FERTILITY AND STERILITY
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Vol. 53, No. 4, April 1990
Printed on acid-free paper in U.S.A.

Sperm counts and reproductive hormones in male marathoners and lean controls

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In women, chronic and intense endurance exercise is frequently associated with menstrual cycle alterations. In men, the effects of similar amounts of exercise are less well-studied. We tested the hypothesis that endurance exercise in men is also associated with alterations in reproductive function. We studied 12 marathon runners and 12 age-matched, lean controls; serum and semen samples were collected every 2 weeks for 12 weeks. Sperm counts, sperm morphologies, and mean levels of testosterone (T), free T, sex hormone binding globulin, cortisol, follicle-stimulating hormone, and biologically active luteinizing hormone (LH) were similar in the two groups. Mean levels of immunologically active LH were somewhat higher in the marathoners. We conclude that this level of strenuous, long-term endurance exercise does not have major adverse effects on reproductive function in men. Fertil Steril 53:688, 1990

In women, strenuous physical exercise, especially running, has been associated with the development of a variety of menstrual cycle alterations, including luteal phase deficiency and hypothalamic amenorrhea.[1-3] In men, however, the effects of exercise on reproductive hormones and reproductive function have not been as thoroughly studied. Effects of acute exercise bouts have been reported,[4-6] and several investigators have studied hormonal indices of reproductive function in elite athletes on one occasion,[7-9] but effects of long-term, strenuous endurance exercise on spermatogenesis have not been well-studied. To test the hypothesis that endurance exercise regimens in men are associated with alterations of reproductive function analogous to those seen in women, we measured serial sperm counts and resting hormone levels in 12 marathon runners and 12 age-matched, lean controls.

Received July 10, 1989; revised and accepted December 5, 1989.

Supported in part by National Institutes of Health grant P-50-HD-12629, the Veterans Administration, and by the Clinical Research Center at the University of Washington, Seattle, Washington. National Institutes of Health grant RR-37.

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MATERIALS AND METHODS

Subjects

Twelve marathon runners, aged 21 to 37 years, participated in the study. Runners were recruited by advertisement in a local running magazine. To be eligible to participate in the study, runners were required to meet the following criteria: (1) completion of at least one marathon in the last year, with a current minimum weekly mileage of 40 miles; (2) to be weight-stable (no gain or loss of more than 2.5 kg within the past year), with regular meal patterns; (3) no history of reproductive disorders (3 of the men had fathered children); (4) normal physical exam, routine laboratory tests, and urinalysis; and (5) no current medications. One runner did not complete the study for personal reasons.

Each runner was matched to a control subject of similar age. Control subjects were recruited by ad-

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vertisement in the community. Each control was required to be within 10% of ideal body weight and to be weight-stable. None participated in any form of aerobic exercise more than once per week. One of the control men had fathered children. All control subjects had normal physical exams, complete blood counts, routine laboratory chemistries, and urinalyses. None of the men took medications or abused alcohol, and all subjects signed a consent form approved by the University of Washington Human Subjects Committee.

Study Protocol

Six blood samples were drawn from each man at 2-week intervals; each blood sample was drawn between 4 P.M. and 9 P.M. Each sample was drawn after the subject had rested in a chair for at least 10 minutes and at least 8 hours after the completion of the last exercise session. Subjects collected semen samples by masturbation after at least 48 hours of abstinence. Each man collected semen samples at 2-week intervals for 12 weeks, for a total of six samples per person. One sample from each man was analyzed within 2 hours of ejaculation; the other samples were mailed or delivered to the analysis facility on the day of collection.

Body composition was determined once during the study period, using the hydrostatic weighing method described by Siri.[10] Residual lung volumes were determined by helium dilution on a Collins DS421 spirometer (Warren E. Collins, Inc., Braintree, MA). Six runners and their matched controls were tested for maximal aerobic capacity by treadmill exercise to exhaustion, using the protocol of Bruce et al.[11] All runners ran until volitional terminal fatigue. Oxygen consumption was measured using an Ametek modular oxygen uptake system (Ametek, Inc., Thermox Instruments Division, Pittsburgh, PA). A maximum effort was considered to be one or more of the following: respiratory quotient (RQ) > 1.10 and/or maximum heart rate > 90% of age estimated maximal heart rate. Electrocardiograms and heart rates were monitored throughout the exercise period and for 10 minutes afterwards.

Hormone Assays

Serum Luteinizing Hormone and Follicle-Stimulating Hormone Radioimmunoassays

The serum radioimmunoassays (RIAs) for luteinizing hormone (LH) and follicle-stimulating hormone (FSH) have been described previously.[12] The RIA for LH used reference standard LER-907 and first antibody (antihuman LH batch 2). The tracer was purified human chorionic gonadotropin radioiodinated with ^{125}I using chloramine-T.[13] The limit of detectability of the assay was 2.0 ng/mL, and the intra-assay and interassay coefficients of variation (CV) were 5.5% and 8%, respectively. All samples were run in one assay.

