

FEMALE ATHLETE TRIAD – PROBABLE BUT DIFFICULT TO CONFIRM IN FEMALE ICE HOCKEY PLAYERS

Patricia K. DOYLE-BAKER^{1,2}, Leanne MCLEAN¹, Tak FUNG³

¹ University of Calgary, Faculty of Kinesiology, Human Performance Lab

² University of Calgary, Faculty of Environmental Design

³ University of Calgary, Research Computing Services, Information Technologies

Corresponding author:

Patricia K. DOYLE-BAKER

Human Performance Lab, Faculty of Kinesiology

University of Calgary, Calgary, Alberta, Canada T2N1N4

Tel.: 011 403 2207034

Email: pdoyleba@ucalgary.ca

ABSTRACT

Female hockey players have high energy expenditure and may enter a negative energy balance (EB) without noticeable body composition changes. Menstrual cycle (MC) and luteal phase (LP) length, EB, and bone mineral density (BMD) were tracked over nine months (mean, SD (\pm)) in 12 ice hockey players (HP; age 21.1 ± 3.4 yrs; height (HT) 165.9 ± 4.6 cm; weight (WT) 64.7 ± 8.1 kg; body fat percent (BF %) 2.8 ± 3.8 %) and 12 non-athlete controls (C; age 21.4 ± 2.8 yrs; HT 169.5 ± 5.5 cm; WT 65.4 ± 5.4 kg; BF % 20.0 ± 3.1 %). HP MC (35.8 ± 11.2 days) was longer than C (29.8 ± 4.3 days) and HP LP (10.1 ± 2.1 days) was also longer than C (9.6 ± 2.8 days). Anovulation occurred in 50.0 % of HP versus 39.2 % of C. No group BMD differences were observed in lumbar spine ($p = 0.9$), hip ($p = 0.5$), and radial ($p = 0.7$) sites. A negative EB was identified (HP = -1026.52 ± 450.1 ; C = -780.00 ± 310.19 kcal / day), yet no significant within-group differences in WT (HP $p = 0.7$; C $p = 0.8$), BF % (HP $p = 0.97$; C $p = 0.6$), or fat free mass (HP $p = 0.6$; C $p = 0.98$) were found over the study duration. Rigorous hockey schedule likely contributed to 28 % completion of the Basal Body Temperature and MC recordings in HP compared to 70 % in C. Both groups entered a state of negative EB, but did not exhibit a BF % change associated with the Female Athlete Triad.

Keywords: *menstrual cycle, female ice hockey players, bone mineral density.*

ŽENSKA ŠPORTNA TRIADA – VERJETNA, A JO JE PRI HOKEJISTKAH TEŽKO DOKAZATI

IZVLEČEK

Za hokejistke je značilna visoka poraba energije, ki lahko vodi do negativnega energijskega ravnovesja (EB) brez opaznih sprememb v telesni sestavi. V obdobju 9 mesecev smo spremljali menstrualni ciklus (MC) in dolžino lutealne faze (LP), EB in mineralno gostoto kosti (BMD) pri 12 hokejistkah (HP; starost $21,1 \pm 3,4$ let; telesna višina (HT) $165,9 \pm 4,6$ cm; telesna masa (WT) $64,7 \pm 8,1$ kg; %telesnih maščob (BF %) $22,8 \pm 3,8$ %) in pri 12 kontrolnih ne-športnikih (C; starost $21,4 \pm 2,8$ let; HT $169,5 \pm 5,5$ cm; WT $65,4 \pm 5,4$ kg, BF % $20,0 \pm 3,1$ %). Pri skupini HP je bil zabeležen daljši MC ($35,8 \pm 11,2$ dni) kot pri C ($29,8 \pm 4,3$ dni) in pri HP je bil LP prav tako daljši ($10,1 \pm 2,1$ dni) kot pri C ($9,6 \pm 2,8$ dni). Pri 50,0 % HP je prišlo do anovulacije, medtem ko pri C le pri 39,2 %. Nismo ugotovili razlik v BMD na lumbarnih vretencih ($p=0,9$), medenici ($p=0,5$) in koželjnici ($p=0,5$). V času izvajanja študije smo zaznali negativno EB (HP $-1026,52 \pm 450,1$ kcal / dan; C $-780,00 \pm 310,19$ kcal / dan), ne pa tudi pomembnih razlik znotraj skupine pri WT (HP $p = 0,7$; C $p = 0,8$), BF % (HP $p = 0,97$; C $p = 0,6$), ali pusti masi (HP $p = 0,6$; C $p = 0,98$). Strog urnik hokejistk je najbrž razlog za zgolj 28 % popolnost njihovih zapisov bazalne temperature in MC, za razliko od 70 % poročanja pri C. Obe skupini sta dosegli negativno EB, ni pa bila vidna sprememba BF % v povezavi z žensko športno triado.

