Eur J Appl Physiol (2012) 112:3267–3273
DOI 10.1007/s00421-011-2304-6

ORIGINAL ARTICLE

Physically active men show better semen parameters and hormone values than sedentary men

Diana Vaamonde · Marzo Edir Da Silva-Grigoletto · Juan Manuel García-Manso · Natalibeth Barrera · Ricardo Vaamonde-Lemos

Received: 19 July 2011 / Accepted: 27 December 2011 / Published online: 11 January 2012

Abstract Physical exercise promotes many health benefits. The present study was undertaken to assess possible semen and hormone differences among physically active (PA) subjects and sedentary subjects (SE). The analyzed qualitative sperm parameters were: volume, sperm count, motility, and morphology; where needed, additional testing was performed. The measured hormones were: follicle-stimulating hormone (FSH), luteinizing hormone (LH), testosterone (*T*), cortisol (*C*), and the ratio between *T* and *C* (*T*/*C*). Maximum oxygen consumption was also assessed to check for differences in fitness level. Statistically significant differences were found for several semen parameters such as total progressive motility (PA: 60.94 ± 5.03; SE: 56.07 ± 4.55) and morphology (PA: 15.54 ± 1.38, SE: 14.40 ± 1.15). The seminological values observed were supported by differences in hormones, with FSH, LH, and *T* being higher in PA than in SE (5.68 ± 2.51 vs. 3.14 ± 1.84; 5.95 ± 1.11 vs. 5.08 ± 0.98; 7.68 ± 0.77 vs. 6.49 ± 0.80, respectively). Likewise, the *T*/*C* ratio, index of anabolic versus catabolic status, was also higher in PA (0.46 ± 0.11 vs. 0.32 ± 0.07), which further supports the possibility of an improved hormonal environment. The present study shows that there are differences in semen and hormone values of physically active subjects and sedentary subjects. Physically active subjects seem to have a more anabolic hormonal environment and a healthier semen production.

Keywords Male fertility · Seminological profile · Hormonal profile · Exercise · Sedentary · Physical activity

Introduction

There is growing concern on sperm quality since documentation and research exists stating a declining trend in semen quality over the past 50 years onwards (de Mouzon et al. 1996; Carlsen et al. 1992; Merzenich et al. 2010). This decline is associated with many external agents such as environmental pollutants and xenoestrogens, as well as with inherent daily activities related to one's profession (pesticide exposure, solvents in paints, extended sitting periods, high temperature exposure) or to lifestyle and leisure activities (cell phone use, laptop use, cigarette and alcohol consumption, sauna and hot tub use) (Mendiola et al. 2009; Pacey 2010). Moreover, decreased semen quality has been related to high training loads (Vaamonde et al. 2009a).

It is accepted that physical exercise's main objective is the increase and improvement of physical performance of

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Communicated by Susan A. Ward.

A part of the results have been presented at: 15th Annual Congress of the European Congress of Sport Sciences, Antalya, Turkey, 2010.

D. Vaamonde (✉) · R. Vaamonde-Lemos
Department of Morphological Sciences, School of Medicine, University of Córdoba, Avda. Menéndez Pidal s/n 14071, Córdoba, Spain
e-mail: fivresearch@yahoo.com; cm1vamad@uco.es

M. E. Da Silva-Grigoletto
Andalusian Center of Sports Medicine and Scientific Sport Association, Córdoba, Spain

J. M. García-Manso
Department of Physical Education, School of Physical Activity and Sport Sciences, University of Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Spain

N. Barrera
Center for Reproductive Medicine, Cleveland Clinic, Cleveland, Oh, USA

the practitioners regardless of their performance level, as well as fitness maintenance. Furthermore, a physically active lifestyle is recommended for preventing systemic illnesses such as obesity and associated pathologies, cardiovascular diseases, etc. Moreover, it is also recommended for an improvement in quality of life due to prevention of muscle loss, decrease in bone mineral density loss, and falls in the elderly (Pedersen and Saltin 2006). However, not having a proper knowledge of how this task must be undertaken might lead to negative side effects, injuries or illnesses, especially associated with high training loads. When training becomes prolonged and excessive, or when recovery is insufficient or improperly managed, many of the physiological changes associated with physical training, instead of being favorable to the organism, are reversed in what is termed as overreaching/overtraining status (Fry et al.1998; Jürimäe et al. 2011).