The RIA for FSH used reference standard LER-907 and first antibody (antihuman FSH, batch 5). The tracer was HS-1 radioiodinated with ^{125}I using chloramine-T.[13] The limit of detectability of the assay was 21 ng/mL, and the intra-assay and interassay CVs were 7.3% and 9.7%, respectively. All samples were run in the same assay. Assay results for both hormones were calculated using the program of Burger et al.[14]

Luteinizing Hormone Bioassay

Bioactive LH was measured in vitro using a modification[15] of the procedures described by Van Damme[16] and Dufau.[17] In this assay, T production is measured from dispersed Leydig cells isolated from immature Swiss-Webster mice. The reference standard is LER-907. All samples were run in duplicate at a volume of 10 μL.

Testosterone and Estradiol RIA

The RIAs for serum testosterone (T) and estradiol (E_2) were described previously.[18] Hormones were separated from serum by ether extraction, and separation of bound from free hormone was accomplished by dextran-coated charcoal. The assay sensitivity was 0.1 ng/mL for T and 12 pg/mL for E_2. The intra-assay and interassay variations were 5.1% and 9.5%, respectively for T, and 8.2% and 5.8%, respectively for E_2.

Sex-Hormone Binding Globulin and Free Testosterone

Quantitation of sex-hormone binding globulin (SHBG) was performed by saturation analysis and a RIA (using material obtained from Farmos Diagnostica, Ousaland, Finland); these techniques have been previously described.[19] Non-SHBG-bound T was calculated by a modification of the mass action equation of Pearlman.[20]

Cortisol

Serum cortisol was determined by RIA using Immuchem's Covalent-Coat Immunoassay (Immu-

Table 1 Physical Characteristics of the Highly Trained Male Runners and Matched Controls

	Runners[a] (n = 11)	Controls[a] (n = 12)	P value
Age	32.7 ± 1.2	32.2 ± 1.4	NS[b]
Wt (kg)	72.5 ± 1.8	76.5 ± 2.1	NS
BMI (kg/m^2)	23.1 ± 0.5	23.6 ± 0.5	NS
% Body fat	12.9 ± 1.4	17.7 ± 1.4	<0.05
VO_2 max (ml/kg/min)	63.9 ± 1.3	47.2 ± 3.5	<0.01

[a] Values are means ± SE.
[b] NS, not significant.

chem Corp., Carson, CA).[21] The mean intra-assay and interassay CVs were <10%. The normal range for serum cortisol between 4 P.M. and 9 P.M. is 3 to 11 μg/dL, as reported by the suppliers.

Seminal Fluid Analysis

Sperm counts, motilities (percent normal, forwardly mobile), and morphologies were determined as previously described.[12] Total spermatozoa per ejaculate were determined by multiplying the sperm count (10^6/mL) by the volume of the ejaculate.

Statistical Methods

For each subject, mean hormone values and sperm counts were computed, and these were used to compute the mean values for each group. Mean values were compared using an unpaired Student's *t*-test. As sperm counts are not normally distributed, geometric means were also computed and used in the statistical comparisons. In Tables 1 and 2, arithmetic means are reported. A P value of <0.05 was considered significant.

RESULTS

The physical characteristics of the runners and the control men are listed in Table 1. There were no differences in age, weight, or body mass index (kg/m^2) between the groups. The runners were significantly leaner and had a greater maximal oxygen uptake (VO_2 max) than did the controls, confirming the much greater exercise activity reported by the runners.

As shown in Table 2, sperm counts and total spermatozoa per ejaculate were similar between the two groups. Analysis of the fresh specimens revealed no significant differences in mean percent motilities or morphologies.

Mean total and free T, percent free T, and SHBG were similar in the two groups (Table 2). Serum cortisol and FSH levels were also similar in both groups. Although mean levels of bioactive LH were similar in both groups, levels of immunoactive LH were higher in the runners (42.2 ± 3.3 versus 29.8 ± 3.9; $P < 0.05$).

DISCUSSION

We have measured serial sperm counts and resting cortisol and reproductive hormone levels in a matched group of marathon runners and in healthy, lean controls. We found that with the exception of immunoreactive LH, there were no differences between the groups. These data suggest that long-term, strenuous exercise at this level does not exert major effects on reproductive function in men. This is in contrast to the situation in women, in whom strenuous endurance exercise regimens frequently lead to menstrual disorders.[1–3]

We found no difference in mean sperm count between the exercising and sedentary men, and no runner was oligospermic, nor were there any consistent abnormalities of motility or morphology in the runners' semen samples. Ayers et al.[22] collected single semen samples from 20 marathon runners and found that the analyses of 18 of the 20 samples were normal. Sperm counts are widely variable, and a single sample may not accurately reflect fertility status.[23] Our results therefore provide