Ključne besede: *menstruacijski ciklus, hokejistke, mineralna gostota kosti*

INTRODUCTION

There has been a dramatic increase in female athletic participation and intense physical activity (PA) in the past 30 years (Chen & Bryzyski, 1999; Highet, 1989; Nattiv, Agostini, Drinkwater, & Yeager, 1994; Prior, Vigna, & McKay, 1992). A growing concern among health care clinicians and practitioners is the potential detrimental effect of long term training on bone mineral density (BMD), which may be preceded by low energy availability (EA) (Olympic Charter, 2011). EA is defined as energy obtained through oral nutrition minus energy expended during exercise. It is reasonable to conclude that low energy may result because of increased energy expenditure (EE), decreased oral intake (either intentional or unintentional), or both (Kishner, 2016). Subsequently, musculoskeletal and reproductive dysfunction from this prolonged energy deficit may occur, inducing the amenorrhoeic condition (International Olympic Committee, 2005; Mountjoy et al., 2014; Nattiv et al., 1994; Otis, Drinkwater, Johnson, & Wilmore, 1997).

BMD decreases with the number of missed menstrual cycles (MC) accumulated over months and years. More specifically, a regular MC with either anovu-

lation (absence of ovulation) or short luteal phase length (SLP) may pose also a risk for bone remodeling, imbalance and bone loss (Seifert-Klauss & Prior 2010). The Female Athlete Triad (Triad) and/or its individual components (decreased EA, menstrual dysfunction, and low BMD) have previously been identified in athletic women (Egan, Reilly, Whyte, Giacomoni, & Cable, 2003; Koehler, Achtzehn, Braun, Mester, & Schaenzer, 2013; Reed, De Souza, & Williams, 2013). All female athletes in any sport regardless of the competition level are at potential risk to develop the Triad. However, those females participating in endurance sports, such as track and field, swimming, and rowing, or in those events requiring subjective judging, such as gymnastics and figure skating, are most at risk (Martinsen & Sundgot-Borgen, 2013). The current risk profile of the Triad includes very little information on female athletes having ‘average body weights and lean body mass’ (LBM), who participate in predominantly team oriented, weight-bearing sports (e.g. ice hockey, field hockey, soccer, basketball, and volleyball). Female athletes in weight bearing sports may also be energy deficit without knowing it and have ovulatory disturbances leading to future bone loss (osteoporosis) or bone weakening (osteopenia).

The sport of ice hockey requires a long-term commitment to skill development and physical fitness which may impact a player’s EE levels. It is possible that over time players may enter a state of negative EB without noticeable body weight change. The prevalence of inadvertent low EA is unknown in female ice hockey players. Therefore, the primary purpose of this study was to describe menstrual disturbances using basal body temperature (BBT) analysis to determine luteal phase (LP) length, and occurrence of anovulatory cycles in a group of female ice hockey players (HP) (17-25 years of age) participating in the Olympic Oval High Performance Training Program (HPTP). Our control (C) group were non-athlete students recruited from the University of Calgary Community. We hypothesized that HP would: (Ho₁) exhibit longer MC, shortened LP (<10 days), with a greater number of anovulatory cycles as indicated by the MC Diary and BBT measurements when compared with C; (Ho₂) be in a state of negative EB in the absence of any change in body composition; and (Ho₃) have greater baseline BMD values at the spine, hip, and radial site compared to C and the population reference standards.

