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The Association of a High Drive for Thinness With Energy Deficiency and Severe Menstrual Disturbances: Confirmation in a Large Population of Exercising Women

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A high drive-for-thinness (DT) score obtained from the Eating Disorder Inventory-2 is associated with surrogate markers of energy deficiency in exercising women. The purposes of this study were to confirm the association between DT and energy deficiency in a larger population of exercising women that was previously published and to compare the distribution of menstrual status in exercising women when categorized as high vs. normal DT. A high DT was defined as a score ≥7, corresponding to the 75th percentile for college-age women. Exercising women age 22.9 ± 4.3 yr with a BMI of 21.2 ± 2.2 kg/m^2 were retrospectively grouped as high DT (n = 27) or normal DT (n = 90) to compare psychometric, energetic, and reproductive characteristics. Chi-square analyses were performed to compare the distribution of menstrual disturbances between groups. Measures of resting energy expenditure (REE) (4,949 ± 494 kJ/day vs. 5,406 ± 560 kJ/day, $p < .001$) and adjusted REE (123 ± 16 kJ/LBM vs. 130 ± 9 kJ/LBM, $p = .027$) were suppressed in exercising women with high DT vs. normal DT, respectively. Ratio of measured REE to predicted REE (pREE) in the high-DT group was 0.85 ± 0.10, meeting the authors' operational definition for an energy deficiency (REE:pREE <0.90). A greater prevalence of severe menstrual disturbances such as amenorrhea and oligomenorrhea was observed in the high-DT group ($\chi^2 = 9.3$, $p = .003$) than in the normal-DT group. The current study confirms the association between a high DT score and energy deficiency in exercising women and demonstrates a greater prevalence of severe menstrual disturbances in exercising women with high DT.

***Keywords**:* resting energy expenditure, female athlete triad, subclinical disordered eating, amenorrhea, oligomenorrhea, eating attitudes and behavior

Subclinical disordered eating behavior has been well documented in premenopausal women engaging in recreational and competitive exercise regimens (Sundgot-Borgen, 1994) and has been shown to promote chronic energy deficiency, potentially leading to the development of clinical consequences associated with the female athlete triad (Nattiv et al., 2007; Sundgot-Borgen, 1994). The female athlete triad is a syndrome described by low energy availability (with or without disordered eating), functional hypothalamic amenorrhea, and low bone-mineral density (Nattiv et al., 2007), alone or in combination, in exercising women. A tool often used to discriminate between disordered versus healthy eating behavior and attitudes in college-age women is the Eating Disorder Inventory-2 (EDI-2; Garner & Olmsted, 1991). The drive-for-thinness (DT) subscale of the EDI-2 is used to predict the presence of a subclinical (if severely high, clinical) variant of disordered eating that is often observed in exercising women. Such demonstration of DT is characterized by a preoccupation with body weight and body shape, fear of gaining weight, and high dietary cognitive restraint (Sands, 2000).

A large body of evidence supports strong correlations between subclinical disordered eating, DT, and amenorrhea in exercising women (De Souza, Hontscharuk, Olmsted, Kerr, & Williams, 2007; Nattiv et al., 2007; Torstveit & Sundgot-Borgen, 2005). Exercise-related menstrual disturbances are proposed to begin with intense pressures to achieve an unrealistic standard of thinness and to enhance weight control (Beals & Manore, 2002; Sundgot-Borgen, 1994). A high DT has also been proposed as a key factor in the development of the female athlete triad (De Souza et al., 2007a; Sundgot-Borgen, 1994). Because a high DT promotes diet and exercise behaviors consistent with the achievement of the thin ideal, we reasoned that a high DT might be related to behavioral changes that reflect dietary energy restriction or high exercise volume, likely resulting in the development of an energy deficiency (De Souza, Hontscharuk, et al., 2007).

We have previously demonstrated that a high DT score may serve as an indicator of underlying energy

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deficiency based on the observation of a significant negative relationship between DT scores and resting energy expenditure (REE) when expressed as the ratio of measured REE to the Harris-Benedict-predicted REE (REE:pREE; De Souza, Hontscharuk, et al., 2007). The exercising women with a high DT in our previous study exhibited significantly suppressed REE adjusted for fat-free mass and a lower REE:pREE. REE:pREE is often used in published reports of energy-deficient women with anorexia nervosa, for whom a ratio of 0.60–0.80 is often observed (Konrad, Carels, & Garner, 2007; Melchior, Rigaud, Rozen, Malon, & Apfelbaum, 1989; Polito et al., 2000). It is notable that we have previously reported an REE:pREE of 0.86 ± 0.03, which met our operational definition of an energy deficiency (REE:pREE <0.90; De Souza, Hontscharuk, et al., 2007; De Souza et al., 2008).

Physiological evidence of an energy deficiency in exercising women can be demonstrated by a disruption in energetic and endocrine homeostasis, which triggers a reduction in REE, and alterations in fasting hormone concentrations, including reduced tri-iodothyronine (TT_3) and elevated ghrelin concentrations (Danforth & Burger, 1989; De Souza, Hontscharuk, et al., 2007; De Souza, Lee, et al., 2007). These energetic adaptations act as energy-conserving mechanisms translating effects to metabolism (De Souza, Hontscharuk, et al., 2007; De Souza, Lee, et al., 2007) and reproduction. As such, menstrual disturbances are often observed in energy-deficient exercising women, and, therefore, we hypothesized that these menstrual disturbances may be associated with a high DT (De Souza, Hontscharuk, et al., 2007; O'Connor, Lewis, & Kirchner, 1995; Vescovi, Scheid, Hontscharuk, & De Souza, 2008).

