effect—No clear evidence exists of a positive effect of resistance training on semen parameters. Arce et al.² has observed, when comparing endurance and resistance athletes, that the latter did not manifest negative alterations as seen in endurance athlete's

semen characteristics so this could be indicative that, at least, this type of training is not substantially detrimental to semen quality.

Mixed modalities

Many team sports, such as soccer, basketball and rugby, among others, because of their inherent characteristics must be considered as mixed modalities as their training is not purely endurance or resistance. Athletes participating in such sports may also be at risk for altered hormone and semen values. Exercise may be especially deleterious in case of existing pathologies like varicocele⁷⁷ and the pathology may be especially aggravated in times of intensified training or competition.⁶⁴ Sperm motility has also been observed to be negatively altered in some soccer players.⁴⁰

Scientific evidence seems to support the existence of a minimum level of volume, the so-called volume-threshold, for detrimental effects to take place, either hormonal or seminological.^{2,3,8} As Hackney et al.^{8,33} highlight, alterations may well represent the accumulative effect, more than the acute response, of years of training load. Competition or post-competition periods, as well as periods of intensified training seem to be particularly deleterious. Some of the latest research has shown that, training intensity, and not only volume, is greatly important in this equation as well, as Vaamonde et al.⁷⁸ point out with even correlation to sperm DNA damage and alteration is oxidative stress-related parameters. Nevertheless, high-load exercise seems to exert negative impact on male fertility potential, modulated by duration, volume, intensity and type of modalities, though most of the observed alterations are subclinical and revert upon ceasing or decreasing practice.

We believe many other inherent parameters of exercise training (frequency, recovery, clothing, environmental temperature, degree of muscular-skeletal damage, infections and/or inflammations) may play in to affecting reproductive function and looking at just intensity or volume is too delimiting to research designs. The final influence-effect, as in other physiological systems, will depend on the subject's own characteristics and how well his adaptive systems are prepared for the challenge training imposes (see Fig. 1). It is important that well designed studies with standardized assessment tools regarding testing, exercise conditions and subject characteristics (fertility especially) be performed; this especially holds true for mixed modalities sports, probably the most widely practiced and the least studied in this context at this time.

In our opinion, one critical aspect necessary in this research is a more encompassing questionnaire that addresses key issues regarding exercise practice and fertility status. To this end, we have developed and included with this review a new developed instrument based upon our collective experience, to use by researchers wanting to study exercise and fertility more extensively (see Appendix 1). It is important to note that this questionnaire, if used in research, be used with the subjects' informed consent and Ethics Committee approval.

In conclusion, awareness must be raised that exercise must be considered as a potential cause for urological and andrological male fertility problems. As such, exercise training should be assessments in males. Also, more research is needed to reflect the positive effect

of moderate and low-level exercise on reproductive potential in order to make safe recommendation in lifestyle practices to help couples in achieving pregnancy.