Exercise produces a wide array of systemic and endocrine changes. Of all the changes induced by exercise in sportsmen, there are many studies dedicated to assessing changes at the sympathetic suprarenal and the hypothalamic–pituitary levels of the endocrine system, and also at the reproductive system as observed by menstrual disturbances and semen alterations (Ronsen et al. 2001; Duclos et al. 1996; Hackney et al. 1988, 1990, 1998; Loucks 2001; Loucks et al. 1989; Vaamonde et al. 2006, 2009b). Some studies have reported decrease in *T* values when athletes undergo chronic exhaustive endurance exercise (Hackney 2001). In line with this, we have previously described how exercise can be detrimental for semen quality and hormones (Vaamonde et al. 2006), and how differences in semen profiles exist due to inherent characteristics and requirements of the sport modality and level being practiced (Vaamonde et al. 2009b). This scarcely studied effect could be dependent on the metabolic characteristics and requirements of different sports modalities, but, above all, it is affected by the level at which they are practiced and the physical fitness of the practitioner.

Yet, few negative effects have been reported in the regular practice of moderate exercise. Moreover, practicing regular physical activity has been shown to improve overall health in subjects (Pedersen and Saltin 2006). It has been observed that, when comparing physically active subjects with other groups that undergo a more intense exercise routine, the less demanding physical activity does not promote any semen alterations, while the other two do (Vaamonde et al. 2006). In fact, a more anabolic environment has been reported by some authors for people who regularly exercise (Viru and Viru 2003; Grandys et al. 2009); furthermore, exercise has been proposed as a treatment option in reproduction-related diseases such as polycystic ovarian syndrome, hypogonadism and erectile dysfunction (Alessio et al. 2005; Badawy and Elnashar 2011; Pieper et al. 1988, 1995; Zheng et al. 2011; Maio et al. 2010). So, the beneficial effect of sports practice seems to also have an effect on the reproductive system, and also on semen and hormone values.

Thus, it is our hypothesis that a physically active lifestyle might result in a more favorable environment for reproduction-related processes and might improve or, at least, prevent degradation of hormonal and semen parameters. Therefore, the aim of the present study was to compare semen and hormone values of sedentary and physically active subjects.

Methods

Subjects

Thirty-one healthy males volunteered for the study; all of them gave written consent regarding their participation. A physician reviewed their medical histories. None of the volunteers had had previous infertility or hypothalamic–pituitary problems. The sample was allocated according to their own characteristics to one of the two groups: physically active (PA, 16 subjects) and sedentary (SE, $n = 15$). Physically active subjects had regularly been practicing endurance activities, except bicycling, for over a year while sedentary subjects had not systematically practiced any physical activity during the previous year. The basic characteristics of the participants are shown in Table 1 (see "Results" section). The exclusion criteria were any factors that could interfere with normality, while the inclusion criteria were a minimum practice of 2–4 h/w, for at least three different days, and a maximum oxygen uptake ($VO_{2\max}$) $\geq$ 40 ml min^{-1} kg^{-1} for the PA group, and not practicing any physical activity and a $VO_{2\max} <$ 40 ml min^{-1} kg^{-1} for SE. $VO_{2\max}$ was determined by means of a maximum exercise test.

Table 1 Basic characteristics of physically active men and sedentary men

	Physically active ($N = 16$)	Sedentary ($N = 15$)
Age (years)	19.2 ± 1.9	19.0 ± 1.8
Weight (kg)	73.8 ± 9.1	73.1 ± 8.3
Height (cm)	176.14 ± 5.2	175.9 ± 4.2
Body fat (%)	13.2 ± 3.5	15.6 ± 3.0
$VO_{2\max}$ (ml/min/kg)	51.1 ± 4.9	36.9 ± 3.2*

Values are expressed as mean ± SD

No differences were found for these variables except for $VO_{2\max}$ which was an analyzed variable for assuring right subject allocation

