Reproductive function in male endurance athletes: sperm analysis and hormonal profile

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Reproductive function in male endurance athletes: sperm analysis and hormonal profile. J. Appl. Physiol. 81(6): 2627–2636, 1996.—The purpose of this investigation was to study the effects of endurance exercise on male reproductive function (sex hormones and seminograms). Professional cyclists (n = 12; mean age 24 ± 2 (SD) yr), elite triathletes (n = 9; 26 ± 3 yr), recreational marathon runners (n = 10; 32 ± 6 yr), and sedentary subjects (control group; n = 9; 30 ± 4 yr) were selected as subjects. For each group, the following parameters were measured three times during the sports season (training period: winter; competition period: spring; resting period: fall): percentage of body fat, hormonal profile (resting levels of follicle-stimulating hormone, luteinizing hormone, total and free testosterone, and cortisol), and seminograms (quantitative parameters: sperm volume and sperm count; qualitative parameters: sperm motility and morphology). The following comparisons were made in the measured parameters: 1) within groups (longitudinal design) and 2) between groups in each of the three periods (cross-sectional design) and over time (mixed design). In addition, both the volume and the intensity of training of each subject during the season (except for the control group) were quantified. Despite significant differences in training characteristics and in body fat percent, in general no significant differences (P > 0.05) were found in hormonal profiles or in semen characteristics between or within groups. A lower sperm motility (46.2 ± 19.5%), however, was observed in the cyclists during the competition period when compared either with the other groups during this same period (P < 0.05) or with themselves during the other two periods of study (P < 0.01). In any case, the later phenomenon was attributed to physical factors associated with cycling, such as mechanical trauma to the testis and/or increased gonadal temperature. In conclusion, our findings suggest that endurance exercise does not adversely affect the hypothalamic-pituitary-testis axis.

sex hormones; male fertility; exercise

IN FEMALE ATHLETES, it is well documented that strenuous physical exercise, particularly running, can be associated with numerous menstrual cycle abnormalities, ranging from luteal-phase defects to amenorrhea (15). In men, however, the effects of exercise on the reproductive function have not been as thoroughly investigated. Indeed, most authors have focused only on the effects of endurance exercise on hormonal indexes of male reproductive function. In this regard, it has been documented that a subset of endurance-trained men, especially runners, might exhibit some subclinical alterations in their hypothalamic-pituitary-gonadal (H-P-G) axis. Such changes include primarily a reduction in circulating levels of total and free testosterone (3, 4, 13, 14, 28, 29), alterations in the release of luteinizing hormone (LH) (18, 19), and alterations in the pituitary response to hypothalamic (14, 18, 26) or pharmacological stimulation (14). Nevertheless, some researchers have not identified significant alterations at any level of the H-P-G axis (5, 22).

Less attention has been directed toward identifying changes in other fundamental components of male reproductive function, such as spermatogenesis and fertility capacity. A few studies have evaluated semen characteristics of male endurance athletes (almost exclusively runners), with controversial findings (3–5, 9, 12, 20). It appears, however, that, in high-mileage runners, nonspecific modifications in the quality of semen ejaculate (decreased motility and several morphological changes) might be present (3, 9). Recently, De Souza and co-workers (9) have reported the existence of a certain “training volume-threshold” (~100 km/wk) for significant alterations to occur in male reproductive function. In their study, it was indeed shown that a high volume of endurance running (>104 km/wk) was associated with subclinical alterations in both the profile of sex hormones (decreased levels of total and free testosterone) and the quality of semen (particularly decreased motility and increased number of immature cells).

Several pathophysiological mechanisms have been proposed to explain the perturbation of the H-P-G axis documented in highly trained runners, including peripheral (intrinsic failure of steroid biosynthesis in the testes) (29) and central mechanisms (altered central stimulation of the gonads) (18, 19). In addition, some factors associated with the stress of intense exercise might alter spermatogenesis, such as decrease in body weight and body fat content (24), inadequate caloric intake (6), and increases in intrascrotal temperature and testicular microtrauma during exercise (10).

