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Effects of Oral Contraceptives on Body Composition and Physical Performance in Female Athletes

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Menstrual disturbances are common among female athletes, and oral contraceptives (OCs) are often recommended as estrogen substitution. However, there is little information about the effects of OC use in athletes, and there is great concern that OCs might impair physical performance. The aim of this study was to investigate the effects of OC use on body composition and physical performance in female athletes. Twenty-six endurance athletes (13 with oligo-/amenorrhea and 13 regularly menstruating athletes) and 12 sedentary controls were examined before and after 10 months of treatment with a low dose, monophasic, combined OC. Significant changes in body composition were recorded in the athletes, but not in the controls. There was an increase in weight and fat mass only in

athletes with oligo-/amenorrhea. These changes were associated with a decrease in ovarian androgens. OC treatment also increased bone mineral density, with the largest increase in athletes with a low bone mineral density at baseline. Despite significant changes in body composition, little impact on physical performance was recorded. We have demonstrated that OC treatment in female athletes has predominantly beneficial effects on body composition without adverse effects on physical performance and could be used for the prevention of osteoporosis in athletic amenorrhea. However, it cannot be excluded that a marked increase in fat mass might have unfavorable effects for athletic performance in individual women. (*J Clin Endocrinol Metab* 89: 4364–4370, 2004)

ORAL CONTRACEPTIVES (OC) are used by numerous women all over the world. Although the main purpose is birth control, OCs are also frequently used for medical treatment, e.g. in women with long-standing amenorrhea. Circulating estrogen levels are known to be important to maintain bone mass, and limited data suggest that modern low dose OCs prevent bone loss in premenopausal women (1–3). However, there are also studies reporting no beneficial effect (4–6). OCs are generally well tolerated, but some women experience side effects, such as headache, nausea, breast tenderness, and weight gain (7, 8). These side effects are of great clinical importance because they often lead to discontinuation of treatment. Young women may be especially concerned about weight gain (9). Despite extensive clinical experience, many metabolic effects of OC treatment remain to be explored. Changes in appetite and weight are known to occur in some women, but the association with treatment is unclear. There are only a few studies evaluating body composition during OC treatment, and these show no significant change in body weight or body fat (10–12).

The questions about weight gain and metabolic effects of OCs are of particular relevance to female athletes, because a change in body composition could have a negative impact on physical performance. Menstrual disturbances are common among female athletes, especially in endurance sports, and

have been associated with insufficient dietary intake (13, 14). Long-standing amenorrhea and estrogen deficiency are associated with increased bone resorption and osteoporosis, particularly of trabecular bone, such as in the spine (15–18). Menstrual disturbances in athletes are also related to an increased incidence of stress fractures (19). Eating disorders, amenorrhea, and osteoporosis are related medical conditions and have been referred to as the female athlete triad (20, 21). This triad is currently considered a most serious medical problem in female elite sport. Although the need for treatment of estrogen deficiency may be apparent in amenorrheic athletes, there is virtually no information about the effects of OC on bone mass and body composition (22). Furthermore, few studies have investigated the effect of OC use on physical performance. There are reports on reduced maximal oxygen uptake (VO_2 max) associated with short-term use of OC (23, 24), whereas other studies have failed to confirm a negative effect of OCs in performance tests (25, 26). Within the world of sports there is a great demand for more knowledge about the effects of OC use on body composition and physical performance.

The aim of this study was to investigate whether OC use affects body composition and physical performance in female athletes. Endurance athletes with and without menstrual disturbances and sedentary controls were investigated before and after an average of 10 months of OC use.

Subjects and Methods

Subjects

Female athletes in endurance sports were recruited from universities and high schools specializing in sports and in connection with public sports events and championships. The inclusion criteria were as follows: age, 16–35 yr; body mass index (BMI), 18–24; nullipara; healthy; and

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Abbreviations: A-4, 4-Androstene-3,17-dione; BMD, bone mineral density; BMI, body mass index; CBG, corticosteroid-binding globulin; DHEAS, dehydroepiandrosterone sulfate; fT_3 , free T_3 ; fT_4 , free T_4 ; OC, oral contraceptive; T, testosterone; VO_2 max, maximal oxygen uptake.

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nonsmoking. Endurance training criteria were defined as a minimum of 6 h of aerobic weight-bearing training or a minimum of 70 km of running or 6 h of specific endurance training weekly. Age- and BMI-matched controls with the same inclusion criteria as athletes were recruited from universities and high schools and from hospital staff at Karolinska Hospital. They were restricted to 1 h of light aerobic training a week. Information about menstrual status (amenorrhea, no bleeding for the last 3 months; oligomenorrhea, periods at intervals exceeding 6 wk; and regular monthly periods) was provided by the subjects. No medications were allowed. Intake of minerals/vitamins or nutritional supplements was accepted. Three groups of women characterized on the basis of endurance training and menstrual status and matched for age and BMI were studied: 13 athletes with amenorrhea (8) or oligomenorrhea (5), 13 regularly menstruating athletes, and 12 sedentary regularly menstruating controls.