* Significant difference between groups ($P < 0.05$). *t* Student test

Semen analysis

The participants refrained from sexual relations for 3–6 days prior to semen analysis. Semen was collected into sterile collection cups following the instructions given for collection and handling of the sample. Upon arrival at the laboratory, they filled a brief questionnaire with essential and relevant information. Evaluation was performed 30 min after sample collection. Semen analysis included physical parameters (volume, pH, liquefaction state, odor, color, absence or presence of agglutination and gelatinous bodies, viscosity, and dirt) as well as qualitative parameters of sperm (number, motility, and morphology). We examined the ejaculate volume (expressed in ml), sperm concentration (expressed as million/ml), motility (classified as a, b, c, and d types), and morphology (expressed as percentage of normal forms), as the standards for sample normality as recommended by WHO (World Health Organization 1999). Concentration and motility were assessed using the Makler chamber (Sefi Medical, Israel). Regarding motility, sperms were classified as having either type “a”, “b”, “c” or “d” velocities. Two slides were prepared for morphology and stained with Diff Quick (Panreac, Barcelona, Spain). Two hundred sperms were analyzed at 100× under oil, using Kruger's strict criteria. If needed, additional tests were performed.

Hormone analysis

Subjects refrained from any physical activity during the 3 days prior to hormonal evaluation. After a 12-h fast and a 30-min rest at the laboratory, blood samples were drawn from the antecubital vein and collected into sterile Vacutainer tubes; blood samples were obtained at the same time (9:00 a.m.) to avoid, as much as possible, diurnal variations. Hormonal analyses were performed by RIA (all by the same technician, so as to reduce possible procedural errors) with high-specificity single-antibody commercial kits (Diagnostic Products Corporation, Los Angeles, CA, USA) having extremely low cross-reaction with other substances. The hormones evaluated were: T (μg/l), C (μg/dl), LH (U/l), (FSH, U/l); additionally, the T/C ratio, an indicator of anabolic versus catabolic state, was also calculated.

Maximum exercise test

All subjects from both groups performed a test to determine their $VO_{2\max}$, using a “breath-by-breath” automatic gas analyzer system (CPX, Medical Grafics, St. Paul, MN, USA). Both groups performed a graded ergometric test until exhaustion on a cycloergometer (Ergoline 900, Ergometrics, Germany) to assess $VO_{2\max}$. The $VO_{2\max}$ test was performed using a regularly calibrated gas analyzer (for details, see Vaamonde et al. 2006).

Reproducibility of measurements

Biochemical measurements were generally made at the hospital laboratory in accordance with Standard ISO 15189. The laboratory is involved in internal and external quality control programs. External quality control is provided monthly by the Spanish Society of Clinical Biochemistry and Molecular Pathology. The hormone analysis of testosterone, cortisol and the gonadotropins FSH and LH enabled good reproducibility of measurements (ICC = 0.967, 0.955, 0.928 and 0.933, respectively).

Statistical analysis

On the basis of a pilot study, as well as available literature, a power analysis was performed to determine the appropriate number of subjects. Fifteen subjects were required to detect a minimum difference of 0.11 in T/C, and 5% in type a + b velocity, considering a standard deviation of 0.10 and 4.7, respectively (Granmo 5.2 for Windows; IMIM, Barcelona, Spain); this would be required to achieve 80% statistical power. Shapiro–Wilk tests were used to determine data normality for all dependent variables. Independent *t* Student’s test was used to compare means between groups. Significance level was set at $P < 0.05$ (SPSS 13.0 for Windows; SPSS Inc., Chicago, IL).

Results

Table 1 shows the morphofunctional characteristics of both groups.

Statistical differences were found for several semen parameters: type “b”, “d” and “a + b” velocities, and percentage of normal forms ($P < 0.05$); of those, the most clinically important differences were in type “a + b” as well as in percentage of normal forms. The other parameters, sperm concentration and semen volume, albeit being higher in PA, did not reach statistical significance. With regard to hormone analysis, statistical differences were found for the gonadotrophs (FSH and LH) and testosterone. Cortisol, albeit being lower in PA, did not reach statistical significance. The T/C ratio, indicative of the anabolic versus catabolic status, was significantly different between groups ($P < 0.05$) (Table 2).