References

1. Du Plessis S, Kashou A, Vaamonde D, Agarwal A. Is there a link between exercise and male factor infertility. *Open Reprod Sci J*. 2011; 3:105–13.
2. Arce JC, De Souza MJ, Pescatello LS, Luciano AA. Subclinical alterations in hormone and semen profile in athletes. *Fertil Steril*. 1993; 59(2):398–404. [PubMed: 8425638]
3. De Souza MJ, Arce JC, Pescatello LS, Scherzer HS, Luciano AA. Gonadal hormones and semen quality in male runners. A volume threshold effect of endurance training. *Int J Sports Med*. 1994; 15(7):383–91. [PubMed: 8002116]
4. Viru AM, Hackney AC, Valja E, Karelson K, Janson T, Viru M. Influence of prolonged continuous exercise on hormone responses to subsequent exercise in humans. *Eur J Appl Physiol*. 2001; 85:578–85. [PubMed: 11718288]
5. Maïmoun L, Lumbroso S, Manetta J, Paris F, Leroux JL, Sultan C. Testosterone is significantly reduced in endurance athletes without impact on bone mineral density. *Horm Res*. 2003; 59(6):285–92. [PubMed: 12784093]
6. Hackney AC. Exercise as a stressor to the human neuroendocrine system. *Medicina (Kaunas)*. 2006; 42:788–97. [PubMed: 17090977]
7. Vaamonde D, Da Silva ME, Poblador MS, Lancho JL. Reproductive profile of physically active men after exhaustive endurance exercise. *Int J Sports Med*. 2006; 27(9):680–9. [PubMed: 16944397]
8. Hackney AC. Effects of endurance exercise on the reproductive system of men: the exercise-hypogonadal male condition. *J Endocrinol Invest*. 2008; 31(10):932–8. [PubMed: 19092301]
9. Hill EE, Zack E, Battaglini C, Viru M, Viru A, Hackney AC. Exercise and circulating cortisol levels: the intensity threshold effect. *J Endocrinol Invest*. 2008; 31(7):587–91. [PubMed: 18787373]
10. Safarinejad MR, Azma K, Kolahi AA. The effects of intensive, long-term treadmill running on reproductive hormones, hypothalamus-pituitary-testis axis, and semen quality: a randomized controlled study. *J Endocrinol*. 2009; 200(3):259–71. [PubMed: 19066291]
11. Vaamonde D, Da Silva-Grigoletto ME, García-Manso JM, Vaamonde-Lemos R, Swanson RJ, Oehninger SC. Response of semen parameters to three training modalities. *Fertil Steril*. 2009; 92(6):1941–6. [PubMed: 19013565]
12. Fitzgerald LZ, Robbins WA, Kesner JS, Xun L. Reproductive hormones and interleukin-6 in serious leisure male athletes. *Eur J Appl Physiol*. 2012; 112(11):3765–73. [PubMed: 22382666]
13. Manna I, Jana K, Samanta PK. Effect of intensive exercise-induced testicular gametogenic and steroidogenic disorders in mature male Wistar strain rats: a correlative approach to oxidative stress. *Acta Physiol Scand*. 2003; 178(1):33–40. [PubMed: 12713513]
14. Manna I, Jana K, Samanta PK. Intensive swimming exercise-induced oxidative stress and reproductive dysfunction in male wistar rats: protective role of alpha-tocopherol succinate. *Can J Appl Physiol*. 2004; 29(2):172–85. [PubMed: 15064426]
15. Manna I, Jana K, Samanta PK. Effect of different intensities of swimming exercise on testicular oxidative stress and reproductive dysfunction in mature male albino Wistar rats. *Indian J Exp Biol*. 2004; 42(8):816–22. [PubMed: 15573534]
16. Lucía A, Chicharro JL, Pérez M, Serratos L, Bandrés F, Legido JC. Reproductive function in male endurance athletes: sperm analysis and hormonal profile. *J Appl Physiol (1985)*. 1996; 81(6):2627–36. [PubMed: 9018515]
17. Kujala UM, Alen M, Huhtaniemi IT. Gonadotrophin-releasing hormone and human chorionic gonadotrophin tests reveal that both hypothalamic and testicular endocrine functions are suppressed during acute prolonged physical exercise. *Clin Endocrinol (Oxf)*. 1990; 33(2):219–25. [PubMed: 2121394]
18. Mathur DN, Toriola AL, Dada OA. Serum cortisol and testosterone levels in conditioned male distance runners and nonathletes after maximal exercise. *J Sports Med Phys Fitness*. 1986; 26(3):245–50. [PubMed: 3795918]