METHODS

Our study took place over 9-months and encompassed the fall and winter university semesters (October to June). Recruitment occurred at the start of the fall semester (September 1999) and the data collection period had a staggered study start; October for HP and November for C. The staggered start was necessary because of scheduling issues and conflicts with booking the Dual Energy X-ray Absorptiometry (DXA) machine.

Volunteers were invited to participate: 1) if HP had a five-year history of hockey specific training and if they committed to four or more 75 minute training sessions per week at the Olympic Oval in Calgary, Alberta, 2) following completion of the

Baecke Questionnaire of Habitual Physical Activity (Baecke, Burema & Frijters, 1982), used to evaluate their physical activity level, and 3) following completion of the Eating Disorder Inventory (EDI-2) questionnaire and screening tool (EDI-SC) to identify predisposition towards disordered eating (Garner, 1991).

Volunteers were excluded if they: (1) had used oral contraceptives during the preceding six months, (2) were smokers, (3) showed predispositions to disordered eating tendencies based on the EDI-2 and EDI-SC results, or (4) were involved in shift work (e.g. night shifts) as this would interfere with the accuracy of BBT methods (Prior, Vigna, Schulzer, Hall, & Bonen, 1990). Of the 38 volunteers, 4 HP and 5 C were excluded due to their use of oral contraceptives, and one HP scored positively for disordered eating tendencies and was referred to counseling.

Data Collection Procedures and Measurement

Participants attended a 2-hour information / education session during their study start week where demographic information, menstrual history and current menstrual status data were collected. A registered dietician provided education on how to correctly complete the 7-day dietary record including accurate recording of dietary intake, serving sizes, calories per serving, and how to read food labels and recall techniques. The participants were given similar detailed information on how to correctly complete the 7-day Activity Record, MC diary, and BBT measurements. During the study, multiple reminders (e.g. follow-up telephone contacts and emails) and assurances of confidentiality were incorporated into the data collection methods to increase response rate and decrease non-sampling errors (Ransdell, 1996).

Menstrual Cycle Length

MC was tracked on a calendar and participants were asked to identify the first day with a phone call to the research coordinator (RC). MC start was defined as the first day of menstrual flow and the final day was defined as the day before the onset of the next menstrual flow. MC length was calculated as the difference between the day before the onset of menstrual flow and the first day of the previous cycle and was calculated as the mean length of each recorded cycle from month 1 through to month 6 of the data collection period.

Basal Body Temperature

Participants were instructed to measure their oral BBT immediately upon waking and before standing using a low-reading digital thermometer read to the nearest 0.05°C. These measurements were recorded in the MC diary and in addition participants re-

corded their subjective observations about late rising, illness, amount of menstrual flow, emotions, and disturbed sleep. Participants also commented on subjective markers of ovulation such as mucous secretion and breast tenderness (Prior et al., 1990; Prior, 1996).

Luteal Phase Length

We chose the mean temperature method (MTM) to predict the onset of LP using pre-established criteria from Vollman (1977). According to Prior et al., (1990) the LP length determined by MTM is comparable to directly measured serum mid-cycle luteinizing hormone (LH) on the peak day ($r = 0.891$).

The temperatures of a given MC were averaged and a corresponding mean line drawn across the graph of the data. The start of the LP was defined as the first temperature to rise above the mean line and remain above for three consecutive days. The end of the LP was defined as the day before the onset of the next menstrual flow (Prior et al., 1990). Temperatures of more than 0.5°C above the mean were discarded as febrile values (Vollman, 1977). SLP was defined as those cycles having LP length < 10 days within a cycle of normal length (Prior et al., 1990).

Anovulation can be determined by a lack of thermal shift in BBT (Vollman, 1977). We designated anovulatory MCs as those cycles having irregular temperature patterns and the absence of a definite LP when a normal MC length of 21 to 36 days was maintained (Personal Communication, J. C. Prior, October 1999). The number of anovulatory cycles was expressed as a percentage of the total number of eligible cycles recorded for the study period.