The purpose of this study was twofold: to confirm a high DT score as an indicator of energy deficiency in a larger population of exercising women (n = 117) than in our previous publication and to compare the distribution of menstrual disturbances in exercising women when categorized as either high or normal DT. We hypothesized that the exercising women with high DT would exhibit signs of energy deficiency (suppressed adjusted REE and REE:pREE <0.90) and thus confirm our previous findings in a larger cohort and that the exercising women with high DT would present with a greater prevalence of severe menstrual disturbances (amenorrhea and oligomenorrhea), as corroborated using measures of luteinizing hormone (LH) and daily urinary estrone-1-glucuronide (E1G) and pregnanediol glucuronide (PdG) metabolites.

Methods

Experimental Design

This was a cross-sectional study comparing exercising women with high DT (n = 27) and exercising women with normal DT (n = 90) with respect to psychometric, energetic, and reproductive characteristics. Volunteers were retrospectively grouped according to their DT scores. Women were considered to be exercising if they were currently participating in 2 or more hr/week of purposeful exercise and had a maximal oxygen uptake (VO_{2max}) ≥40 ml · kg^{-1} · min^{-1} (Saltin & Astrand, 1967). Exercising women (n = 117) with high or normal DT were monitored for one complete menstrual cycle if eumenorrheic (menstruating) or at least one 28-day monitoring period if not regularly menstruating. Energy status was determined by measuring REE and corroborated by serum measurement of TT_3. The reproductive evaluation included a description of menstrual history, confirmation of the presence of an LH peak, and quantification of daily urinary ovarian steroid metabolites E1G and PdG. The current investigation includes data from a cross-sectional study designed to assess cardiovascular status in exercising women and data from the baseline period of a prospective study designed to assess the effects of a 12-month intervention of increased caloric intake on indices of bone health and menstrual status in exercising women with menstrual disturbances versus exercising women with ovulatory cycles.

Volunteers

Eligibility criteria for this study included age 18–35 years; good health as determined by a medical exam; no chronic illness, including hyperprolactinemia and thyroid disease; stable menstrual status over the preceding 3 months; currently participating in 2 or more hr/week of purposeful exercise corroborated by a VO_{2max} ≥40 ml · kg^{-1} · min^{-1}; nonsmoker; not currently dieting and weight stable for the preceding 3 months; not taking any hormonal therapy for at least 6 months; no history or current clinical diagnosis of eating disorders; and no other contraindications that would preclude participation in the study. This study was approved by Institutional Research, and volunteers signed an approved informed-consent document.

Study Time Period

Volunteers completed psychometric measurements of eating attitudes and behaviors. This appointment was followed by an REE test and a fasting blood sample to measure TT_3. Eumenorrheic (menstruating, cycle length 26–35 days) women collected urine samples for one complete menstrual cycle, oligomenorrheic (inconsistent and irregular cycle length of 36–90 days) women collected urine samples for up to 90 days, and amenorrheic (no menses for at least 90 days) women collected urine samples for one 28-day monitoring period. The daily urinary samples permitted the characterization of menstrual status (ovulatory, anovulatory, oligomenorrheic, or amenorrheic).

Group Categorization

Participants were retrospectively grouped according to DT score and categorized into one of two groups: exercising women with high DT (n = 27) or exercising women with normal DT (n = 90).

Anthropometric Data

Total body mass was measured to the nearest 0.1 kg on at least two occasions (within a 4-week period), and the mean of these measurements is presented. Participants were expected to stay within ±2.5 kg of their first body-mass measurement and were weighed in shorts and a T-shirt. Height was measured to the nearest 1.0 cm. Body-mass index (BMI) was calculated as the average body mass divided by height squared (kg/m^2). Body composition was assessed using dual-energy X-ray absorptiometry in a total of 99 subjects. It is notable that we did not standardize for time of day or food and fluid intake for the measurement of body mass and body composition. Subjects were scanned on either a GE Lunar Prodigy (n = 76, enCORE 2002 software version 6.50.069) or a GE Lunar iDXA (n = 23, enCORE 2008 software version 12.10.113). Consistent with International Society of Clinical Densitometry guidelines, a cross-calibration study was performed to remove systematic bias between the systems. Fourteen participants were scanned in triplicate on both machines. The values were highly correlated, with no significant difference between the population mean values. Biases in the total bone-mineral density, total bone-mineral content, total fat, and percentage fat relative to the magnitude of the variable were observed. Equations were derived using simple linear regression to remove these biases and report the Prodigy values calibrated to the iDXA.

REE

REE was measured on a single occasion during the study. It was determined by methods previously published in detail (De Souza et al., 2008). The pREE (kJ/day) was calculated using the Harris-Benedict equation (Harris & Benedict, 1919). A ratio of the measured REE in the laboratory to pREE (REE:pREE) was calculated.

Dietary Energy Intake

Dietary energy intake was assessed on two occasions during the study from 3-day nutritional logs recorded for 2 weekdays and 1 weekend day, as previously described (De Souza, Hontscharuk, et al., 2007). Three-day nutritional logs recording food intake have been demonstrated to provide data comparable to 7-day records in women who may underreport their food intake, including lean women (Goris & Westerterp, 1999). Daily dietary energy intake (kJ/day) over the 3-day recording periods was expressed as the mean value during the study. It is notable that some participants (n = 18) completed only one diet record.