To our knowledge, no prospective study has been published concerning the effects of endurance exercise on male reproductive function during a typical sports season, which usually includes different periods in terms of training volume and/or intensity (i.e., precompetition or training, competition, and postcompetition or rest periods). In addition, scarce data are available in the literature concerning the effects of exercise training on the H-P-G axis of male endurance athletes other than long-distance runners. Finally, it has not been studied to date whether exercise could affect the reproductive function of top-level athletes (i.e., those exposed...
to the demands of elite competition, such as Olympic-class marathons or professional cyclists).

The purpose of this investigation was to study the reproductive function (hormonal profile and semen characteristics) of three groups of endurance athletes of three different training levels (ranging in descending order: professional road cyclists, elite triathletes, and recreational marathon runners) and that of a control group of sedentary men over a sports season (precompetition, competition, and rest periods). We also compared the results obtained in each group of subjects during each period of the season.

METHODS

Subjects

To be eligible to participate in the study, subjects were required to meet the following criteria: 1) 20–39 yr of age; 2) in good health, as determined by a normal physical examination and routine laboratory tests within the previous year; 3) no history of chronic disease, including reproductive disorders (6 of the subjects had fathered children); 4) no history of use of medications that could alter the H-P-G axis, such as anabolic steroids; 5) regular eating patterns and no history of depressive illness; and 6) appropriate history of physical activity for the different groups described below. Informed consent was obtained from each subject in accordance with the regulations of the Complutense University. Before the initiation of the study protocol, each of them was introduced to the methods of this investigation.

Forty subjects were selected for this study and divided into 4 groups: 1) professional cyclists (C; n = 12); 2) elite triathletes (T; n = 9); 3) moderate-mileage marathon runners (M; n = 10); and 4) sedentary control subjects (SC; n = 9).

C had an average competition experience of 2 ± 1 yr in the professional category. Eight had previously participated in at least one of the most important professional 3-wk stage races (Vuelta a España, Giro d’Italia, or Tour de France), and some had won some major professional races (stages in the Vuelta a España, 1-day races, etc.). Two had previously participated once with the Spanish team in the World Championships for professional cyclists.

T had an average competition experience of 6 ± 2 yr. All were ranked among the 15 top triathletes in Spain within the previous year. Three had previously participated in the Hawaii Ironman, and one had won the bronze medal in the European Championships (junior category).

M had an average competition experience of 6 ± 2 yr, having previously participated in 5 ± 3 marathon races. They had completed an average of ~90 km/wk within the last year, and their personal best times in a marathon race ranged from 2 h 20 min to 3 h 10 min.

Finally, SC were weight stable (no gain or loss of >3.0 kg for the total duration of the study) and had not performed any type of vigorous exercise regularly within the last 2 yr.

Maximal Exercise Tests

Before the initiation of the study protocol, each subject from the groups of C, T, and M performed a test session to determine maximal oxygen uptake (VO\textsubscript{2max}) and ventilatory thresholds 1 and 2 (VT\textsubscript{1} and VT\textsubscript{2}, respectively) with the use of an automated breath-by-breath system (CPX, Medical Graphics, St. Paul, MN). C and T performed an incremental bicycle ergometer test to exhaustion (Ergoline 900, Ergometrics), which consisted of a ramp protocol, starting at 0 W. The workload was increased by 25 W/min, and pedaling frequency was kept constant at 60–80 revolutions/min. In runners, VO\textsubscript{2max} was determined by an incremental treadmill protocol to exhaustion (E 6000, Erich Jaeger, Wuerzburg, Germany), in which running velocity was increased by 1 km/h each minute, starting at 8 km/h. Treadmill inclination was kept constant at 1.0%. All exercise tests were terminated voluntarily by the subjects or when established criteria of test termination were met (27). VT\textsubscript{1} was determined by using the criteria of an increase in the ratio of minute ventilation to oxygen uptake (VE/VO\textsubscript{2}) without an increase in the ratio of VE to carbon dioxide production (VE/V\textsubscript{CO2}), whereas VT\textsubscript{2} was determined by using the criteria of an increase in both VE/VO\textsubscript{2} and VE/V\textsubscript{CO2} and the departure from linearity of VE (8).