Total Energy Expenditure (TEE)

EE includes the components of resting energy expenditure (REE), the thermic effect of food (TEF) and the energy expended through PA (EPA). REE is the largest single source of EE and accounts for approximately 50 to 75 % of an individual's TEE (Mahan & Escott-Stump, 1996; Van Zant, 1992). TEE is defined as the energy expended due to resting physiological functions (e.g. ventilation, cardiovascular activity, protein, glycogen, and triglyceride synthesis, and electrical activity within the cells) (Thompson & Manore, 1996).

We employed the Cunningham equation (1980) because of the ability to include fat free mass (FFM) in the calculation for estimated REE: $(\text{kcal} / \text{day}) = 500 + 22 (\text{FFM})$ (McArdle, Katch, & Katch, 1991). Thompson and Manore (1996) compared this equation against directly measured REE and to several predictive REE equations. The REE estimate derived from the Cunningham equation was the only estimate that was not significantly different than the directly measured REE in a study of 24 male and 13 female endurance athletes.

TEE was determined using estimated REE plus EPA and TEF (7 % of REE + EAP) (Personal Communication, K.A. Carter-Erdman, January 2000; Mahan & Escott-Stump, 1996). An estimate of the EPA was derived using the participants' 7-day Activity Records from three time points over the study collection period (October to June). Time 1 for the 7-day Activity Record started on the first day of menstrual flow during the month of October for HP and November for C. Records two and three were collected in similar fashion at two-month intervals. Participants were given instruction on recording daily activity into four 6-hour periods which included: (1) a general description of the activity (e.g. reclining, sitting, standing, walking, running, skating etc.); (2) an estimation of the effort involved (e.g. light, moderate, or vigorous effort); (3) a specific description of the activity performed (e.g. sitting-reading, standing-talking, walking to school etc.); (4) duration in minutes performing each activity; and (5) a check mark designating those activities that were sport-specific. Sport-specific activity was defined in this study as the performance of hockey related training.

Verbal instructions with working examples were given regarding the accurate measurement and recording of activity type, intensity, duration and exercising radial pulse counts. The mean heart rate (HR) during exercise was calculated using HR taken at time 1, 2, and 3 as indicated on the Activity Records. Participants were also asked to record their weight each Monday during the study period. Each Activity Record was collected and evaluated at the end of the 7-day period and illegible and/or questionable entries were confirmed via telephone contact or personal interview.

The accuracy of using Activity Records to estimate TEE is variable, with errors of various methods ranging from 6 to 30 % of actual energy need (Campbell, 1999). To establish the accuracy of several commonly employed methods of determining activity level, Miller, Freedson, and Kline (1994) tested five recording questionnaires against direct measurement of PA using a Caltrac accelerometer. The 7-day PA recall and the Caltrac were the only method that resulted in a significant Spearman rank order correlation coefficient ($r = 0.79$).

EPA was also estimated based on each groups' habitual physical activity patterns and calculated as a percentage of REE: EPA = 75 % of REE for HP and 45 % of REE for C (Heyward, 1997; Mahalko & Johnson, 1980). This method is based on the factorial approach to calculating energy requirements of individuals (World Health Organization, 1985).

Energy Intake

EI was collected at the onset of the first day of menstrual flow from the 7-day dietary record. Diet records, three in total, were also collected at two-month intervals simultaneously with the collection of the 7-day Activity Records. To avoid recall bias, participants were instructed to record dietary intake within 30 minutes of ingestion and they were contacted via phone (RC) to fact-check their intake. A nutrition intern categorized data for entry into "Nutritionist 5.0 – version 1.6" software package (First

Data Bank, San Bruno, CA). Data were analysed to yield daily caloric intake, daily percentages for individual nutrients, and macro and micronutrient intakes.

Energy Balance

EB was calculated as the difference between the mean EI from the 7-day diet record and mean TEE calculated using REE, TEF, and EPA estimated by Heyward's (1997) approach, as stated above.