19. Bagatell CJ, Bremner WJ. Sperm counts and reproductive hormones in male marathoners and lean controls. *Fertil Steril.* 1990; 53(4):688–92. [PubMed: 2108059]
20. Flynn MG, Pizza FX, Boone JB Jr, Andres FF, Michaud TA, Rodriguez-Zayas JR. Indices of training stress during competitive running and swimming seasons. *Int J Sports Med.* 1994; 15(1): 21–6. [PubMed: 8163321]
21. Gutin B, Alejandro D, Duni T, Segal K, Phillips GB. Levels of serum sex hormones and risk factors for coronary heart disease in exercise-trained men. *Am J Med.* 1985; 79(1):79–84. [PubMed: 3893124]
22. MacConnie SE, Barkan A, Lampman RM, Schork MA, Beitins IZ. Decreased hypothalamic gonadotropin-releasing hormone secretion in male marathon runners. *N Engl J Med.* 1986; 315(7): 411–7. [PubMed: 3090437]
23. Ayers JW, Komesu Y, Romani T, Ansbacher R. Anthropomorphic, hormonal, and psychologic correlates of semen quality in endurance-trained male athletes. *Fertil Steril.* 1985; 43(6):917–21. [PubMed: 3158553]
24. Hackney AC, Sinning WE, Bruot BC. Reproductive hormonal profiles of endurance-trained and untrained males. *Med Sci Sports Exerc.* 1988; 20(1):60–5. [PubMed: 3343919]
25. McColl EM, Wheeler GD, Gomes P, Bhambhani Y, Cumming DC. The effects of acute exercise on pulsatile LH release in high-mileage male runners. *Clin Endocrinol (Oxf).* 1989; 31(5):617–21. [PubMed: 2627755]
26. Hackney AC, Sinning WE, Bruot BC. Hypothalamic-pituitary-testicular axis function in endurance-trained males. *Int J Sports Med.* 1990; 11(4):298–303. [PubMed: 2228360]
27. Wheeler GD, Singh M, Pierce WD, Epling WF, Cumming DC. Endurance training decreases serum testosterone levels in men without change in luteinizing hormone pulsatile release. *J Clin Endocrinol Metab.* 1991; 72(2):422–5. [PubMed: 1899423]
28. Roberts AC, McClure RD, Weiner RI, Brooks GA. Overtraining affects male reproductive status. *Fertil Steril.* 1993; 60(4):686–92. [PubMed: 8405526]
29. Lucía A, Díaz B, Hoyos J, Fernández C, Villa G, Bandrés F, et al. Hormone levels of world class cyclists during the Tour of Spain stage race. *Br J Sports Med.* 2001; 35(6):424–30. [PubMed: 11726480]
30. Fernández-García B, Lucía A, Hoyos J, Chicharro JL, Rodríguez-Alonso M, Bandrés F, et al. The response of sexual and stress hormones of male pro-cyclists during continuous intense competition. *Int J Sports Med.* 2002; 23(8):555–60. [PubMed: 12439770]
31. Hoogeveen AR, Zonderland ML. Relationships between testosterone, cortisol and performance in professional cyclists. *Int J Sports Med.* 1996; 17(6):423–8. [PubMed: 8884416]
32. Vasankari TJ, Kujala UM, Heinonen OJ, Huhtaniemi IT. Effects of endurance training on hormonal responses to prolonged physical exercise in males. *Acta Endocrinol (Copenh).* 1993; 129(2):109–13. [PubMed: 8372593]
33. Hackney AC, Moore AW, Brownlee KK. Testosterone and endurance exercise: development of the exercise-hypogonadal male condition. *Acta Physiol Hung.* 2005; 92(2):121–37. [PubMed: 16268050]
34. Vervoorn C, Quist AM, Vermulst LJM, Erich WBM, De Vries WR, Thijssen JHH. The behaviour of the plasma free testosterone/cortisol ratio during a season of elite rowing training. *Int J Sports Med.* 1991; 12(3):257–63. [PubMed: 1889932]
35. Urhausen A, Kullmer T, Kindermann W. A 7-week follow-up study of the behaviour of testosterone and cortisol during the competition period in rowers. *Eur J Appl Physiol Occup Physiol.* 1987; 56(5):528–33. [PubMed: 3653093]
36. Rämson R, Jürimäe J, Jürimäe T, Mäestu J. Behavior of testosterone and cortisol during an intensity-controlled high-volume training period measured by a training task-specific test in men rowers. *J Strength Cond Res.* 2009; 23(2):645–51. [PubMed: 19197202]
37. Mäestu J, Jürimäe J, Jürimäe T. Hormonal response to maximal rowing before and after heavy increase in training volume in highly trained male rowers. *J Sports Med Phys Fitness.* 2005; 45(1): 121–6. [PubMed: 16208300]
38. Vinther A, Kanstrup IL, Christiansen E, Ekdahl C, Aagaard P. Testosterone and BMD in elite male lightweight rowers. *Int J Sports Med.* 2008; 29(10):803–7. [PubMed: 18401806]