Protocol

Each of 40 subjects reported to the laboratory three times during the study for the assessment of hormone measurements, semen ejaculate analysis (1 single sample), and percentage of body fat. Each laboratory testing session corresponded to the precompetition (winter: January for all groups), competition (spring: June for T, and April for the rest of the groups), and rest periods (fall: October for all groups) of the sports season. In addition, C, T, and M completed a questionnaire concerning both the volume and the intensity of their average weekly training during the precompetition, competition, and rest periods.

Training. Training volume was expressed both in average hours per week and kilometers per week of cycling (for C); swimming, cycling, and running (for T); and running (for M). The intensity of training, on the other hand, was determined by estimating for each C, T, and M the percentage of his weekly training performed at a heart rate corresponding to an exercise intensity below VT\textsubscript{1} (low-intensity training), between VT\textsubscript{1} and VT\textsubscript{2} (moderate-intensity training), and above VT\textsubscript{2} (high-intensity training). All of these subjects wore a heart rate telemeter (Sport Tester, Polar Electro, Finland) during each training session. Because of the specific characteristics of professional cycling, which includes numerous competition days (~100 days) during the season, heart rate recordings during races were downloaded into a computer program (Polar heart rate analysis software, Polar Electro) and included in the training log of the competition period of the respective athlete.

Percentage of body fat. We estimated percentage of body fat by using the Faulkner equation after measuring skinfold thickness with a constant pressure skinfold caliper (Holtain) at four different sites (11)

\[
\text{percentage of body fat} = \left[ (\text{chest} + \text{subscapular} + \text{suprailiac} + \text{abdominal}) \times 0.153 \right] + 5.783
\]

All measurements were made in triplicate on the right side of the body by the same investigator.

Hormone Measurements. All subjects reported to the laboratory at the same time of day (between 0830 and 0900) after an overnight fast, having consumed no alcohol or caffeine for at least 24 h nor exercised within the previous 24 h. Subjects were settled and made comfortable for at least 10 min. Thereafter, three blood samples were drawn by repetitive clean venipuncture (antecubital vein) from each subject at 20-min intervals for the determination of the resting levels of the following hormones: total and free testosterone, follicle-stimulating hormone (FSH), LH, and cortisol.

All blood samples were collected into sterile chilled tubes. The samples were allowed to clot at room temperature and then were centrifuged at 2,000 g for 20 min at 4°C. Separated serum was aliquoted and stored at 2–8°C for the...
RESULTS

Subjects

Values of subjects' mean (± SE) age, height, and weight (at the beginning of the study) were the following: 26 ± 2 yr, 175.6 ± 4.4 cm, 68.7 ± 4.9 kg (C); 26 ± 3 yr, 176.3 ± 3.8 cm, 67.1 ± 5.3 kg (T); 32 ± 6 yr, 174.9 ± 4.7 cm, 73.2 ± 7.3 kg (M); and 30 ± 4 yr, 178.8 ± 6.2 cm, 83.7 ± 9.3 kg (SC).

\[ V_{O2}max \]

The \( V_{O2}max \) values of C, T, and M were 74.0 ± 5.4, 73.3 ± 3.7, and 60.5 ± 6.8 ml·kg⁻¹·min⁻¹, respectively.

Training Characteristics

C. The precompetition period included the months of November, December, and January. During these months, none of these subjects had participated in any cycling race. The competition period started in February and lasted until the end of September. Before the second laboratory testing session (April), C had completed an average of 25 ± 7 competition days, which included several 1-wk stage races. The rest period corresponded to the month of October and included 2 wk of rest from any type of physical activity; in addition, during the other 2 wk of this month, C did not practice his sport but performed other types of exercise (swimming, running, rowing, mountain biking, etc.) at low intensities. The training characteristics of this group are shown in Table 1. Training volume was significantly higher (P < 0.01) during the precompetition period than during the other two periods. Training intensity was also significantly higher (P < 0.01) during the competition period than during the precompetition period.