Experimental design

The women were examined before and after 10 months of treatment with a low dose, monophasic, combined OC (30 μ g ethinyl estradiol and 150 μ g levonorgestrel on d 1–21, followed by a hormone- and tablet-free interval on d 22–28). Subjects with irregular menstruation underwent gynecological examination and assessment of the degree of menstrual disturbance before treatment. Regularly menstruating subjects were examined in the early follicular phase (menstrual cycle d 1–5) before OC treatment, and all subjects were examined at the end of a treatment cycle during OC. The women were examined in the morning, starting at 0730 h, at the Women's Health Clinical Research Unit, Karolinska University Hospital. Body weight, height, and blood pressure were recorded, and general health condition was examined. Fasting blood samples were collected from a peripheral vein in a resting state. After centrifugation of blood samples, sera were stored at -20°C until assayed.

Endocrine assays

Serum concentrations of testosterone (T), SHBG, and corticosteroid-binding globulin (CBG) were determined with RIA in untreated serum, using commercial kits obtained from Diagnostic Products Corp. (Los Angeles, CA; Coat-a-Count Testosterone), Eurodiagnostics AB (Malmö, Sweden; SHBG), and Medgenix Diagnostics SA (Fleurus, Belgium; CBG) according to the manufacturers' protocols. Serum levels of 4-androstene-3,17-dione (A-4) and dehydroepiandrosterone sulfate (DHEAS) were determined after extraction with diethyl ether by radioimmunological methods, the details of which have been given previously (27). In the assay of DHEAS, the conjugate was cleaved by thermal hydrolysis before extraction.

Serum levels of IGF-I were determined by RIA after acid-ethanol extraction with a commercial kit from Nichols Institute (San Capistrano, CA). The levels are expressed as micrograms per liter of WHO First International Reference Reagent IGF-I 87/518 (1988). Serum insulin was determined by RIA, using a commercial kit obtained from Pharmacia Biotech (Uppsala, Sweden), and was expressed as milliinternational units per liter of WHO International Reference Preparation 66/304. Serum levels of estradiol, cortisol, TSH, free T_4 (fT₄), and free T_3 (fT₃) were determined by time-resolved fluorescence immunoassay, using commercial kits from Wallac Oy (Turku, Finland; Autodelphia). The concentration of TSH was expressed as milliunits per liter of Second TSH International Reference Preparation 80/558. Osteocalcin was resolved in a solid phase immunoradiometric assay (CIS Biointernational, Gif-sur-Yvette, France; Elsa-Osteo).

Detection limits and within- and between-assay coefficients of vari-

ation were: for T, 0.1 nmol/liter, 6%, and 10%; for SHBG, 0.05 nmol/liter, 4%, and 8%; for CBG, 0.3 mg/liter, 4%, and 6%; for A-4, 0.6 nmol/liter, 6%, and 10%; for DHEAS, 200 nmol/liter, 8%, and 12%; for IGF-I, 6 μ g/liter, 5%, and 7%; for insulin, 2 mIU/liter, 6%, and 6%; for estradiol, 50 pmol/liter, 5%, and 8%; for cortisol, 15 nmol/liter, 4%, and 5%; for TSH, 0.005 mIU/liter, 3%, and 5%; for fT₄, 2 pmol/liter, 5%, and 4%; for fT₃, 2 pmol/liter, 9%, and 5%; and for osteocalcin, 0.4 ng/ml, 4%, and 5%, respectively.

Apparent concentrations of free T were calculated from values of total T, SHBG, and a fixed albumin concentration of 40 g/liter by successive approximation using a computer program based on an equation derived from the law of mass action (28). Apparent concentrations of free cortisol were calculated from cortisol and CBG values using a formula derived from the law of mass action, as specified by the manufacturer of the CBG kit.

Body composition

Bone mineral density (BMD; grams per square centimeter) and lean and fat masses were determined for the whole body with dual energy x-ray absorptiometry measurements using DPX-L equipment (Lunar Corp., Madison, WI). From the whole body dual energy x-ray absorptiometry measurement, the spinal BMD was determined. The spinal region comprised the lower part of the cervical spine, the thoracic, and most of the lumbar spine (approximately L1–L4). The Lunar software automatically calculates the amount of fat in trunk and legs. The limit between the leg and trunk regions was defined as the line drawn from the upper margin of the iliac crest through the femoral neck. As an estimate of the upper/lower fat mass ratio, we determined the trunk/leg fat mass ratio. The reproducibility of the whole body BMD is calculated as less than 0.01 g/cm² or $0.1 \times \text{SD}$ (29, 30).