Table 2 Seminal Fluid and Reproductive Hormone Indices in Highly Trained Male Runners and Matched Controls

	Runners[a] (n = 11)	Controls[a] (n = 12)	P value
Sperm count (10^6/mL)	119.9 ± 64.4	108.9 ± 91.7	NS[b]
Total spermatozoa per ejaculate ($\times 10^6$)	436.8 ± 64.6	316.1 ± 79.8	NS
% Oval forms	81.1 ± 1.8	78.9 ± 2.7	NS
Motility (%)	82.0 ± 4.6	73.2 ± 3.5	NS
T (ng/mL)	4.4 ± 0.3	4.5 ± 0.3	NS
Free T (ng/mL)	0.29 ± 0.06	0.23 ± 0.03	NS
% Free T	5.31 ± 0.66	5.45 ± 1.09	NS
SHBG (ng DHT bound/mL)	11.6 ± 1.0	11.6 ± 1.2	NS
LH-immuno (ng/mL)	42.0 ± 3.0	30.0 ± 4	<0.05
LH-bio (ng/mL)	102.0 ± 11.0	114.0 ± 18	NS
FSH (ng/mL)	93.0 ± 14.0	91.0 ± 12	NS
Cortisol (μg/dL)	8.9 ± 0.8	9.8 ± 0.5	NS

[a] Values are means ± SE.
[b] NS, not significant.

stronger evidence that highly trained endurance athletes have spermatogenic and reproductive endocrine function comparable to untrained but healthy normal men.

Total and free T, as well as SHBG, were similar in the two groups. MacConnie et al.[7] reported similar total T levels in marathoners and control men, but others[8,9,22] have found lower total and free T in marathon runners. Wheeler et al.[8] reported lower SHBG levels as well. The reason for this variation in T levels is not clear, as the runners in each study were of similar body composition and had similar training levels, and all were reported to be healthy and adequately nourished. Although T does have a circadian rhythm, our samples and those of Wheeler et al.[8] were both drawn late in the day, so circadian variation in T levels cannot account for the different findings.

We found no difference in mean FSH levels between the groups; this confirms the findings of Rogol et al.[6] These investigators also reported no difference in mean LH, LH pulse frequency, or LH pulse amplitude between athletes and controls, whereas we found significantly higher mean LH in the runners. Hackney et al.[9] recently reported an elevated mean LH level in athletes, although they found no difference in LH pulse frequency or amplitude. These investigators also reported lower total and free T levels in the runners, with no difference in E_2, and it is possible that reduced negative feedback of T accounted for the increased LH they observed in the athletes. We cannot invoke this mechanism, as total and free T were normal in our study. In addition, we found that the athletes and controls had similar levels of biologically active LH. Levels of bioactive LH have not been reported in previous studies, but it is possible that the pituitaries of some highly trained male runners respond to chronic, intense exercise by secreting a molecule that has immunologic but not biologic activity.

We found similar resting afternoon cortisol levels in the runners and the controls; this was also reported by Hackney and co-authors,[9] whereas Luger et al.[24] found elevated resting afternoon cortisol levels in very highly trained runners. Androgen and gonadotropin levels in these men were not reported, but elevated serum cortisol levels and increased cortisol production have been reported in amenorrheic female runners,[21] and acute rises in serum cortisol may result in reduced T levels in men.[25] It is therefore possible that elevated basal cortisol levels may be associated with altered reproductive hormone levels in athletes. Since our runners had normal afternoon cortisol levels, the lack of difference in androgen and FSH levels, as well as the lack of difference in sperm counts, is not surprising.

In conclusion, we found that with the exception of immunoactive LH, highly trained male runners have sperm counts and reproductive hormone levels that are similar to those of lean but sedentary men of similar age. Although reproductive abnormalities and/or infertility may develop in some professional athletes or in amateur athletes who train to the point of chronic exhaustion or extreme thinness (the so-called male anorectics), it appears that strenuous exercise at the level reported by our subjects does not have major adverse effects on reproductive function in healthy men.

Acknowledgments. We appreciate the assistance of Robert S. Schwartz, M.D., and Leo Jaeger, M.S., in the performance and interpretation of body composition measurements, spirometry, and treadmill testing. the technical assistance of Ms. Dorothy McGuinness, Arlen Sarkissians, B.A., Florida Flor, M.S., and Ms. Connie Pete, and the assistance of Liza Noonan, M.S., with statistical analyses and Larry Mix, B.A., with manuscript preparation. Steven R. Plymate, M.D., (Madigan Army Medical Center, Tacoma, WA) provided the SHBG and free T measurements. Seminal fluid analyses were performed in the Seminal Fluid Core Unit (Director: C. Alvin Paulsen, M.D.) of the Population Research Center for Research in Reproduction of the University of Washington. The National Hormone and Pituitary program supplied reference standard LER-907 and anti-human LH and FSH. The reagents for the T and E_2 RIA were provided by the WHO Matched Reagent Programme.

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