T. The precompetition period included the months of November to March. During these months, none of these subjects had competed in any triathlon race. The competition period started in April and lasted until the end of September. Before the second laboratory session (June), T had completed an average of 6 ± 2 triathlon races. The rest period corresponded to the month of October and included 2 wk of rest from any type of physical activity; during the other 2 wk of this month T practiced other sports different from triathlon (mountain biking, rowing, hiking, etc.) at low intensities. The training characteristics of T are shown in Table 2.

Table 1. Training characteristics of cyclists

<table>
<thead>
<tr>
<th></th>
<th>Precompetition</th>
<th>Competition</th>
<th>Rest</th>
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</thead>
<tbody>
<tr>
<td>Training volume</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>km/wk</td>
<td>657 ± 81.9†</td>
<td>884 ± 44.7†</td>
<td>0.0 ± 0.0*</td>
</tr>
<tr>
<td>h/wk</td>
<td>22 ± 4†</td>
<td>26 ± 2†</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>Training intensity, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low intensity</td>
<td>82.7 ± 15.1*</td>
<td>50.2 ± 4.9</td>
<td></td>
</tr>
<tr>
<td>Moderate intensity</td>
<td>15.8 ± 12.9*</td>
<td>31.5 ± 1.8</td>
<td></td>
</tr>
<tr>
<td>High intensity</td>
<td>1.5 ± 3.7⁺</td>
<td>18.2 ± 3.8</td>
<td></td>
</tr>
</tbody>
</table>

Values are means ± SD. *Precompetition vs. competition period, P < 0.01. †Precompetition vs. rest period, P < 0.01. ‡Competition vs. rest period, P < 0.01.
Although training volume was not significantly different during the precompetition and competition periods, training intensity was significantly higher (P < 0.05) during the competition period.

M. The precompetition period included the months of November, December, and January. During these months, none of these subjects had participated in any marathon race. The competition period included the months of February to September. In the week before the second laboratory session (April), all the subjects of this group had completed the Madrid Marathon in an average time of 2h 58 min (range from 2h 35 min to 3h 30 min). None of the subjects participated in any other marathon during this period. Finally, the rest period corresponded to the month of October. During this month, subjects did not refrain from running, although both training volume and intensity were considerably reduced. The training characteristics of M are shown in Table 3. Both training volume and intensity were significantly reduced (P < 0.01) during the rest period in comparison with the other two periods.

### Table 2. Training characteristics of triathletes

<table>
<thead>
<tr>
<th>Training volume</th>
<th>Precompetition</th>
<th>Competition</th>
<th>Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>km/wk</td>
<td>12.8 ± 5.0*</td>
<td>14.3 ± 5.8†</td>
<td>0.0 ± 0.0</td>
</tr>
<tr>
<td>Swimming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cycling</td>
<td>27.9 ± 80.8*</td>
<td>316.1 ± 79.0†</td>
<td>0.0 ± 0.0</td>
</tr>
<tr>
<td>Running</td>
<td>43.9 ± 14.1*</td>
<td>54.3 ± 7.2†</td>
<td>0.0 ± 0.0</td>
</tr>
<tr>
<td>h/wk</td>
<td>17 ± 4*</td>
<td>19 ± 4†</td>
<td>0 ± 0</td>
</tr>
</tbody>
</table>

Comparisons within groups. No significant difference was noted during this period of study. Finally, no interactive effect (group × period) existed.