39. Purge P, Jürimäe J, Jürimäe T. Hormonal and psychological adaptation in elite male rowers during prolonged training. *J Sports Sci.* 2006; 24(10):1075–82. [PubMed: 17115522]
40. Grandi M, Celani MF. Effects of football on the pituitary-testicular axis (PTA): differences between professional and non-professional soccer players. *Exp Clin Endocrinol.* 1990; 96(3):253–9. [PubMed: 2128052]
41. Martínez AC, Seco Calvo J, Tur Marí JA, Abecia Inchaurregui LC, Orella EE, Biescas AP. Testosterone and cortisol changes in professional basketball players through a season competition. *J Strength Cond Res.* 2010; 24(4):1102–8. [PubMed: 20375720]
42. Bonifazi M, Bela E, Carli G, Lodi L, Martelli G, Zhu B, et al. Influence of training on the response of androgen plasma concentrations to exercise in swimmers. *Eur J Appl Physiol Occup Physiol.* 1995; 70(2):109–14. [PubMed: 7768232]
43. Hackney AC, Premo MC, McMurray RG. Influence of aerobic versus anaerobic exercise on the relationship between reproductive hormones in men. *J Sports Sci.* 1995; 13(4):305–11. [PubMed: 7474044]
44. Kraemer WJ, Hakkinen K, Newton RU, McCormick M, Nindl BC, Volek JS, et al. Acute hormonal responses to heavy resistance exercise in younger and older men. *Eur J Appl Physiol Occup Physiol.* 1998; 77(3):206–11. [PubMed: 9535580]
45. Willoughby DS, Taylor L. Effects of sequential bouts of resistance exercise on androgen receptor expression. *Med Sci Sports Exerc.* 2004; 36(9):1499–506. [PubMed: 15354030]
46. Muller M, den Tonkelaar I, Thijssen JH, Grobbee DE, van der Schouw YT. Endogenous sex hormones in men aged 40–80 years. *Eur J Endocrinol.* 2003; 149(6):583–9. [PubMed: 14641001]
47. Ari Z, Kutlu N, Uyanik BS, Taneli F, Buyukyazi G, Tavli T. Serum testosterone, growth hormone, and insulin-like growth factor-1 levels, mental reaction time, and maximal aerobic exercise in sedentary and long-term physically trained elderly males. *Int J Neurosci.* 2004; 114(5):623–37. [PubMed: 15204068]
48. Hawkins VN, Foster-Schubert K, Chubak J, Sorensen B, Ulrich CM, Stanczyk FZ, et al. Effect of exercise on serum sex hormones in men: a 12-month randomized clinical trial. *Med Sci Sports Exerc.* 2008; 40(2):223–33. [PubMed: 18202581]
49. Grandys M, Majerczak J, Duda K, Zapart-Bukowska J, Kulpa J, Zoladz JA. Endurance training of moderate intensity increases testosterone concentration in young, healthy men. *Int J Sports Med.* 2009; 30(7):489–95. [PubMed: 19301220]
50. Vaamonde D, Da Silva-Grigoletto ME, García-Manso JM, Barrera N, Vaamonde-Lemos R. Physically active men show better semen parameters and hormone values than sedentary men. *Eur J Appl Physiol.* 2012; 112(9):3267–73. [PubMed: 22234399]
51. Jensen J, Oftebro H, Breigan B, Johnsson A, Ohlin K, Meen HD, et al. Comparison of changes in testosterone concentrations after strength and endurance exercise in well-trained men. *Eur J Appl Physiol Occup Physiol.* 1991; 63(6):467–71. [PubMed: 1765061]
52. Deschenes MR, Kraemer WJ. Performance and physiologic adaptations to resistance training. *Am J Phys Med Rehabil.* 2002; 81(11 Suppl):S3–16. [PubMed: 12409807]
53. Tsolakis CK, Vagenas GK, Dessypris AG. Strength adaptations and hormonal responses to resistance training and detraining in preadolescent males. *J Strength Cond Res.* 2004; 18(3):625–9. [PubMed: 15320685]
54. Cadore EL, Lhullier FL, Brentano MA, da Silva EM, Ambrosini MB, Spinelli R, et al. Hormonal responses to resistance exercise in long-term trained and untrained middle-aged men. *J Strength Cond Res.* 2008; 22(5):1617–24. [PubMed: 18714223]
55. Tremblay MS, Copeland JL, Van Helder W. Effect of training status and exercise mode on endogenous steroid hormones in men. *J Appl Physiol (1985).* 2004; 96(2):531–9. [PubMed: 14514704]
56. Häkkinen K, Pakarinen A. Acute hormonal responses to two different fatiguing heavy-resistance protocols in male athletes. *J Appl Physiol (1985).* 1993; 74(2):882–7. [PubMed: 8458810]
57. Kraemer WJ, Marchitelli L, Gordon SE, Harman E, Dziados JE, Mello R, et al. Hormonal and growth factor responses to heavy resistance exercise protocols. *J Appl Physiol (1985).* 1990; 69(4):1442–50. [PubMed: 2262468]