Exercise Logs

Volunteers kept logs of their purposeful exercise for at least two separate 7-day intervals during the study. These logs provided a measurement of exercise volume (min/week).

VO_{2max}

VO_{2max} was measured on a single occasion during the study using methods that have been previously published (De Souza, Hontscharuk, et al., 2007).

DT Score

DT score was obtained from the EDI-2 (Garner & Olmsted, 1991), which was completed once during the study. A normal DT score was defined as less than 7. About 75% of college-age women have scores less than 7 (Garner & Olmsted, 1991). In the current study, a high DT score was defined as 7 or greater or when the scores on the EDI-2 indicated a "fake profile," a strategy identified by O'Connor et al. (1995) that demonstrated a qualitative description of low scores on all the EDI-2 subscales with the exception of a high score on the perfectionism subscale. We have modified this strategy herein to provide more specific criteria (Figure 1). The presence of a fake profile was determined when the DT and body-dissatisfaction scores were ≤3 and the bulimia score was ≤1 with a concomitant high score (≥9) on the perfectionism subscale. This strategy was intended to account for response bias. Women with fake profiles (n = 8) were grouped with the high-DT women, and their

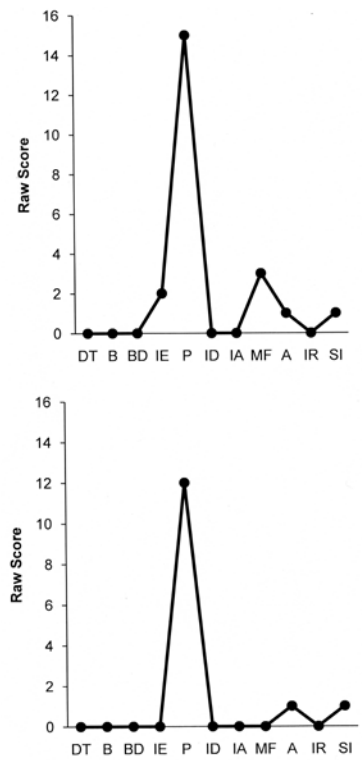

Figure 1 — Graphical representation of a "fake" profile in two subjects in the high-drive-for-thinness (DT) group. B = bulimia; BD = body dissatisfaction; IE = ineffectiveness; P = perfectionism; ID = interpersonal distrust; IA = interoreceptive awareness; MF = maturity fears; A = asceticism; IR = impulse regulation; SI = social insecurity.

scores were adjusted to reflect the mean DT score of the high-DT group. Figure 1 depicts an example of a typical fake profile we observed. Athletes with subclinical eating disorders have been shown to have elevated scores on the DT, bulimia, and body-dissatisfaction subscales (Garner & Olmsted, 1991). Thus, low scores on these three subscales were considered, along with a high perfectionism score, paramount indicators of a fake profile.

The rationale for the cutoff of ≥7 on the DT subscale was based on our previous publication (De Souza, Hontscharuk, et al., 2007). Other corroborative data included data from Ramacciotti et al. (2002), who defined a high DT score as ≥7. Torstveit and Sundgot-Borgen (2005) suggested using a DT score of ≥15 to classify athletes at risk for the female athlete triad; however, we believe that a score that high is likely associated with clinical pathology, and our focus was on identifying indications of subclinical disordered eating. Thus, to capture indications of subclinical disordered eating, we chose a cutoff on the DT subscale of 7.

Exercise Status

Volunteers were required to participate in 2 or more hr/week of purposeful exercise as documented in the exercise logs during the study and from exercise history review. We also used a VO_{2max} of <40 ml · kg^{-1} · min^{-1} to reflect sedentary status and ≥40 ml · kg^{-1} · min^{-1} to reflect exercising status consistent with other reports (Saltin & Astrand, 1967).

Energy Status

Energy status was defined using an objective laboratory-based measure, REE, to identify individuals who experience energetic adaptations to an energy deficiency (De Souza, Lee, et al., 2007; De Souza et al., 2008; Myburgh, Berman, Novick, Noakes, & Lambert, 1999). Reductions in REE have been observed in several studies examining exercising women who present with amenorrhea (De Souza et al., 2008). We compared laboratory-assessed REE with a prediction equation for REE to estimate how much each individual's measured REE deviated from the pREE. In women with anorexia nervosa (Konrad et al., 2007; Melchior et al., 1989; Polito et al., 2000), most data published used the Harris-Benedict equation (Harris & Benedict, 1919) to predict REE, and, as such, we determined that this equation was most useful for our purposes. A previous study by our laboratory group provided our reasoning for using the Harris-Benedict equation over the Cunningham equation (De Souza et al., 2008). In brief, it has been shown during periods of low body weight, and before refeeding in anorexic women (Konrad et al., 2007; Melchior et al., 1989; Polito et al., 2000), that a reduced ratio of measured REE to Harris-Benedict-predicted REE (Harris & Benedict, 1919) of 0.60–0.80 is often reported. The Cunningham equation has not been used in anorexic women. We have previously published data using operationally defined energy deficiency as an REE:pREE less than 0.90 (De Souza, Hontscharuk, et al., 2007; De Souza, Lee, et al., 2007; De Souza et al., 2008). We chose to use this REE:pREE cutoff (<0.90) in the current study as our operational definition of energy deficiency to best discriminate the exercising women who may present with an energy deficiency from those who are energy replete.