### Table 4. Percentage of body fat of subjects

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>T</th>
<th>M</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precompetition</td>
<td>9.4 ± 0.7</td>
<td>9.4 ± 0.5</td>
<td>11.2 ± 1.6</td>
<td>15.9 ± 3.2*</td>
</tr>
<tr>
<td>Competition</td>
<td>9.0 ± 0.6†</td>
<td>9.2 ± 0.5</td>
<td>11.0 ± 1.4†</td>
<td>15.8 ± 2.9*</td>
</tr>
<tr>
<td>Rest</td>
<td>10.2 ± 1.4</td>
<td>9.5 ± 0.4</td>
<td>11.4 ± 1.3</td>
<td>15.8 ± 3.3*</td>
</tr>
</tbody>
</table>

Values are means ± SD. *Precompetition vs. rest, P < 0.01. †Competition vs. rest, P < 0.01. ‡Precompetition vs. competition, P < 0.05. §Precompetition vs. competition, P < 0.01.

Percentage of Body Fat

Percentage of body fat of the four groups of subjects during the study is given in Table 4.

Comparisons within groups. No significant differences existed, with the exception of C, who were significantly leaner during the competition period than during the period of rest (P < 0.05).

Comparisons between groups. For the precompetition, competition, and rest periods, the percentage of body fat was higher (P < 0.01) in SC than in the other three groups and was higher in M than in C (P < 0.05). Finally, no interactive effect (group × period) existed.

### Hormonal Profile

The hormonal profile of the four groups during the precompetition, competition, and rest periods is shown in Figs. 1, 2, 3, 4, and 5. For each of four groups, the average levels of all hormones evaluated were consistently within normal limits (3) for the total duration of the study.

Comparisons within groups. No significant differences were observed for the total duration of the study within any of the four groups.

Comparisons between groups. During the precompetition period, circulating levels of FSH were higher in T than in SC (P < 0.05), and total testosterone was higher (P < 0.05) in C than in the other three groups (Figs. 1 and 3, respectively). No other significant difference was noted during this period of study. During the competition period, on the other hand, the hormonal profile was similar in all four groups, without any exception. Finally, during the rest period, circulating levels of all hormones were also similar among groups, except the levels of FSH, which were significantly higher (P < 0.05) in T and M than in the other two groups (Fig. 1). On the other hand, no interactive effect (group × period) existed for any of the hormones evaluated.
Seminal Analysis

The period of sexual abstinence was consistently longer than 48 h in all cases, and it ranged from 2 to 5 days for most subjects (except in C during the competition period). Seminal characteristics of each of four groups during the precompetition, competition and rest periods are shown in Figs. 6, 7, 8, 9, 10, and 11. For each of four groups, the average values of the seminal parameters evaluated in this study were within normal limits (30), except for a lower than normal (<50%) sperm motility in C during the competition period (Fig. 8).

Comparisons within groups. No significant differences existed between groups during the study, except for a lower \( P < 0.01 \) sperm motility in C during the competition period in comparison with the other two periods.

Comparisons between groups. During the precompetition period, no significant differences existed between groups. Seminal characteristics of C, T, M, and SC were also similar during the competition period, except for a significantly lower \( P < 0.05 \) sperm motility in C compared with the other three groups (Fig. 8). Finally, no significant differences were observed among groups during the rest period, with the exception of sperm motility, which was significantly higher \( P < 0.05 \) in C than in M (Fig. 8). No interactive effect (group \( \times \) period) was found in any of the seminal parameters, except in sperm motility \( P < 0.05 \).

Finally, the percentage of immature forms was <20% in all four groups for the total duration of the study.

Correlation Coefficients

Significant relationships \( P < 0.05 \) existed between the following parameters: percentage of body fat and sperm volume and percentage of body fat and sperm count \( r = 0.26 \) and \( r = 0.27 \), respectively), training volume and percentage of body fat \( r = -0.66 \), percent-

![Image](https://via.placeholder.com/150)
age of moderate-intensity training and percentage of body fat ($r = -0.44$), training volume and FSH levels ($r = 0.32$), training volume and total testosterone ($r = 0.34$ for all groups and $r = 0.50$ for C) and free testosterone ($r = 0.25$ for all groups and $r = 0.60$ for C), and percentage of low-intensity training and total testosterone ($r = 0.32$). Finally, no significant relationship existed between training characteristics and seminal parameters.