58. Cadore EL, Lhullier FL, Alberton CL, Almeida AP, Sapata KB, Korzenowski AL, et al. Salivary hormonal responses to different water-based exercise protocols in young and elderly men. *J Strength Cond Res.* 2009; 23(9):2695–701. [PubMed: 19910806]
59. De Souza MJ, Miller BE. The effect of endurance training on reproductive function in male runners. A “volume threshold” hypothesis. *Sports Med.* 1997; 23(6):357–73. [PubMed: 9219320]
60. Hall HL, Flynn MG, Carroll KK, Brolinson PG, Shapiro S, Bushman BA. Effects of intensified training and detraining on testicular function. *Clin J Sport Med.* 1999; 9(4):203–8. [PubMed: 10593214]
61. Vaamonde D, Da Silva-Grigoletto ME, García-Manso JM, Cunha-Filho JS, Vaamonde-Lemos R. Sperm morphology normalcy is inversely correlated to cycling kilometers in elite triathletes. *Rev Andal Med Deporte.* 2009; 2(2):43–6.
62. Vaamonde D, Diaz A, Rodriguez I. Preliminary results of trans-resveratrol as an effective protector against exercise-induced morphology abnormalities on mice sperm. *Fertil Steril.* 2011; 96(3 Suppl):S166–7.
63. Vaamonde D, Da Silva-Grigoletto ME, Garcia-Manso JM, Vaamonde-Lemos R. Differences in sperm DNA fragmentation between high- and low-cycling volume triathletes: preliminary results. *Fertil Steril.* 2012; 98(3 Suppl):S85.
64. Naessens G, De Slypere JP, Dijs H, Driessens M. Hypogonadism as a cause of recurrent muscle injury in a high level soccer player. A case report. *Int J Sports Med.* 1995; 16(6):413–7. [PubMed: 7591395]
65. Burge MR, Lanzi RA, Skarda ST, Eaton RP. Idiopathic hypogonadotropic hypogonadism in a male runner is reversed by clomiphene citrate. *Fertil Steril.* 1997; 67(4):783–5. [PubMed: 9093212]
66. Leibovitch I, Mor Y. The vicious cycling: bicycling related urogenital disorders. *Eur Urol.* 2005; 47(3):277–86. [PubMed: 15716187]
67. Palmer NO, Bakos HW, Owens JA, Setchell BP, Lane M. Diet and exercise in an obese mouse fed a high-fat diet improve metabolic health and reverse perturbed sperm function. *Am J Physiol Endocrinol Metab.* 2012; 302(7):E768–80. [PubMed: 22252945]
68. Chigurupati S, Son TG, Hyun DH, Lathia JD, Mughal MR, Savell J, et al. Lifelong running reduces oxidative stress and degenerative changes in the testes of mice. *J Endocrinol.* 2008; 199(2):333–41. [PubMed: 18701639]
69. Tartibian B, Maleki BH. Correlation between seminal oxidative stress biomarkers and antioxidants with sperm DNA damage in elite athletes and recreationally active men. *Clin J Sport Med.* 2012; 22(2):132–9. [PubMed: 22246344]
70. Tartibian B, Maleki BH. The effects of honey supplementation on seminal plasma cytokines, oxidative stress biomarkers, and antioxidants during 8 weeks of intensive cycling training. *J Androl.* 2012; 33(3):449–61. [PubMed: 21636735]
71. Derby CA, Mohr BA, Goldstein I, Feldman HA, Johannes CB, McKinlay JB. Modifiable risk factors and erectile dysfunction: can lifestyle changes modify risk? *Urology.* 2000; 56(2):302–6. [PubMed: 10925098]
72. Zhao X, Bian Y, Sun Y, Li L, Wang L, Zhao C, et al. Effects of moderate exercise over different phases on age-related physiological dysfunction in testes of SAMP8 mice. *Exp Gerontol.* 2013; 48(9):869–80. [PubMed: 23751407]
73. Joseph AM, Nguyen LM, Welter AE, Dominguez JM 2nd, Behnke BJ, Adihetty PJ. Mitochondrial adaptations evoked with exercise are associated with a reduction in age-induced testicular atrophy in Fischer-344 rats. *Biogerontology.* 2014; 15(5):517–34. [PubMed: 25108553]
74. Torres-Calleja J, González-Unzaga M, DeCelis-Carrillo R, Calzada-Sánchez L, Pedrón N. Effect of androgenic anabolic steroids on sperm quality and serum hormone levels in adult male bodybuilders. *Life Sci.* 2001; 68(15):1769–74. [PubMed: 11270623]
75. Bonetti A, Tirelli F, Catapano A, Dazzi D, Dei Cas A, Solito F, et al. Side effects of anabolic androgenic steroids abuse. *Int J Sports Med.* 2008; 29(8):679–87. [PubMed: 18004690]
76. Naraghi MA, Abolhasani F, Kashani I, Anarkooli IJ, Hemadi M, Azami A, et al. The effects of swimming exercise and supraphysiological doses of nandrolone decanoate on the testis in adult male rats: a transmission electron microscope study. *Folia Morphol (Warsz).* 2010; 69(3):138–46. [PubMed: 21154283]