Three-Factor Eating Questionnaire

The Three-Factor Eating Questionnaire is a questionnaire that measures three dimensions of human eating behavior: dietary cognitive restraint, disinhibition, and hunger (Stunkard & Messick, 1985). This questionnaire was administered once during the study, primarily to identify restrictive eating behaviors.

Blood Sampling and Storage

Blood samples were collected between 7:30 and 10 a.m. on a single occasion, stored, and processed as previously described (De Souza, Hontscharuk, et al., 2007).

Serum Hormone Measurements

TT_3 concentration was analyzed as previously described (Souza, Hontscharuk, et al., 2007).

Menstrual Status

Menstrual history was determined in all subjects and defined as the number of self-reported menstrual cycles in the past 3 months. Menstrual status was abnormal or severe if a volunteer was amenorrheic (reported no menses for the past 3 months), oligomenorrheic (reported irregular menses at intervals of 36–90 days), or normal or regular, if a volunteer was eumenorrheic (reported regular menses at intervals of 26–35 days).

Self-reported menstrual status was then confirmed prospectively by classifying menstrual cycles by length of the intermenstrual interval, length of follicular and luteal phases, presence of menses, and ovulatory status (ovulatory or anovulatory) as described in previous publications from our laboratory (De Souza et al., 1998; De Souza et al., 2010). These determinations were made from the measurement of daily urinary E1G and PdG, as previously described (De Souza et al., 1998; De Souza et al., 2010). Eumenorrheic women collected daily urine samples for one menstrual cycle, oligomenorrheic women for no more than 90 days, and amenorrheic women for one 28-day monitoring period.

To determine estrogen and progesterone exposure, E1G and PdG urinary metabolites were compared among groups of menstrual cycles using the trapezoidal integrated area under the curve and mean levels of E1G and PdG during the follicular and luteal phases and across the entire cycle. Values from each repeated cycle or monitoring period were averaged. Composite graphs of menstrual cycles depicted by daily E1G and PdG concentrations were determined by taking the

mean values from each repeated cycle or monitoring period. For graphing purposes, the E1G and PdG data for eumenorrheic, ovulatory women were aligned by the day of the LH peak, defined as Day 0. The amenorrheic, oligomenorrheic, and anovulatory participants' E1G and PdG data were aligned by chronological day of urinary collections. Both the high-DT and normal-DT group included oligomenorrheic, amenorrheic, anovulatory, and eumenorrheic, ovulatory women. The first days of the cycles of anovulatory, oligomenorrheic, and amenorrheic women were aligned with Day –17 of the cycles from the eumenorrheic, ovulatory women as per our previous publication (Vescovi et al., 2008).

Statistical Analysis

All data sets were tested for nonnormality, homogeneity of variance, and outliers before statistical hypothesis tests were performed. Data were expressed as $M \pm SD$. Because the TT_3 concentrations were not normally distributed, a logarithmic conversion of them was used to normalize the data. Clinical characteristics (i.e., age, height, body mass, BMI, body composition, VO_{2max}, exercise volume, age of menarche, gynecological age) and data for all psychometric, energetic, and reproductive characteristics were compared among the groups using an independent Student's *t* test. In addition, chi-square analyses were performed as a cross-tabulation between (a) DT score and energy status to determine the association between a high DT score and our operational definition of an energy deficiency and (b) DT score and menstrual status to compare the distribution of menstrual disturbances in exercising women when categorized as high versus normal DT. All data were analyzed using the SPSS for Windows (version 16.0, Chicago, IL) statistical software package.

Results

Clinical Characteristics

The clinical characteristics of the volunteers are presented in Table 1. Age, gynecological age, age of menarche, height, body mass, and BMI were similar ($p > .05$) between the high-DT and normal-DT groups. Body composition was also similar ($p > .05$) between groups. All the women in this study were considered to be of above average physical fitness by American College of Sports Medicine (2006) classification. They exhibited an exercise volume greater than or equal to 120 min/week and a VO_{2max} of ~46 ml · kg^{-1} · min^{-1}.

DT Score and Energy Status

A chi-square analysis of DT score and energy status demonstrated that significantly more cases of energy deficiency were observed in women with high DT than in women with normal DT ($\chi^2 = 5.119$, $p = .024$).

Psychometric Parameters

The psychometric profile data of the volunteers are presented in Table 2. By study design, DT scores were higher ($p < .001$) in the high-DT group than in the normal-DT group. Scores on the EDI-2 subscales for bulimia ($p = .007$), body dissatisfaction ($p = .009$), ineffectiveness ($p = .002$), and interoceptive awareness ($p = .023$) were also higher in the high-DT group than the normal-DT group. The high-DT group exhibited significantly higher scores on the perfectionism subscale ($p = .002$) than the normal-DT group. The groups were similar ($p > .05$) on all the other EDI subscales including interpersonal distrust, asceticism, maturity fears, social insecurity, and impulse regulation. In addition, the high-DT group had

Table 1 Clinical Characteristics of the Exercising Women Grouped by Drive-for-Thinness (DT) Score, *M* ± *SD*