Discussion

The main finding of the present study is that there are differences in semen and hormonal parameters between the samples of physically active subjects and sedentary subjects assessed. To the best of our knowledge, this is the first

Table 2 Semen and hormone values of physically active men and sedentary men. Values are expressed as mean ± SD

	Mean (±SD)		Mean dif	$T^{\#}$	Sig	95% CI	
	Physically active ($N = 16$)	Sedentary ($N = 15$)	PA-SE		P	Lower	Upper
Concentration (*10^6/ml)	66.50 (±16.27)	58.38 (±16.19)	8.12	1.39	0.175	−3.81	20.05
Volume (ml)	3.24 (±0.81)	3.19 (±0.74)	0.05	0.178	0.783	−0.318	0.418
Vel a (%)	33.60 (±6.18)	32.27 (±8.75)	1.33	0.49	0.627	−4.20	6.87
Vel b (%)	27.35 (±7.18)	21.81 (±6.79)	5.54*	2.20	0.036	0.40	10.68
Vel a + b (%)	60.94 (±5.03)	56.07 (±4.55)	4.87*	2.82	0.009	1.34	8.40
Vel c (%)	8.54 (±4.00)	11.19 (±3.89)	−2.65	−1.87	0.072	−5.55	0.25
Vel d (%)	30.58 (±4.86)	34.78 (±5.69)	−4.20*	−2.22	0.035	−8.08	−0.32
Normal forms (%)	15.54 (±1.38)	14.40 (±1.15)	1.14*	2.49	0.019	0.20	2.08
T (μg/l)	7.68 (±0.77)	6.49 (±0.80)	1.19*	4.22	0.001	0.61	1.76
C (μg/dl)	19.25 (±4.15)	21.24 (±4.30)	−1.99	1.31	0.200	−5.09	1.11
T/C	0.46 (±0.11)	0.32 (±0.07)	0.14*	4.20	0.001	0.07	0.21
FSH (U/l)	5.68 (±2.51)	3.14 (±1.84)	2.54	3.20	0.003	0.91	4.17
LH (U/l)	5.95 (±1.11)	5.08 (±0.98)	0.87	2.31	0.028	0.09	1.64

* Significant difference between groups ($P < 0.05$)

\# *t* Student's test

study undertaken to assess differences in such parameters among both populations. The PA group shows improved values for several seminological and hormonal parameters, which suggests a more anabolic microenvironment and better maintenance of homeostasis for the sperm production process. These favorable conditions are supported by the fact that T/C is higher in PA (≈30%), due to higher T values and lower C values, which means a more anabolic state that might result in improved semen production. These results may be linked to an active lifestyle and are in agreement with previous reports (Grandys et al. 2009).

An improved quality in morphology and total progressive motility have been observed in PA in this study. This fact is supported by the observed hormonal values, with LH, FSH, and T being higher for the PA group since FSH promotes initiation and progression of spermatogenesis and LH promotes testosterone secretion. Furthermore, previous studies have reported that moderate-intensity physical activity, in contrast to what happens with more intense training, positively influences basal values of such hormones or at least does not exert detrimental effects on them (White et al. 2002).

It has been previously shown that intense endurance exercise provokes a diminution in both hormones and semen parameters when subjecting physically active subjects to such physiological stress (Vaamonde et al. 2006; Safarinejad et al. 2009). Similar hormonal changes have been described when assessing basal hormone levels in other endurance sports in which training load could be considered as being high after a long period of time (Wheeler et al. 1984; Hackney et al. 1988, 2005; Flynn et al. 1994; Fernández-Garcia et al. 2002; Maïmoun et al. 2003).

Likewise, a similar pattern has been previously observed for semen parameters when comparing three different populations; in this regard, both triathletes and water polo players had lower-quality semen values than physically active subjects, suggesting, therefore, a decrease of semen quality as training level increases (Vaamonde et al. 2009b). However, not generating the exercise stimulus seems to be counterproductive since, in the present study, moderate-intensity physical activity performed 3 days a week on alternate days was found to be more beneficial than not training at all. In line with these findings, chronic intense endurance exercise has been observed to exert a positive effect on the secretion of several catabolic and stress-related hormones such as CRF, ACTH, cortisol, and B-endorphin while promoting a decrease in anabolic hormones such as T (Rivier and Rivest 1991; Borer 2003). On the contrary, moderate- to high-intensity acute exercise is associated with increases in plasma concentration of sex hormones, with an increase in plasma concentration of androstenedione and total and free testosterone that is dose dependent and ranges between about 30 and 185% at maximum exercise intensities. Plasma androgens increase in men after endurance exercise, such as running and cycling as well as after high-resistance exercise, whether it is of high-loading and low-volume type or low-loading and high-volume type (Borer 2003).