77. Di Luigi L, Gentile V, Pigozzi F, Parisi A, Giannetti D, Romanelli F. Physical activity as a possible aggravating factor for athletes with varicocele: impact on the semen profile. *Hum Reprod.* 2001; 16(6):1180–4. [PubMed: 11387289]
78. Vaamonde D, Da Silva-Grigoletto ME, Fernandez JM, Algar-Santacruz C, García-Manso JM. Findings on sperm alterations and DNA fragmentation, nutritional, hormonal and antioxidant status in an elite triathlete. Case report. *Rev Andal Med Deporte.* 2014; 7(4):143–8.

Appendix A. INPEF (International Network on Physical Exercise and Fertility) Questionnaire for Fertility Assessment in Male Athletes

All professionals using this questionnaire must be aware that, along with the questionnaire, participants from any study need to sign an informed consent about the study/assessment and ethical guidelines must be followed. Moreover, no data or biological samples from the participants must be used without the participants' knowledge and approval.

Dear participant, please fill in all the information you know accurately (may leave things blank if unsure). Questions and answers provide important information on potential fertility problems.

All information provided will be regarded as strictly confidential.

Name: _____ Date of Birth: _____

A. **Health.** Describe your present health. In overall, please rate as very good, good, regular, bad, very bad. State if you have any chronic or long-term illness, if so, specify which and for how long. State any medication for the past three months including the name of drug, condition used for and dose and time of use.

Health _____

Any chronic or long-term illness _____

Medication in the last three months _____

B. Relevant information regarding your (in-utero period(when your mother was pregnant with you), birth and childhood(when possible ask your mother), including location of your mother during the whole time she was pregnant and when she gave birth. Include information on your progenitors' history, like birthplace, smoking status (yes, no, don't know), medical treatment your mother underwent while pregnant (yes, no, don't know, type, length), mother's occupation (yes, no, don't know, type).

Your birth date and place (mm/dd/yyyy) _____

Your birth was at term (40 weeks), pre-term or post-term _____

Weight _____ and height _____ at birth

Mother's location while pregnant with you _____

How long, if any, you lived there _____ years

Mothers birthplace _____ Fathers birthplace _____

Mothers smoking status while pregnant _____ Mother's work while pregnant _____

Any treatment mother underwent while pregnant _____

First year of life and early childhood:

Any serious illness during 1st year of life, if yes, which type _____

Smoking status of parents during your childhood (state yes if any or both did) _____

C. PAST HEALTH HISTORY (there are important health conditions that may have an impact on fertility).

Any medical or surgical treatment in any or both testicles (include all information). How many, which dose if hormonal treatment, how long, age at beginning and at the end. Please refer any trauma, with swelling or hematoma to the scrotum (give dates); state if any undescended testes (either one or both, and which one) at birth that did not need treatment

Mumps as an adult. If you had mumps as adult, please state your age and whether there was any testicular complication related to such condition

Surgery for any of the following conditions. Varicocele, testicular torsion, testicular cancer, penile problems, inguinal hernia, urinary tract, scrotal conditions. Please state any of the following: yes (and when), no, don't know, whether its been resolved

You suffer from or have been informed to have any of the following conditions (epididymal inflammation, bladder problems, gonorrhea, chlamydia, prostate inflammation, varicocele, inguinal hernia, diabetes, thyroid problems. Please state yes (and when you were informed), no, don't know, whether its been resolved

Sexual life: please state if satisfied or unsatisfied and if any of the following apply and how frequently (frequently, sometimes, never): low libido, erectile problems, precocious ejaculation, anejaculation (lack of), other related problem

D. Lifestyle and work

Please state present location (how long have been there). Location history of the last 2 years

Regarding lifestyle please state your smoking (smoker, non-smoker) status, and how long if a smoker, type and daily number of cigarettes. Please refer to your habitual drinking habits, specify whether its beer, wine or liquor. Please state daily water intake, tap or bottled and if you consume organic food.

Please state your education (highest academic degree and total number of years)

Please state if you have regularly worked for the last three months: average weekly hours, daytime or nighttime job and if the schedule is regular, total number of hours your work requires of sitting (and if this is in locomotive means), standing, walking or combination

At work you may be exposed to products or environments that may affect fertility, please state if any of the following apply (painting, metal cutter, metal welding, organic solvents, degreaser, pesticides, photography, nitrogen oxide, laboratory, high temperatures [above 50C/122F], radiation, stress) and the frequency of exposure (everyday, every week, rarely, never). You may add even if not in the list should you suspect it may have an effect.