Physical performance

Endurance capacity and strength were assessed between 1030 and 1500 h at Karolinska Institute, more than 2 h after a light meal. VO_2 max and pulmonary ventilation were determined while the subjects ran on a motor-driven treadmill (Cardionics AB, Stockholm, Sweden), using the leveling-off criterion (31). The running test started with a warm-up period at 9 km/h and 0° elevation. After 4 min, the speed was increased to 10 km/h with 2° of elevation. One minute later, speed was increased to 12 km/h. Thereafter, speed was increased by 1 km/h every minute up to 15 km/h, followed by an elevation of 1° every minute until the subject became exhausted. The total work-time from the start of warm-up to the end of running was used as a measure of physical performance. During the test, the subject breathed through a mouthpiece and valve system. Expired air was sampled in Douglas bags. The volume of air was measured in a Tissot spirometer (W. E. Collins, Inc., Braintree, MA), and oxygen and carbon dioxide contents were determined with a Beckman analyzer (Beckman Coulter, Fullerton, CA).

Endurance was also evaluated using a multistage progressive shuttle-run test, the beep test (32–34), intended to reflect overall performance, including balance and litheness. All tests were performed on a hard synthetic surface in an indoor sports arena. Subjects ran between two lines, 20 m apart, synchronized with beeping signals emitted from an audiocassette. The time interval between sound signals decreased every minute. The test was terminated when the subjects could no longer follow the set pace and failed to reach the target line on three consecutive occasions.

Heart rate was measured with a Polar Sport Tester PE 3000 during treadmill running and beep test. Blood samples, from a prewarmed

TABLE 1. Baseline physical and training characteristics in amenorrheic or oligomenorrheic athletes (OAM), regularly menstruating athletes (RM), and sedentary controls (CTR)

Groups	OAM (n = 13)	RM (n = 13)	CTR (n = 12)	Significance (P)
Age (yr)	19.8 \pm 4.6	21.5 \pm 4.0	20.9 \pm 4.2	NS
BMI (kg/m ²)	19.4 \pm 1.7	19.7 \pm 1.3	19.9 \pm 1.4	NS
Age at menarche (yr)	14.2 \pm 1.4	12.4 \pm 1.3	13.1 \pm 1.4	^a
Age at onset of training (yr)	9.3 \pm 2.9	10.8 \pm 3.1		NS
Amount of endurance training (h/wk)	8.1 \pm 1.6	7.7 \pm 1.8		NS

Values are the mean \pm SD. NS, not significant. Significant differences between OAM *vs.* RM are indicated.

^a $P < 0.01$.

finger tip, were taken for determination of the blood lactate concentration within 1 min after exercise and were analyzed (YSI 2300, YSI, Inc., Yellow Spring, OH). The rate of overall perceived exertion was evaluated using the Borg scale (35).

Isometric extension of the legs was measured in a chair individually calibrated to obtain optimal position of the subjects with their feet and back fixed at a knee angle of 90°. Two pressure-sensitive footplates recorded a pressure curve and measured the maximum amplitude. The best of four trials was registered. Isometric handgrip strength was measured in both hands, using a grip dynamometer (Cardionics AB, Stockholm, Sweden). The best of three trials in the strongest hand was noted.

TABLE 2. Effects of combined OC on hormone levels in amenorrheic or oligomenorrheic (OAM), regularly menstruating athletes (RM), and sedentary controls (CTR)