**DISCUSSION**

To our knowledge, this is the first study using a mixed design (both cross-sectional and longitudinal) to determine whether there is a significant effect of endurance training volume and/or intensity on male reproductive function during a whole typical sports season. In this regard, De Souza and co-workers (9) have shown the existence of a certain “volume threshold” (>104 km/wk) for significant alterations to occur in both testosterone levels and semen quality of distance runners. Their cross-sectional design, however, was limited to a single comparison between two groups of runners of different training levels and sedentary controls. In addition, the effect of the relative intensity of training on the H-P-G axis was not really assessed.

On the other hand, no previous study has analyzed the effects of endurance exercise in top-class athletes (i.e., those exposed to the highest physiological demands, such as professional cyclists). Finally, in the majority of investigations, only distance runners were selected as subjects.

**Hormonal Profile**

Our findings suggest that endurance training, even at the highest level, does not seem to significantly alter male reproductive function (hormones of the H-P-G axis and spermatogenesis). For the whole duration of the study, resting levels of hormones were indeed...
within normal limits in C, T, and M and were comparable to those of SC. Regarding the hypothetical effects of exercise on the secretion of gonadotropins, our results are in agreement with previous research, because the available literature does not provide any evidence showing a decrease in the mean levels of LH (3, 5, 13, 14, 18, 22, 23, 29) or FSH (18, 23, 29) in endurance-trained men compared with sedentary controls. In our investigation, although some significant differences were found between groups in resting levels of FSH during both precompetition and rest periods, such differences were small, and mean values of FSH remained consistently between normal limits. Therefore, our results confirm those of previous prospective studies, which have not been able to demonstrate any detrimental effect of exercise on pituitary secretion of gonadotropins in male athletes (25, 28). Our findings are limited by the fact that we did not assess the pulse frequency and amplitude of FSH and LH secretion. In this regard, no 24-h pulsatility studies in male athletes have been published to date; only two studies have reported a reduction in LH pulse frequency (18) and amplitude (19) in male runners, although the duration of blood sampling was limited to 8 and 6 h, respectively. Further research (24-h studies) is necessary to really discern pulsatile characteristics of gonadotropin secretion in athletes.

Although unanimity does not reign, previous cross-sectional reports suggest a reduction in total and/or free testosterone levels in response to endurance training, specifically in marathon runners of comparable age and training levels to those selected for our investigation as moderate-mileage runners (group of M) (4, 9, 13, 19, 28, 29). Our results, however, do not confirm such findings for any of the groups of endurance-trained men studied by us. Furthermore, training volume was positively correlated (P < 0.05) for both total and free testosterone levels, especially in C (r = 0.50 and r = 0.60, respectively). Both central (altered central stimulation of the gonads) and peripheral mechanisms could account for the decreased levels of circulating testosterone reported by several authors. However, because the relative contribution of hypothetical peripheral mechanisms (i.e., intrinsic failure of gonadal steroid biosynthesis, altered hepatic clearance of testosterone, etc.) remains unproven to date (9), and we found no evidence of altered secretion of gonadotropins (particularly LH), our results for total and free testosterone should not be unexpected. Furthermore, in our investigation, levels of circulating total testosterone were significantly higher (P > 0.05) in C (those endurance-trained athletes exposed to the highest training demands) than in the other subjects during the precompetition period. In this regard, a study by Caballero and co-workers (7) reported a significant increase in the plasma concentrations of sex hormone-binding globulin (SHBG) in professional Spanish cyclists during the precompetition period (month of January, with a training program consisting of 120 km/day of “gentle cycling”) compared with other periods of the season. Such increase in SHBG, in turn, could result from an increased protein synthesis in the liver or an altered distribution between the extra- and intravascular spaces in response to moderate-intensity exercise after a rest period (7). Thus a comparable increase in SHBG in C might have also occurred in our study during the precompetition period, during which training intensity was low to moderate. Because ~60% of the circulating testosterone is bound to SHBG (7), an increase in this protein could explain, at least in part, the higher levels of total testosterone found by us in C in the precompetition period.