It seems clear that while high-intensity stimuli are detrimental for hormones and semen, not having any exercise stimulus may also result in detrimental effects, that is, there seems to be an “inverted U” behavior. Besides being effective in preventing or ameliorating several chronic diseases such as cardiovascular disease, diabetes, cancer, osteoporosis and obesity, moderate exercise has been reported to favor a more anabolic state improving the overall hormonal milieu (Grandys et al. 2009; Viru and Viru 2003; Pieper et al. 1995), even enabling restoration of gonadotropin secretion (Pieper et al. 1988). Also, some studies have reported a decrease in stress-related hormones as a result of moderate exercise (Duclos et al. 1997; Adlard and Cotman 2004). Therefore, it is logical that a more anabolic state (increased testosterone) along with a lowered catabolic state may result in improved hormonal status. Thus, it seems plausible that, as a consequence, moderate exercise might exert a positive effect on semen production as well since semen production is greatly dependent on an adequate hormonal environment. However, since other factors intimately related to a physically active lifestyle may also play a role in this improvement and no specific studies have been conducted to date with these types of populations (which is a limitation to our findings and interpretation), future interventional studies should be done to clarify this fact.

The possible creation of a healthier microenvironment could also be mediated by exercise-related reactive oxygen species (ROS) production and antioxidant system upregulation. It has been lately shown that while intense and exhaustive exercise produces an imbalance between ROS and the antioxidant capacity of the organism, moderate exercise promotes beneficial effects on this relationship (Gomez-Cabrera et al. 2008). Some studies have argued that the effect on the ROS-antioxidant system relation is sports specific, observing differences in the activity of various antioxidant enzymes such as catalase. Since enzymes respond differently to the exercise-related stress and different free radicals are released, the oxidative stress indices vary from one modality to the other (Kostaropoulos et al. 2006). These findings are supported by observed mitochondrial changes in the usage of superoxide dismutase (SOD), glutathione peroxidase (GPX) and catalase (CAT) in response to exercise-related stress to induce lower production of oxidative stress, and inducing the expression of antioxidant enzymes (Radak et al. 2008). Such an effect has not only been observed in different sports modalities, but also within the same modality practiced with different loads (volume and intensity) (Dékány et al. 2006; Knez et al. 2007).

Recently, it has been proposed that the free radicals generated during mild to moderate endurance-type exercise actually form part of a mechanism of adaptation to exercise (Sachdev and Davies 2008). Free radicals are needed in signaling pathways and many physiological processes; ROS act as intracellular signaling molecules that can initiate the adaptation to exercise in a hormetic response; this response implies that moderate ROS production stimulates antioxidant production while high ROS production would result in an inhibitory or insufficient effect. The intensity of the exercise is important for the induction of antioxidant enzymes and defense mechanisms to prevent injury. The induction of antioxidant enzymes seems to be related to activation of factors such as NF-κB and MAPK (Kostaropoulos et al. 2006). These factors are widely recognized to be implicated in the process of spermatogenesis, apoptosis of the germ cell lineages, and several sperm functions such as motility and fertilization potential (Pentikäinen et al. 2002; Rogers et al. 2008; Li et al. 2009). This mechanism would seem responsible for the improvement observed in overall wellness and also in an improved microenvironment for semen production and supportive processes. Moreover, although not yet completely elucidated, there seems to be a relation between free radicals and testosterone, by which testosterone protects against free radicals, but high levels of androgens produce excess free radicals and ROS (Hwang et al. 2011).

In conclusion, we deem possible that exercising at a moderate pace may result in a more proper environment for the sperm production processes. Further studies are needed though to confirm and expand this knowledge, especially with regard to the mechanisms behind such response, especially involving ROS pathways and their interaction with the HPG axis. Likewise, the appropriate threshold of physical activity for favorable effects on semen profile should be determined.

The study was approved by the Ethics Committee of the University of Cordoba, and was performed according to Helsinki Declaration for research involving human beings.

Acknowledgments The authors would like to thank Dr. Jose R Gomez-Puerto, Dr. Bernardo H Viana-Montaner and BS Gianni Curti for their help and suggestions in the manuscript preparation.

Conflict of interest The authors declare that they have no conflict of interest.

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