E. Fathering history and history of partner (as previously stated all information is strictly confidential)

Please state if you have any children (number, sex and age) or have ever got someone pregnant. Please state if you have had regular sexual relations without contraceptive measures during at least one year without female partner getting pregnant

If you and your partner have been trying/have tried to conceive, please state time you had been trying, if you achieved pregnancy or if you quit. Please state if you had any fertility testing/treatment, which one, for how long and if it was successful. Please state whether your partner has any children (number, sex and age) and whether she may have any relevant feature related to health, lifestyle or work

Finally, please feel free to add any other information you may think of interest

This part to be completed by athletes participating in any endurance activities

Years of sports practice:		Years practicing endurance activities:	
Anthropometric and functional data (by physician or sports specialist)			
Body weight:	Height:	Fat Percentage (1):	
VO2max:	Anaerobic threshold:	Resting Heart Rate:	
(1) Please, indicate the method used for determination (skinfolds, bioimpedance, DEXA, etc.)			

TRAINING LOAD: Annual Training Volume (approximate mean values)							
Swimming		Running		Cycling			
Kilometers:		Kilometers:		Kilometers:			
Hours:		Hours:		Hours:			
Last Competition		Swimming		Running		Cycling	
Date:	Mark:	Time:	Time:	Time:	Time:		
Training volume performed the week previous to the last competition undertaken							
Swimming		Running		Cycling			
Kilometers:		Kilometers:		Kilometers:			
Hours:		Hours:		Hours:			
Training performed the last week							
Swimming		Running		Cycling			
Kilometers:		Kilometers:		Kilometers:			
Hours:		Hours:		Hours:			

Determination of weekly training load (6 months, last 6 months)

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
Volume Minutes/day																											
Intensity Zone																											
Training Load																											

Volume: Weekly performed training time (total minutes divided by number of sessions).
 Intensity Zone: Subjective perception of training intensity. Scale 1 to 5.
 Z1: Very low intensity/regenerative; Z1: low intensity; Z3: Medium intensity; Z4: High intensity; Z5: Very high intensity/boomtime.
 Training Load: Result of multiplying Volume x Intensity in each Microcycle

Determination of weekly training load (6 months, months 7-12 before questionnaire)

Week	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	
Volume Minutes/day																											
Intensity Zone																											
Training Load																											

This part to be completed by athletes participating in any strength activities

Years of systematized sports practice (use more than one box if you have practiced more than one sports modality)

Indicate modality	Years of training
Indicate modality	Years of training
Indicate modality	Years of training

Anthropometric data (by physician or sports specialist)

Body weight:	Height:	Fat Percentage (1):
--------------	---------	---------------------

(1) Please, in case of knowing fat percentage indicate the method used for determining it (skinfolds, bioimpedance, DEXA, etc.)

Biological Parameters

Heart rate	Basal (rest)	Maximal
------------	--------------	---------

Performance Parameters

1RM Squat	1RM Bench Press	1RM in any other exercise Indicate exercise and mark (kg)
-----------	-----------------	--

BASIC QUESTIONNAIRE ON TRAINING LOAD CONTROL

1. Global Training Control

TRAINING LOAD

Annual Training Volume
(Indicate approximate average values, if possible, about the different phases of the season)

Performed Volume (repetitions -hours)

Total Year	Repetitions:	Hours:
1st phase ^a : Predominant work zones ^b :		
2nd phase ^a : Predominant work zones ^b :		
3rd phase ^a : Predominant work zones ^b :		
4th phase ^a : Predominant work zones ^b :		
5th phase ^a : Predominant work zones ^b :		

a) Please indicate the name you normally use to designate each phase and introduce it in the first box
 b) To indicate the work zones use the reference table!

2. Training Control in the microcycle of the main competition

Last Competition	Date:				
	Modality:				
	Result:				
Training volume performed the week before the last undertaken competition					
Performed volume (# repetitions)					
ZONES	Arms ^a	Legs ^b	Mixed ^c	Trunk ^d	TOTAL
Zone 1					
Zone 2					
Zone 3					
Zone 4					
Zone 5					
Zone 6					
Zone 7					
Zone 8					
Jumps					

- a) Example: Biceps Curl,
- b) Example: Squat, Biceps femoris Curl,
- c) Clean; Snatch; Deadlift
- d) Crunches; Butterfly;