On the other hand, resting levels of cortisol were not significantly altered in any of the groups for the whole duration of our study. It has been documented that intense physical training might produce a hyperactivation of the hypothalamic-pituitary-adrenal axis (25). In turn, hyperactivity of the adrenal cortex might affect all levels of the H-P-G axis (3, 17, 27). Indeed, it has been shown that the chronic physical stress induced by high-mileage training can result in a certain state of hypercortisolism in female runners, which might, in turn, adversely influence their reproductive function.
In endurance-trained men, however, such state of chronic hypercortisolism has been associated mostly with overtraining states (1). In this regard, our results are in agreement with those obtained by previous studies (5, 9), which have not found significant differences between resting cortisol levels of endurance runners and sedentary controls. Therefore, even the highest level of training (i.e., professional cycling) does not seem to necessarily induce a state of chronic hypercortisolism in endurance-trained athletes. Moreover, no significant relationship existed between training parameters and cortisol levels in our investigation. It appears that, with the exception of overtraining states, endurance training by itself does not represent such a significant source of physical stress so as to induce alterations in male reproductive hormonal profile. For example, it might be that elite cyclists could recover adequately from the demands of daily training, even during the competition period in which their weekly training averaged 5–7 h of exercise at an intensity higher than the anaerobic threshold. Probably, this can be achieved because these athletes do not perform any other type of professional activity, and their lifestyle is specially scheduled to adequately recover from heavy training and competition on a day-to-day basis (sufficient number of sleep hours, balanced diet, etc.). It could be hypothesized that other endurance athletes with a lower training level (such as the moderate-to-high mileage runners used as subjects in most previous studies) might indeed be more exposed to stress situations because their lifestyle (professional occupations, rest hours, etc.) is not primarily oriented to achieve top sport performance and to fully recover from daily training. This phenomenon could explain the alterations in the H-P-G axis reported by other authors in nonelite marathon runners (4, 9, 13, 19, 28, 29).