Groups	OAM (n = 13)		RM (n = 13)		CTR (n = 12)	
	Before	During OC	Before	During OC	Before	During OC
T (ng/dl)	30.6 ± 11.1	13.9 ± 5.6 ^a	33.3 ± 11.1	19.4 ± 11.1 ^a	33.3 ± 11.1	16.7 ± 8.3 ^a
Free T (pg/ml)	7.0 ± 3.2	2.6 ± 1.1 ^a	6.7 ± 2.7	2.9 ± 1.3 ^a	6.6 ± 2.4	2.7 ± 1.4 ^a
SHBG (mg/liter)	3.2 ± 0.8	4.8 ± 1.1 ^b	3.7 ± 1.1	6.0 ± 2.1 ^b	3.7 ± 1.0	5.5 ± 1.6 ^b
A-4 (pg/ml)	2.7 ± 0.9	1.7 ± 0.8 ^a	2.3 ± 0.6	1.5 ± 0.4 ^b	2.8 ± 0.9	1.8 ± 0.6 ^a
DHEAS (ng/ml)	1501 ± 483 ^{c,d}	1539 ± 528	1839 ± 552	1587 ± 604	2375 ± 651	1909 ± 584 ^b
IGF-I (μg/liter)	346 ± 100	305 ± 54	326 ± 75	319 ± 91	319 ± 61	312 ± 95
Insulin (mIU/liter)	5.6 ± 2.3	5.4 ± 1.8	6.1 ± 2.1	7.0 ± 2.9	7.5 ± 3.6	7.7 ± 2.6
Cortisol (μg/dl)	18.8 ± 4.4	30.3 ± 5.0 ^a	16.5 ± 4.0	29.8 ± 4.7 ^a	18.4 ± 5.1	31.0 ± 6.3 ^a
CBG (μg/l)	51.9 ± 7.0 ^e	103.6 ± 13.6 ^a	48.4 ± 6.8	113.9 ± 19.3 ^a	45.1 ± 6.3	105.0 ± 21.6 ^a
Free cortisol (ng/ml)	9.9 ± 2.8	7.9 ± 1.8 ^b	8.3 ± 2.9	6.8 ± 1.7 ^f	12.2 ± 5.8	8.1 ± 2.9 ^f
Free T/cortisol	0.37 ± 0.17	0.08 ± 0.04 ^a	0.40 ± 0.15	0.10 ± 0.05 ^a	0.36 ± 0.16	0.09 ± 0.07 ^a
Free T/free cortisol	0.71 ± 0.30	0.32 ± 0.14 ^a	0.81 ± 0.28	0.43 ± 0.23 ^b	0.54 ± 0.28	0.34 ± 0.23 ^f
Prolactin (μg/liter)	6.6 ± 4.0 ^g	8.3 ± 2.8 ^f	12.1 ± 3.9	11.2 ± 4.9	11.3 ± 4.5	11.5 ± 6.4
TSH (mIU/liter)	2.1 ± 0.7	2.1 ± 0.8	2.4 ± 0.8	2.4 ± 0.8	2.4 ± 0.8	2.5 ± 0.7
fT ₄ (pg/ml)	8.5 ± 1.1 ^{c,d}	7.8 ± 1.2	9.4 ± 1.4	9.1 ± 1.2	10.8 ± 1.6	10.0 ± 1.6 ^f
fT ₃ (pg/ml)	3.3 ± 0.7 ^h	3.0 ± 0.6	3.8 ± 0.5	3.3 ± 0.5 ^b	4.2 ± 0.6	3.6 ± 0.6
Osteocalcin (ng/ml)	31 ± 12	23 ± 8 ^f	35 ± 8	28 ± 4 ^b	35 ± 15	30 ± 10

Values are the mean ± SD. Significant differences within groups are indicated in the *During OC* columns. Significant differences in baseline levels between groups are indicated in the first OAM column. Conversion factors to System International Units: T, 0.035; free T, 3.5; SHBG, 10.8; A-4, 3.5; DHEAS, 2.72; insulin, 6.0; cortisol, 27.6; free cortisol, 2.76; fT₄, 1.28; fT₃, 1.54.

^a *P* < 0.001.

^b *P* < 0.01.

^c *P* < 0.001, OAM *vs.* CTR.

^d *P* < 0.05, RM *vs.* CTR.

^e *P* < 0.05, OAM *vs.* CTR.

^f *P* < 0.05.

^g *P* < 0.01, OAM *vs.* RM.

^h *P* < 0.01, OAM *vs.* CTR.

TABLE 3. Effects of combined OC on body composition in amenorrheic or oligomenorrheic athletes (OAM), regularly menstruating athletes (RM), and sedentary controls (CTR)

Groups	OAM (n = 13)		RM (n = 13)		CTR (n = 12)	
	Before	During OC	Before	During OC	Before	During OC
Weight (kg)	56.2 ± 6.7	58.6 ± 7.5 ^a	56.4 ± 4.3	58.1 ± 4.2	56.4 ± 6.2	57.2 ± 5.9
Fat mass, total (%)	17.3 ± 4.3 ^b	20.4 ± 5.0 ^a	21.2 ± 4.3	22.0 ± 4.7	24.2 ± 4.9	24.3 ± 4.2
Upper body fat mass (kg)	3.8 ± 1.7 ^c	4.8 ± 1.8 ^a	5.0 ± 1.5	5.3 ± 1.5	5.4 ± 1.3	5.7 ± 1.5
Lower body fat mass (kg)	4.5 ± 1.4	5.5 ± 1.7 ^d	5.2 ± 1.3	5.4 ± 1.2	5.8 ± 1.5	5.9 ± 1.5
Upper/lower fat mass ratio	0.81 ± 0.13 ^e	0.89 ± 0.10	0.95 ± 0.15	0.98 ± 0.15	0.96 ± 0.14	0.96 ± 0.11
BMD, total (g/cm ²)	1.14 ± 0.08	1.16 ± 0.07 ^f	1.20 ± 0.04	1.22 ± 0.03	1.16 ± 0.08	1.16 ± 0.08
BMD, spine (g/cm ²)	1.05 ± 0.07 ^e	1.06 ± 0.10	1.15 ± 0.08	1.16 ± 0.09	1.14 ± 0.08	1.15 ± 0.09
BMD, legs (g/cm ²)	1.26 ± 0.11	1.28 ± 0.08	1.31 ± 0.07	1.33 ± 0.07 ^f	1.22 ± 0.12	1.22 ± 0.11
Lean body mass, total (kg)	44.7 ± 4.0 ^c	44.8 ± 4.7	42.8 ± 2.6	42.9 ± 2.5	39.6 ± 4.6	40.4 ± 3.7
Lean body mass, legs (kg)	16.1 ± 2.1 ^c	15.7 ± 1.8	15.3 ± 1.2	15.3 ± 1.1	13.9 ± 2.0	14.2 ± 1.6

Values are the mean ± SD. Significant differences within groups are indicated in the *During OC* columns. Significant differences in baseline levels between groups are indicated in the first OAM column.