	Normal DT (*n* = 90)	High DT (*n* = 27)	*p*
Anthropometric characteristics			
age (years)	23.1 ± 4.3	22.3 ± 4.1	.355
height (cm)	165.9 ± 5.7	164.5 ± 5.8	.283
body mass (kg)	58.5 ± 5.8	57.0 ± 5.2	.210
body-mass index (kg/m^2)	21.3 ± 1.9	21.0 ± 1.5	.546
body fat (%)[a]	25.2 ± 4.5	26.5 ± 4.9	.269
fat mass (kg)[a]	14.9 ± 3.4	15.4 ± 3.6	.591
lean body mass (kg)[a]	42.0 ± 4.5	40.5 ± 4.1	.176
Exercise status			
exercise volume (min/week)	385.4 ± 236.2	439.1 ± 289.8	.376
VO_{2max} (ml · kg^{-1} · min^{-1})	46.7 ± 6.9	44.8 ± 6.3	.303

Note. VO_{2max} = maximal aerobic uptake. High DT score ≥ 7; normal DT score < 7.

[a]Subset of the population with body-composition data High DT (*n* = 20) vs. Normal DT (*n* = 79).

Table 2 Psychometric Data of the Exercising Women Grouped by Drive-for-Thinness (DT) Score, *M* ± *SD*

	Normal DT (*n* = 90)	High DT (*n* = 27)	*p*
EDI-2			
drive for thinness	1.2 ±1.8	10.7 ± 3.3[a]	<.001
bulimia	0.3 ± 1.0	1.6 ± 2.3[a]	.007
body dissatisfaction	4.0 ± 4.5	8.3 ± 7.8[a]	.009
ineffectiveness	0.7 ± 1.5	3.5 ± 4.3[a]	.002
perfectionism	5.9 ± 3.5	8.4 ± 3.7[a]	.002
interpersonal distrust	1.6 ± 2.5	3.4 ± 4.4	.057
interoceptive awareness	1.2 ± 2.3	3.1 ± 4.0[a]	.023
maturity fears	2.2 ± 2.5	2.9 ± 3.2	.077
asceticism	2.8 ± 1.9	3.7 ± 2.2	.246
social insecurity	1.6 ± 2.1	3.0 ± 3.0	.052
impulse regulation	1.0 ± 2.1	1.3 ± 2.4	.653
TFEQ			
disinhibition	5.1 ± 3.2	7.1 ± 3.4[a]	.004
hunger	5.8 ± 2.9	6.5 ± 2.9	.236
cognitive restraint	8.1 ± 4.5	13.9 ± 5.0[a]	<.001

Note. EDI-2 = Eating Disorder Inventory-2; TFEQ = Three-Factor Eating Questionnaire. High DT score ≥ 7; normal DT score < 7.

[a]High-DT group vs. normal-DT group ($p < .05$; independent *t* test).

higher scores for dietary cognitive restraint ($p < .001$) and disinhibition ($p = .004$) than the normal-DT group. However, the groups had similar hunger scores ($p > .05$).

Energy Status and Metabolic Hormones

Energy-status data are presented in Figure 2. REE, expressed as kJ/day ($p < .001$), and REE, expressed as REE:pREE ($p < .001$), were both lower in the women with high DT than in those with normal DT (Figure 2[A]). Adjusted REE, expressed as kJ/kg lean body mass, was lower ($p = .027$) in the high-DT group than our normal-DT group (Figure 2[B]). Daily dietary energy intake was significantly lower ($p = .014$) in the high-DT group than the normal-DT group (Figure 2[C]). To corroborate the relationship between energy status (REE) and a hormonal marker of energy status (TT_3), correlation analyses were performed, and log TT_3 concentrations were positively correlated with REE expressed as a ratio of REE to pREE ($r = .201$, $p = .030$). Log TT_3 concentrations also demonstrated significant positive correlations with REE ($r = .210$, $p = .023$) and adjusted REE ($r = .295$, $p = .003$). They were significantly lower ($p = .043$) in the energy-deficient group than in the energy-replete group.

Menstrual Status

Quantification of daily E1G and PdG metabolites and measurements of LH were completed in 102 volunteers. Certain volunteers with high DT ($n = 4$) and normal DT ($n = 11$) had incomplete daily urinary collection and were excluded from these particular analyses. Significantly more women with high DT, 73.9% (17/23), were categorized as having a severe menstrual disturbance (amenorrhea or oligomenorrhea) than women with normal DT, 38.0% (30/79; $\chi^2 = 9.260$, $p = .002$). Among the women in the high-DT group, 52.2% (12/23) and 21.7% (5/23) were amenorrheic or oligomenorrheic, respectively, and 26.1% (6/23) were eumenorrheic, whereas among the women in the normal-DT group, 26.6% (21/79) and 11.4% (9/79) were amenorrheic or oligomenorrheic, respectively, and 62.0% (49/79) were eumenorrheic. The prevalence of amenorrhea was significantly greater ($\chi^2 = 5.331$, $p = .021$) in the high-DT group than the normal-DT group. The prevalence of oligomenorrhea was similar between groups ($\chi^2 = 1.610$, $p = .204$). When the eumenorrheic cycles were further categorized by ovulatory status, there was a greater prevalence of eumenorrheic and ovulatory cycles in the normal-DT group ($\chi^2 = 7.080$, $p = .008$), 54.4% (43/79), than in the high-DT group, 21.7% (5/23). A high DT score did not discriminate individuals who displayed anovulatory cycles specifically, and there was no statistically significant difference between groups ($\chi^2 = 0.294$, $p = .588$). Figure 3 illustrates these rates of prevalence in both groups. Figure 4 demonstrates the composite graphs of the daily urinary reproductive excretion in exercising women when categorized as high versus normal DT. There were no statistical differences