**Seminal Parameters**

A major finding of our investigation was that most seminal characteristics did not significantly differ within or between groups for the whole duration of our study. A lower motility (46.2 ± 19.5%), however, was observed in C during the competition period when compared either with the other groups during the same period (P < 0.05) or with themselves during precompetition and rest: (P < 0.01). In addition, an interactive effect (group × period) existed (P < 0.05) for this parameter. Nevertheless, the sperm motility of C returned to normal levels with rest so that this parameter was even higher (P < 0.05) in this group than in M. In any case, it must be emphasized that both quantitative and qualitative seminal characteristics remained within the normal range for adult males (30) for the whole duration of the study, except for the sperm motility of C during the period of competition. Finally, the significant variations that existed in the volume or intensity of training during the sports season did not seem to alter spermatogenesis in the group of athletes, because no significant relationship existed between seminal and training parameters. Few studies have reported seminal analyses in nonelite endurance-trained men, such as biathletes (12), triathletes (4), and runners (3–5, 9, 12). Whereas sperm count does not seem to be significantly altered with exercise, results concerning sperm quality are somewhat contradictory. Some authors have found no alterations in sperm quality (4, 5, 9) with moderate volumes of endurance running (54–72 km/wk). Two reports have suggested, on the other hand, that higher volumes of endurance running (~100 km/wk or more) might significantly compromise semen quality (reduced sperm motility, increased number of immature cells in the ejaculate) and decrease fertility potential (reduced in vitro sperm penetration of standard cervical mucus) (3, 9). Finally, in line with our findings, the average values of seminal parameters in endurance-trained men usually range within normal limits, and, when existing, seminal alterations are subclinical in nature (3–5, 9, 12). To our knowledge, our study is the first to assess seminal characteristics in top-level endurance athletes because previous research has been confined mostly to nonelite runners. Our results are in contrast to those found by Arce and De Souza (2) and De Souza et al. (9) because in both studies significant alterations were encountered in the semen quality of distance runners whose weekly mileage was comparable to that of our group of M (in the range of ~95–110 km/wk for all 3 studies) (3, 9). In our investigation, only one parameter, sperm motility, was significantly decreased (reaching even abnormally low values) in C during the competition period. Because the reproductive hormonal profile of these subjects, on the other hand, was not significantly altered during the study, other pathophysiological mechanisms associated with cycling might have been involved. In this regard, it is unlikely that factors related to body fat content or caloric intake might have contributed to the mentioned decrease in sperm motility. Indeed, although the percentage of body fat of C did significantly decrease during the competition period in comparison with the rest period (9.0 ± 0.6 vs. 10.2 ± 1.4%), it did not reach extremely low values, which might have reflected a state of undernutrition. Furthermore, no significant relationship existed between sperm motility and body fat content. On the other hand, our conclusions are limited to the fact that we did not quantify energy intake of C; however, it has been previously shown that professional cyclists do able to balance their energy intake with their energy expenditure on a day-to-day basis, even during a 22-day race such as the Tour de France (24). Other factors that may affect reproductive function include testicular microtrauma and increases in intrascrotal temperature during exercise (2). To our knowledge, no report exists regarding the impact of exercise-induced testicular microtrauma on reproductive function. However, it must be kept in mind that professional cyclists undergo long daily workouts (i.e., they complete an average of 26 h/wk of cycling during the competition months) during which the prostatic gland, for example, might suffer from a continuous friction against the bicycle saddle. Prostatic secretions, on the other hand, enhance sperm motility by contributing certain factors, such as albumin, to seminal plasma
(21). Although it has been well documented that even transient increases (i.e., of 30 min) in intratesticular temperature may negatively affect spermatogenesis and sperm motility (10), there are no reports to date that have determined the impact of exercise-induced increases of body temperature on intratesticular temperature. However, this factor must also be considered in the case of cyclists, who must exercise several hours a day wearing a tight culotte that could directly increase intrascrotal temperature.

On the other hand, our investigation is not without potential limitations. First, our results are limited to the fact that we performed a single semen analysis for each subject during each period of the study, whereas analysis of several (2–3) semen samples collected several weeks apart is desirable to account for the inherent variability that usually exists in semen analyses (2). In contrast, in some previous studies with athletes, at least two semen samples were collected from each subject (3, 5, 9) to minimize the effects of individual variability in seminal parameters. In addition, in our study the interval of sexual abstinence could not be controlled in all cases. Ideally, a period of 3–5 days of sexual abstinence is most desirable because with shorter periods both semen volume and sperm count tend to decrease, whereas after >5 days of abstinence both parameters are usually higher and sperm quality decreases (30). In our study, the period of abstinence was always longer than 48 days, and it ranged from 3 to 5 days in most cases, except in C during the competition period. The longer period of abstinence of C subjects during competition might have contributed, at least in part, to their decreased sperm motility during this period. Finally, the length of the rest period of our athletes (~1 mo) might have not been long enough because the duration of each spermatogenic cycle is considerably longer than 1 mo (10–12 wk) (21). It this regard, it was not possible to increase the duration of this period without disturbing their normal training schedule, especially in the case of C.

In summary, the results reported in this study suggest that, under normal conditions (no overtraining, adequate nutrition, etc.), endurance training itself does not adversely influence male reproductive function. Our conclusions are emphasized by the fact that this is the first investigation to determine the effects of variations in training volume and intensity during several months on the H-P-G axis of elite athletes (C, T). Although sperm motility was abnormally low in C during the competition period, such alteration was transient in nature and was probably mediated by physical factors associated with the specific characteristics of cycling rather than with any pathophysiological effect of endurance training on the H-P-G axis.

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