3. Training Control in the microcycle when fertility assessment took place

Training volume performed the week before the fertility assessment					
Performed volume (# repetitions)					
Phase of season:					
ZONES	Arms ^a	Legs ^b	Mixed ^c	Trunk ^d	TOTAL
Zone 1					
Zone 2					
Zone 3					
Zone 4					
Zone 5					
Zone 6					
Zone 7					
Zone 8					
Jumps					

- a) Example: Biceps Curl,
- b) Example: Squat, Biceps femoris Curl,
- c) Clean; Snatch; Deadlift
- d) Crunches; Butterfly;

Table 1. Reference criteria to select training zones

Work Zone	Load %	Volume	# Maximal Repetitions	Recovery	Effect
Zone 1	>100%	Low	>1 - RM	Elevated	Maximal Eccentric Strength
Zone 2	90-100%	Low	1-5 RM	Elevated	Maximal Strength
Zone 3	75-90%	Medium Low	5-12 RM	Big	Tonic Explosive Strength
Zone 4	75-90%	High	5-12 RM	Small	Maximal Hypertrophic Strength
Zone 5	50-75%	Low	12 -20 RM	Big	Ballistic Explosive Strength
Zone 6	50-70%	High	12 -20 RM	Small	Strength endurance and Hypertrophy
Zone 7	<50%	Medium Low	>20 RM	Medium	Muscle Adaptation Warm-up
Zone 8	<50%	High	>20 RM	Small	Resistance

To be answered by ALL athletes (endurance, resistance or mixed modalities)

Observations from the athlete

--

Include any observation you may deem necessary and helpful to better characterize your training program (you may indicate "competitive, professional athlete", "competitive, non-professional athlete", or "recreational athlete" or any other information of interest).

Have you recently taken any medicine? (in the past 3 months) Indicate the name of the medicine, reason for taking it, dose and time taken		
Type	Duration	Reason
Type	Duration	Reason
Type	Duration	Reason

Control of oxidative stress and antioxidant supplementation use

Do you take any antioxidant supplements on a regular basis? If yes, indicate which one, dose and for how long have you been taking it			
Vitamin A	Vitamin C	Vitamin E	Coenzyme Q10
Resveratrol	Glutathion	Lipoic acid	Polyphenols
Zinc	Manganese	Selenium	OTHER

Control of the hypothalamic-pituitary-testicular axis.

Do you take any androgen or derivative? If yes, specific which one, dose and for how long have you been taking it? (add more lines if		
Type	Dose	Duration
Type	Dose	Duration
Type	Dose	Duration

Place: _____ Date: ____/____/____

Signature: _____

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

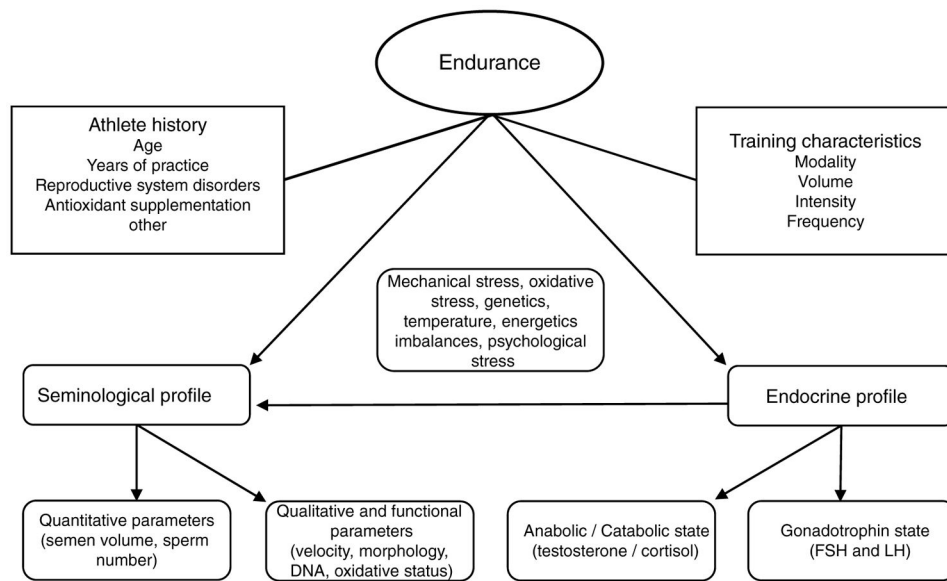


Fig. 1. Factors possibly involved in the relation between endurance exercise and fertility. DNA, deoxyribonucleic acid; FSH, follicle stimulating hormone; LH, luteinizing hormone.