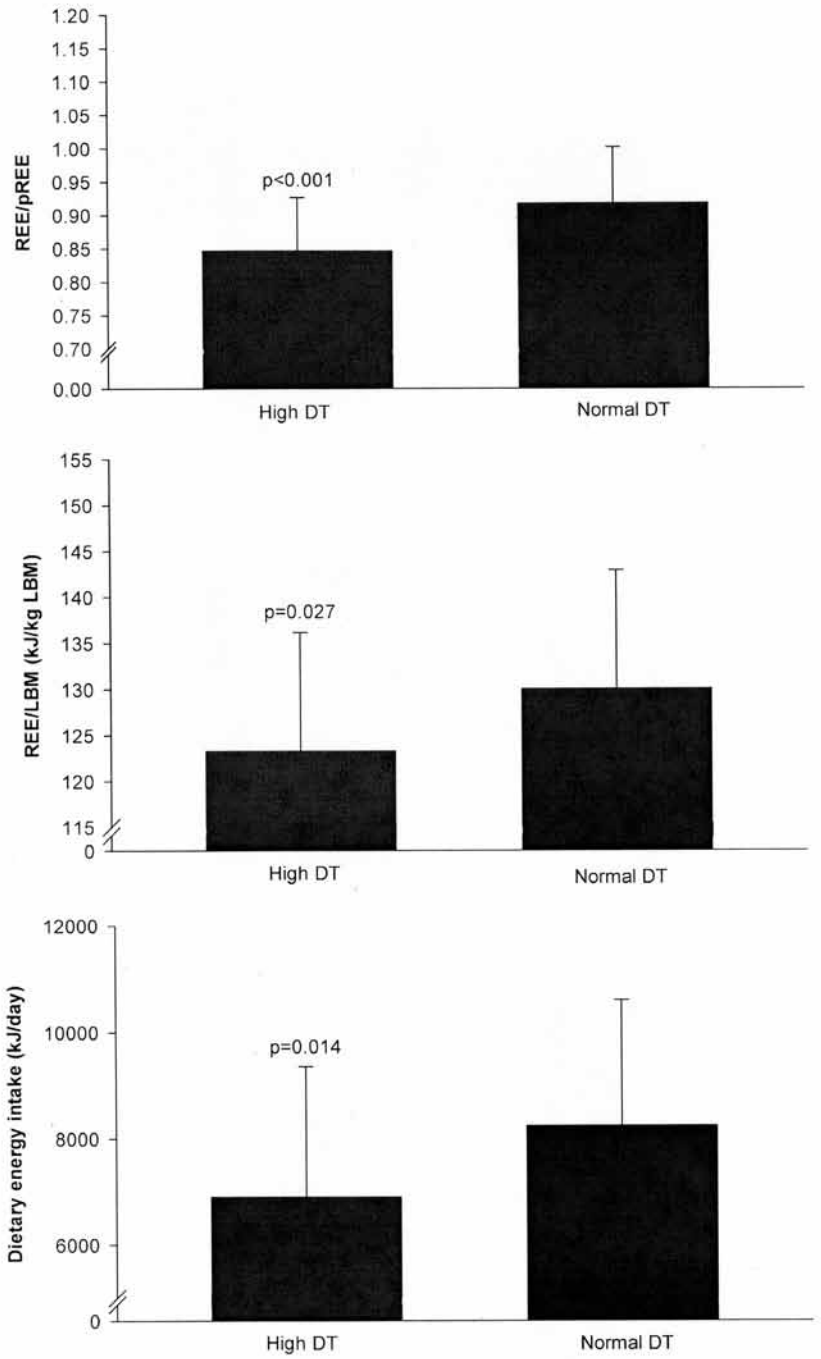

Figure 2 — Data for energy status and dietary energy intake in high- and normal-drive-for-thinness (DT) groups. (A) Ratio of measured to predicted resting energy expenditure (REE). (B) REE (kJ/day) adjusted for kilograms lean body mass (LBM). (C) Daily dietary energy intake (kJ/day). Dietary energy intake conversion kcal × 4.186 = kJ. REE conversion kcal × 4.186 = kJ. Data are expressed as $M \pm SD$, except Panel C ($M \pm SEM$).

observed between groups with respect to menstrual-cycle parameters or daily ovarian steroid excretion (Table 3).

Correlations

Pearson's correlation analyses demonstrated significant negative correlations between DT score and REE parameters: REE ($r = -.285$, $p = .002$), adjusted REE ($r = -.205$, $p = .041$), and REE:pREE ($r = -.290$, $p = .002$). In addition, DT score was inversely related to menstrual history, more specifically the number of menses self-reported in the 3 months before participation in this study ($r = -.268$, $p = .004$), and to dietary energy intake ($r =$