^a *P* < 0.01.

^b *P* < 0.01, OAM *vs.* CTR.

^c *P* < 0.05, OAM *vs.* CTR.

^d *P* < 0.001.

^e *P* < 0.05, OAM *vs.* RM and OAM *vs.* CTR.

^f *P* < 0.05.

Statistical analysis

Values are given as the arithmetic mean and SD. Differences within and between groups were analyzed using a two-way ANOVA with one within factor (OC treatment) and one between factor (groups). *Post hoc* analyses were performed using Tukey's highest significant difference test. For the within effects, a paired *t* test was used, with *P* values adjusted for multiple comparisons. Correlations were assessed using Pearson's coefficient of correlation or Spearman's rank-order correlation coefficient according to distribution. The software used were Statistica

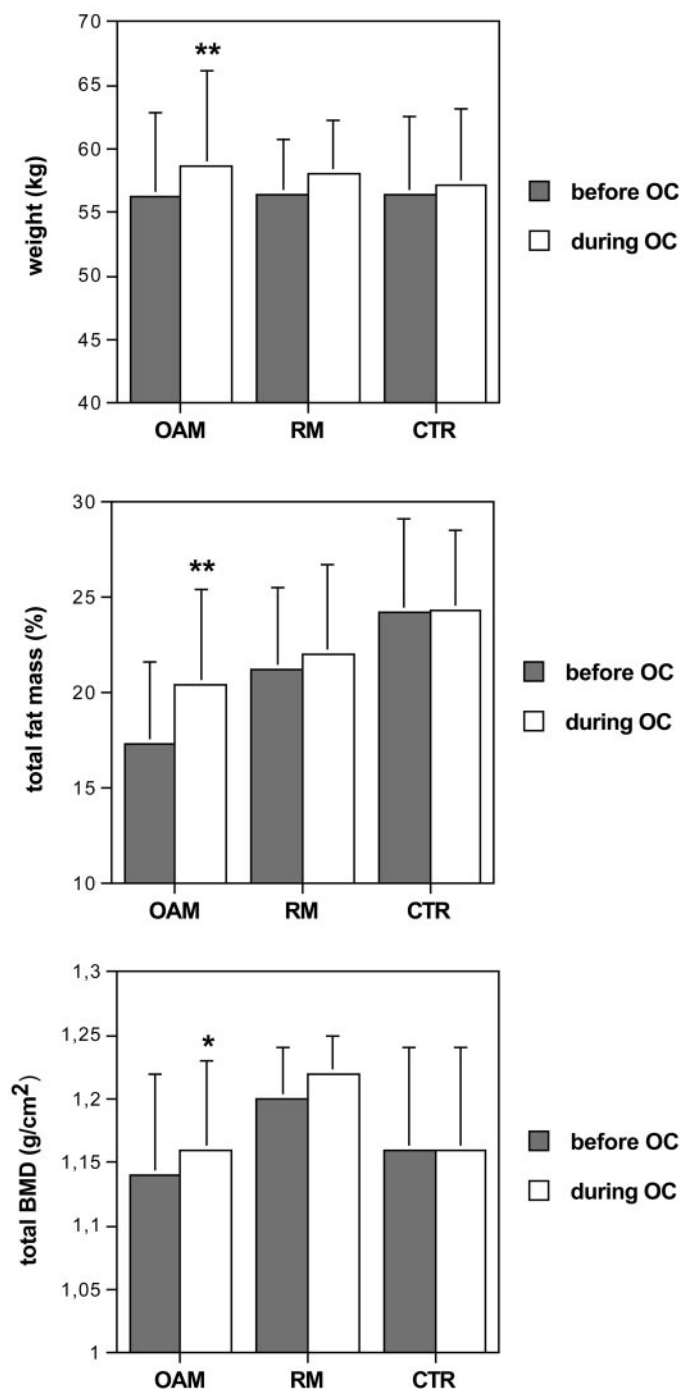


FIG. 1. Effects of combined OC use on weight, percent fat mass, and total BMD in oligo-/amenorrheic athletes (OAM), regularly menstruating athletes (RM), and sedentary controls (CTR). Oligo-/amenorrheic athletes increased significantly in weight (**, $P < 0.01$), percent fat mass (**, $P < 0.01$), and total BMD (*, $P < 0.05$), whereas regularly menstruating athletes and controls showed no change in these variables.

6.1 (StatSoft, Inc., Tulsa, OK) and SAS System 8.2 (SAS Institute, Inc., Cary, NC).