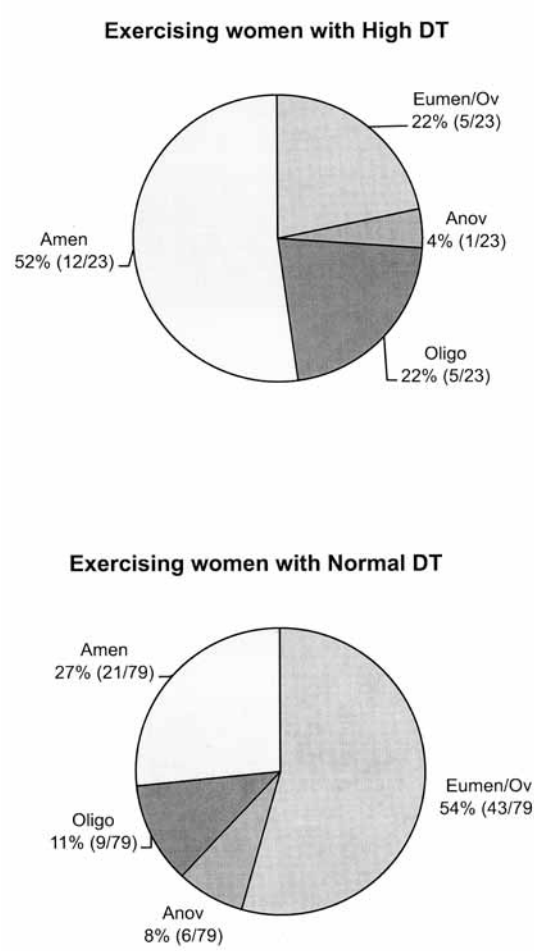

Figure 3 — Prevalence of menstrual disturbances among exercising women grouped by drive for thinness using daily hormone measures of estrogen and progesterone metabolites. Amen = amenorrheic cycle; Eumen = eumenorrheic cycle; Ov = ovulatory cycle; Anov = anovulatory; Oligo = oligomenorrheic cycle.

–.231, $p = .013$). DT score and dietary cognitive restraint exhibited a significant positive correlation ($r = .542$, $p < .001$). From a psychometric standpoint, DT score was correlated positively with perfectionism score ($r = .322$ $p < .001$), indicating how these psychometric measures are coupled and corroborating the strategy to account for "fake" profiles.

Discussion

In the current study, we compared 117 exercising women with high DT (scores ≥7) and normal DT (scores < 7) who displayed a range of psychometric, energetic, and reproductive characteristics. We report that a high DT is associated with energy deficiency in exercising women when energy deficiency was identified using a ratio of actual to predicted REE (REE:pREE), confirming our previous publication (De Souza, Hontscharuk, et al., 2007). We also demonstrated that a high DT was associated with suppressed reproductive function, as corroborated by daily urinary E1G and PdG metabolites. There was a significantly greater prevalence of severe menstrual disturbances among women with high DT than in women with normal DT (74% vs. 38%). Based on these results, a high DT score may provide valuable information to coaches, athletic trainers, and health practitioners trying to get an indication of energy and menstrual status in large groups of exercising women when direct assessment is not feasible.

In exercising women with high DT, the average REE:pREE was 0.85, which is below 0.90, our operational cutoff for an energy deficiency (De Souza, Hontscharuk, et al., 2007; De Souza et al., 2008; Myburgh et al., 1999). REE:pREE was significantly associated with TT_3, such that the lower the ratio, the lower the circulating concentration of this metabolic hormone. This observation is not surprising, because earlier reports from our laboratory (De Souza, Hontscharuk, et al., 2007) have confirmed an association between low TT_3 and adaptive changes in energy expenditure. Low circulating TT_3 concentrations contribute to energy conservation typically observed in undernourished or energy-deficient individuals (Onur et al., 2005). In the current study, TT_3 concentrations were clearly related to REE.

To date, this is the first study to compare ovarian steroid profiles of exercising women with high DT with those of exercising women with normal DT. Our findings support the notion that a high DT may successfully identify severe menstrual disturbances, given the high prevalence of oligomenorrhea and amenorrhea in the high-DT group (74%). Because of the inaccuracy of self-reported menstrual status and retrospective menstrual history questionnaires (De Souza et al., 1998; De Souza et al., 2010), these findings are undoubtedly important because menstrual status was objectively characterized by urinary measures of LH, E1G, and PdG metabolites, and clear qualitative differences were observed in the hormonal profiles between our groups. Reproductive profiles of the normal-DT group were indicative of ovulation and luteinization. In contrast, the high-DT group displayed chronically suppressed levels of E1G and PdG. These qualitative ovarian profiles coincide appropriately with the significant differences observed in menstrual-status classifications (ovulatory vs. amenorrheic) and energy-status classifications (deficient vs. replete).

Our findings also confirm that a high DT is associated with dietary cognitive restraint and menstrual disturbances, a finding we and others have previously reported (De Souza, Hontscharuk, et al., 2007; McLean, Barr, & Prior, 2001; Vescovi et al., 2008). We also report that our women with high DT had significantly lower daily dietary energy intake than those with normal DT. However, it is notable that underreporting of energy intake is often suspected in exercising women (Beidleman, Puhl, & De Souza, 1995; Edwards, Lindeman, Mikesky, & Stager, 1993), and it is possible that women with high DT may be particularly susceptible to underreporting. It

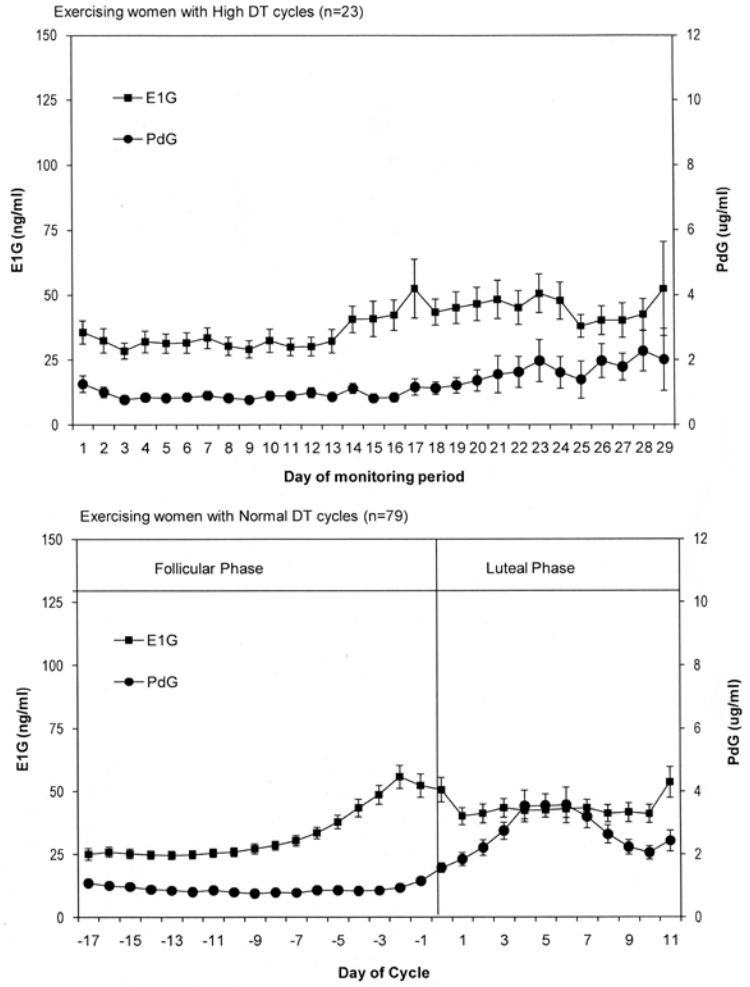

Figure 4 — Composite graphs of daily urinary reproductive excretion in exercising women categorized as high or normal drive for thinness (DT). (A) Mean daily E1G and PdG concentrations of exercising women with high DT (n = 23) categorized as having eumenorrheic, ovulatory; anovulatory; oligomenorrheic; or amenorrheic cycles. (B) Mean daily E1G and PdG concentrations of exercising women with normal DT (n = 79). E1G = estrone-1-glucuronide; PdG = pregnanediol glucuronide. Data are expressed as $M \pm SEM$.

Table 3 Reproductive Profiles of the Exercising Women Grouped by Drive-for-Thinness (DT) Score, *M* ± *SD*

	Normal DT (n = 90)	High DT (n = 27)	p
Menstrual-cycle characteristics			
age of menarche (years)	12.9 ± 1.4	13.0 ± 1.6	.707
gynecological age (years)	10.2 ± 4.5	9.2 ± 4.8	.337
cycle length (days)	31.4 ± 6.7	32.3 ± 4.5	.702
duration of amenorrhea (days)	77.5 ± 15.9	143.5 ± 31.3	.060
Daily ovarian steroid excretion[a]			
E1G-cycle AUC	1,110.2 ± 649.0	1,094.6 ± 624.6	.919
E1G days 2–5 AUC	100.0 ± 55.0	120.7 ± 63.4	.129
E1G days 2–12 AUC	298.1 ± 158.3	334.5 ± 166.5	.340
PdG-cycle AUC	48.1 ± 32.6	40.3 ± 35.4	.482

Note. E1G = estrone-1-glucuronide; AUC = area under the curve: PdG = pregnanediol glucuronide. High DT score ≥ 7; normal DT score < 7.

[a]Subset of the population with daily ovarian steroid excretion data, high DT (n = 23) vs. normal DT (n = 79).

is also possible that self-reported physical activity was not a sensitive measure capable of detecting differences in exercise energy expenditure. We are therefore unable to conclude whether the energy deficit observed in the exercising women with high DT was attributable to differences in restrictive eating or exercise energy expenditure.

Our study is not without limitations. One limitation of using the DT subscale is that some women may present with "fake profiles." We chose to adopt the definition of fake profiles first described by O'Connor et al. (1995) to effectively identify exercising women who may distort their answers. Those authors provided a systematic approach for identifying a fake profile. The perfectionism score is rarely high in the presence of normal eating attitudes and behavior (O'Connor et al., 1995). Based on these findings, our approach was to define more specific criteria than that proposed by O'Connor et al. and to provide a useful operational definition of a fake profile. The mean perfectionism scores observed in exercising women were variable, ranging from 3 to 9 (Garner & Olmsted, 1991; O'Connor et al., 1995). We chose to define a high perfectionism score as ≥9 to rigidly reflect the eating pathology motivating these subclinical disordered eating attitudes and behavior that may result in risk or the presence of an energy deficiency.

In conclusion, the current study confirms the findings of a previous publication (De Souza, Hontscharuk, et al., 2007) that a high DT score is reflective of surrogate markers of energy deficiency in a large population of exercising women (De Souza, Hontscharuk, et al., 2007). In addition, a greater prevalence of severe menstrual disturbances (amenorrhea or oligomenorrhea) was observed in exercising women with high DT, whereas a greater prevalence of eumenorrheic ovulatory cycles was observed in exercising women with normal DT. Therefore, a high DT score may provide useful information to coaches, athletic trainers, and health practitioners assessing energy and menstrual status in a large group of exercising women.

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