Results

Data pertaining to age and physical and training characteristics for the two groups of athletes with and without

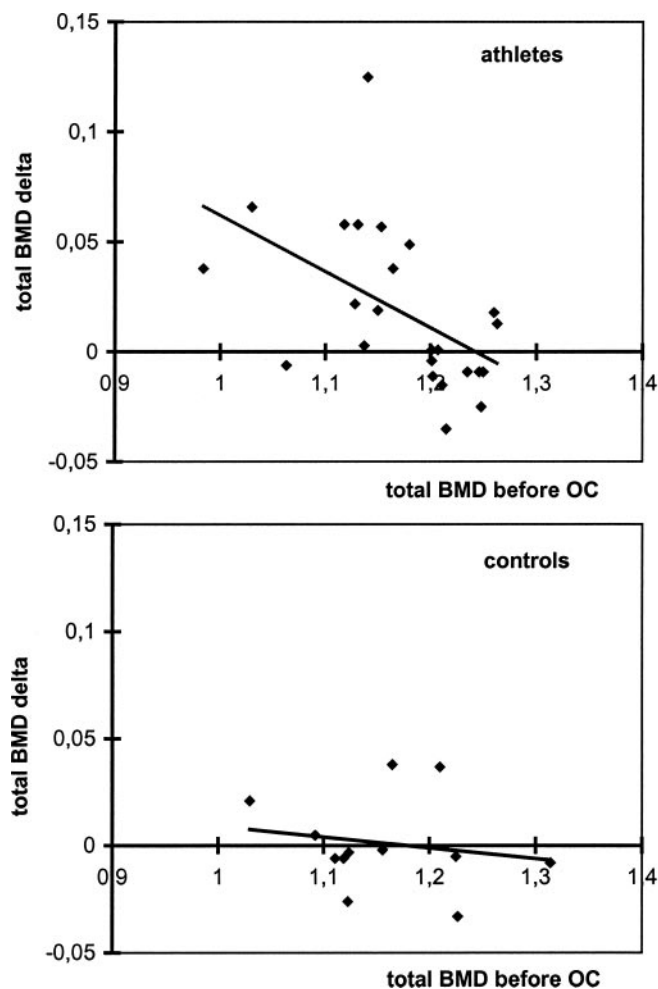


FIG. 2. Correlation between total BMD before OC and the change in BMD during OC use in the athlete groups and controls. There was a significant negative correlation in the athletes ($r = -0.51$; $P < 0.01$), but not in the controls ($r = -0.17$).

menstrual disturbances and for sedentary controls are presented in Table 1. Age at menarche was higher in the oligo-/amenorrheic athletes than in the regularly menstruating athletes. Estradiol levels were not significantly different between groups, although the group of athletes with menstrual disturbances had the lowest values (athletes with oligomenorrhea, 29.4 ± 13.5 ; regularly menstruating athletes, 34.6 ± 12.9 ; sedentary regularly menstruating controls, 47.5 ± 17.4 pg/ml). The conversion factor to Systeme International units (picomoles per liter) is 3.7. Of the 13 oligo-/amenorrheic athletes, the majority ($n = 10$) displayed low levels of gonadotropins with FSH and/or LH levels below 5 IU/liter, indicating that the menstrual disturbance due to hypothalamic inhibition. Two of the five athletes with oligomenorrhea were considered hyperandrogenic based on an increased ratio of LH/FSH (>2) and an increased ratio of testosterone/SHBG (>0.05) (32). One amenorrheic athlete had levels of gonadotropins, T, and SHBG within the normal range.

Effects of OCs on hormone levels

Levels of hormones and binding proteins before and during OC treatment in the two groups of athletes and controls

are shown in Table 2. In all three groups, serum levels of total and free T and A-4 were markedly decreased, and SHBG was increased during OC treatment. However, levels of DHEAS were significantly lower in the athlete group with menstrual disturbance before treatment and remained unchanged during OC use, whereas the DHEAS levels in controls decreased. During OC treatment, serum levels of cortisol and CBG increased, whereas free cortisol and the free T/free cortisol ratio decreased in all groups. Prolactin levels were significantly lower in the athlete group with menstrual disturbance at baseline and increased during treatment, in contrast to those in regularly menstruating groups. Concentrations of fT₄ and fT₃ were lowest in the oligo-/amenorrheic athletes before treatment, with no significant change, whereas regularly menstruating subjects showed a decrease in thyroid hormones. TSH levels were unchanged by OC treatment in all three groups. The athlete groups displayed a significant decrease in osteocalcin with OC use. Oligo-/amenorrheic athletes had the lowest osteocalcin levels during treatment, which were significantly lower than control values ($P < 0.05$).

Effects of OCs on body composition

Variables of body composition before and during OC treatment in the two groups of athletes and controls are given in Table 3. Athletes with menstrual disturbances displayed highly significant changes in body composition after OC treatment, whereas most of these variables remained unchanged in the regularly menstruating athletes, and no change in body composition was recorded in the controls. There were significant increases in weight and fat mass only in the oligo-/amenorrheic athlete group. Total BMD was also significantly increased in women with oligo-/amenorrhea. For those with regular menstruation, athletes and controls, no such effect was recorded. However, BMD in the legs was increased in regularly menstruating athletes. Lean body

mass was unchanged in all groups. Figure 1 demonstrates that the oligo-/amenorrheic athletes had the lowest fat mass and BMD before OC and displayed the largest increase in weight, total fat mass, and total BMD.

Effects of OCs on physical performance

Physical performance values before and during OC treatment in the two groups of athletes and controls are shown in Table 4. There were highly significant differences between athletes and sedentary controls in almost all physical performance and physiological parameters measured at baseline. Most of these variables were unchanged by OC treatment in both athletes and controls. Thus, there were no changes in endurance assessed by VO₂ max and rate of perceived dyspnea-exertion. However, for the oligo-/amenorrheic group, there was a 6% decline in performance levels using the beep test.

Correlations

There was a significant negative correlation between the total fat mass (percentage) before OC and the change in fat mass during OC in all subjects ($r = -0.43$; $P < 0.01$). The change in A-4 levels was negatively correlated with the change in weight and BMI in both athletes ($r_s = -0.49$, $P < 0.05$ and $r_s = -0.50$, $P < 0.05$, respectively) and controls ($r_s = -0.76$, $P < 0.05$ and $r_s = -0.71$, $P < 0.05$, respectively). In all subjects there was also a negative correlation between the decline in levels of free T and the changes in weight, BMI, and total fat mass ($r_s = -0.35$, $P < 0.05$; $r_s = -0.36$, $P < 0.05$; and $r_s = -0.34$, $P < 0.05$, respectively). There was no correlation between the increase in total fat mass and the decline in beep test performance in the oligo-/amenorrheic group ($r = 0.00$). In the athlete groups, there was a highly significant negative correlation between total BMD before OC and the change in

TABLE 4. Effects of combined OC on physical performance in amenorrheic or oligomenorrheic athletes (OAM), regularly menstruating athletes (RM), and sedentary controls (CTR)

Groups	OAM (n = 13)		RM (n = 13)		CTR (n = 12)	
	Before	During OC	Before	During OC	Before	During OC
Treadmill						
Time to exhaustion (min)	10.8 ± 0.8 ^a	10.5 ± 1.2	10.2 ± 1.2	10.8 ± 1.7	6.4 ± 0.6	6.5 ± 0.7
VO ₂ max (liters/min)	3.25 ± 0.38 ^a	3.27 ± 0.38	3.15 ± 0.18	3.23 ± 0.22	2.41 ± 0.28	2.43 ± 0.27
VO ₂ max (ml/kg × min)	56.7 ± 4.1 ^a	55.6 ± 4.5	55.3 ± 4.4	55.6 ± 3.1	41.9 ± 3.3	41.7 ± 3.1
V _E (liters/min)	99 ± 16 ^{b,c}	100 ± 12	103 ± 11	102 ± 10	82 ± 12	84 ± 15
Peak heart rate (beats/min)	189 ± 6	192 ± 7	191 ± 10	194 ± 9	196 ± 6	196 ± 7
Blood lactate (mmol/liter)	9.6 ± 1.6	9.9 ± 1.6	8.7 ± 1.7	8.9 ± 1.6	9.9 ± 1.4	8.9 ± 1.4
Perceived dyspnea-exertion (points)	16.3 ± 0.9	16.6 ± 1.3	16.9 ± 1.6	17.3 ± 1.3	16.9 ± 2.0	17.7 ± 1.3
Beep test						
Performance (levels)	12.1 ± 1.0 ^a	11.4 ± 1.3 ^d	11.6 ± 1.0	11.6 ± 1.1	7.1 ± 1.1	6.7 ± 1.0
Peak heart rate (beats/min)	188 ± 8	190 ± 8	193 ± 10	194 ± 9	194 ± 8	192 ± 12
Blood lactate (mmol/liter)	8.3 ± 2.3 ^c	8.3 ± 1.9	7.6 ± 0.7	8.2 ± 1.1	10.0 ± 1.1	8.6 ± 1.6
Perceived dyspnea-exertion (points)	16.0 ± 3.5	16.8 ± 1.5	15.4 ± 1.8	16.1 ± 2.3	15.1 ± 2.5	15.6 ± 1.6
Isometric measurements						
Knee extension (N)	143 ± 35	144 ± 36	135 ± 21	140 ± 22	119 ± 17	122 ± 13
Hand grip (N)	33.4 ± 6.5	36.2 ± 3.7	32.2 ± 4.9	34.1 ± 3.6	33.6 ± 4.4	34.4 ± 4.4

Values are the mean ± SD. Significant differences within groups are indicated in the *During OC* columns. Significant differences in baseline levels between groups are indicated in the first OAM column.

^a $P < 0.001$, OAM *vs.* CTR and RM *vs.* CTR.

^b $P < 0.05$, OAM *vs.* CTR.

^c $P < 0.01$, RM *vs.* CTR.

^d $P < 0.05$.

BMD during OC ($r = -0.51$; $P < 0.01$), but this association was not found in the controls ($r = -0.17$; Fig. 2). The change in BMD spine was negatively correlated with the change in osteocalcin levels among the athletes ($r_s = -0.41$; $P < 0.05$), but not in the controls ($r_s = -0.18$).

Discussion

To our knowledge this is the first report on the effects of OCs on body composition in relation to physical performance in female athletes. These issues are important because even small changes in body composition may have an impact on performance and competitive capacity. The hormonal effects of OC treatment have previously only been elucidated among nonathlete women. Overall there was a suppression of the ovarian androgens, T and A-4, and the increased SHBG levels further contributed to a marked decline in free T levels. These effects were apparent and of comparable magnitude among both athletes and sedentary controls. Moreover, there was a rise in total cortisol, but after the increase in the binding protein CBG, the free fraction of cortisol was reduced. Prolactin levels were increased only in the oligo-/amenorrheic group of athletes. In the regularly menstruating subjects, there was a slight decline in free thyroid hormones during treatment, probably as a consequence of an increase in their binding proteins, which was not measured.

The hormonal effects of OC treatment were quite similar between the athlete groups and controls. Nevertheless, marked changes in body composition were recorded only among the oligo-/amenorrheic athletes. In this group the mean body weight increase was 2.4 kg after 10 months of OC treatment. The increase in body weight was mainly caused by an increase in body fat, and there was no change in lean body mass. As expected, oligo-/amenorrheic athletes had the lowest amount of body fat before treatment. During treatment, there was an increase in both upper and lower body fat in the oligo-/amenorrheic athletes. Athletic amenorrhea and estrogen deficiency is well known to reflect energy deficiency (13, 14). Within the groups of athletes, the largest increase in weight and body fat was found in women with menstrual disturbances. There was also an association between low fat mass at baseline and a larger increase in body fat during OC use.

Sex steroids have been shown to interfere with appetite and metabolic functions. Estradiol inhibits feeding in animals (36), whereas high dose progestins are appetite stimulating (37). OCs may also decrease insulin sensitivity, and the effect on carbohydrate metabolism has been attributed to the progestin component (38). Furthermore, sex steroids may exert metabolic effects in adipose tissue. In postmenopausal women oral administration of estrogen was found to reduce postprandial lipid oxidation and increase fat mass (39). In this study we found the increase in weight and fat mass to be associated with the decline in androgen levels, but no associations were found with the other hormonal changes. Although endogenous androgens are related to abdominal obesity (40), exogenous androgen treatment has been shown to reduce body fat and weight in postmenopausal women (41). The precise mechanisms responsible for the increases in

weight and body fat during OC treatment remain to be elucidated.

Amenorrhea and a hypogonadal state are common among female endurance athletes (13, 14). Increased bone resorption, in particular, loss of trabecular bone, constitutes a serious consequence of this condition (15–18). Menstrual disturbances in athletes are also related to an increase in musculoskeletal injuries and a 2- to 4-fold higher risk of stress fractures (19). In clinical practice, OC treatment is often recommended to prevent bone loss during conditions of estrogen deficiency, but data on the effects of OCs in athletes have been lacking (22). In this study we found a small, but significant, increase in total BMD in oligo-/amenorrheic athletes after a relatively short treatment period. Those athletes with low BMD at baseline were found to gain the most from treatment. No effects on bone mass were found among sedentary controls. These findings may explain why some studies failed to demonstrate beneficial effects of OC use on bone mass (4–6). The apparent inhibition of bone turnover after estrogen/progestin replacement was illustrated by the inverse correlation between serum levels of osteocalcin and BMD of the spine in the athletes. To some extent the effects on bone mass could relate to weight-bearing exercise, because a positive effect on leg BMD was recorded in the regularly menstruating athletes.

Despite significant changes in body composition caused by OC treatment in athletes, little impact on physical performance was recorded. Thus, different endurance tests were largely unchanged during treatment. These are important findings, because within the world of sports there is great concern that OCs might impair physical performance. Our results are in agreement with previous findings in nonathletes, in whom no change in functional aerobic capacity was recorded during short-term use of OC (25, 26), but there are also data to suggest reduced VO_2 max during OC treatment (23, 24). From our results, we conclude that, in general, OCs can be recommended to athletes. However, we found a slight decline in overall performance, assessed by the beep test, for the oligo-/amenorrheic group. Although this finding was not related to the gain in fat mass, it cannot be excluded that a pronounced increase in fat mass might have unfavorable effects for athletic performance, particularly in such endurance sports where coordination is crucial.

In summary, we have demonstrated that OCs in female athletes have primarily beneficial effects on body composition without adverse effects on physical performance. OC treatment significantly increased BMD, particularly in those with low BMD at baseline, and could therefore be recommended to prevent bone loss in athletes with long-standing amenorrhea and estrogen deficiency.

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