Bone Mineral Density

Baseline BMD testing of the lumbar spine (L1-L4), femoral neck, and distal radius occurred in week 1 for each group. DXA measurements were completed by a nuclear medicine technician (Hologic QDR2000– rectilinear scanner; Hologic, Inc.). Scan time was approximately 2 to 4 minutes and the coefficient of variation (CV) was better than 1.0 % for spinal measurements and approximately 2 to 3 % for femoral neck measurements (Hologic Manufacturers Inc., [On-line] August 1999; Personal Communication, Dr. R. Kloiber, April 2000). Individual BMD measurements in g/cm² were compared to Hologic QDR 2000 reference standards of mean young adult BMD (T-score: standard deviation from the peak bone mass or young normal values of a female reference population) as well as across the groups (Kanis, Melton, Christiansen, Johnston & Khaltsev, 1994; Maggi, 1993). All reporting of the BMD values (BMD three decimal places; T-scores and Z-scores one decimal place) follow the Recommendations for Bone Mineral Density Reporting in Canada (Siminoski, et al., 2005).

Body Composition

A sport anthropometrist measured participant's height (HT), weight (WT), girths (10 sites), limb dimensions (8 sites), and skinfold thickness (15 sites) at start and end of the study, using a medical scale, Harpenden skinfold caliper, an anthropometer, and steel tape. The equations of Parizkova (1978) and Matiegka (1921) were used to estimate BF %, FFM (kg), and muscle mass percent (LMM %). Body composition in this study included: WT, BF, and FFM.

DATA ANALYSIS

The main outcome was the identification of menstrual disturbances related to MC length (> 36 days oligomenorrhea vs < 21 days polymenorrhea), and SLP (< 10 days), as indicated by the MC diary and BBT measurements. The independent variables were: EI, TEE, EB, body composition, and BMD.

Sample size

Sample size was calculated from the results of a one-year prospective study investigating the proportion of menstrual disturbances in runners, as no available literature on female ice hockey players was found. Thirteen subjects (N = 66) were identified as experiencing menstrual disturbances based on their SLP (≤ 10 days) (Prior et al. 1990). Therefore, a conservative estimate of 20 participants was required to achieve a power of 80 % and an alpha of 0.05 for this study (Brant sample size calculator [On-line], August 1998).

Statistics

Statistical analyses were not performed because of the descriptive nature of the study; partly due to low compliance from HP. We report means (SD (\pm)) and box plots with median values, 25th and 75th percentiles, ranges, and outliers for percent change in WT, BF, FFM, BMD, T-Scores, Z-Scores, EI, TEE, EB, MC length and LP length. Percent change in WT, BF, and FFM were calculated to describe the pre (T1)-post (T2) body composition change (Percent change = [(Time 2 – Time 1)/Time 2]X100).

RESULTS

Three HPs were excluded because they did not provide MC diary data and one HP was excluded from the BMD analysis due to multiple missed appointments. Twelve hockey players (mean, SD (\pm): age = 21.1 \pm 3.4 years; HT = 165.9 \pm 4.6 cm; WT = 64.7 \pm 8.1 kg; BF % 22.8 \pm 3.8) and 12 non-athletes (age = 21.4 \pm 2.8 years; HT = 169.5 \pm 5.5 cm; WT = 65.4 \pm 6.4 kg; BF % 20.0 \pm 3.1) were enrolled in all testing sessions (n = 24). Anthropometric characteristics and exercise patterns for HP and C are listed in Table 1. No differences were observed between groups in anthropometric characteristics at the study start. The HP participated in 10.3 \pm 4.1 as compared to the C 4.4 \pm 1.8 number of exercise sessions per week. The calculated mean HR per exercise session was 151.1 \pm 17.5 bpm and 137.2 \pm 9.7 bpm in the HP and C, respectively. (see Table 1).

Table 1: Mean and standard deviations (SD (\pm)) of Hockey Player and Control group's anthropometric and exercise characteristics.

	Mean, SD	Min	Max
HP (n = 12)			
Fat Free Mass (kg)	49.80 \pm 5.10	41.30	57.40
Muscle Mass (kg)	23.70 \pm 4.30	16.70	31.80
Fat Mass (kg)	14.90 \pm 3.90	10.50	21.60
Body Fat (%)	22.80 \pm 3.80	17.00	29.20
Volume of thigh (cm ³)	9217.90 \pm 1336.70	7477.80	12130.20
Number of exercise / week	10.30 \pm 4.10	5.00	21.00
Exercise duration / session (min.)	73.80 \pm 14.90	60.00	90.00
Heart Rate / Session (bpm)	151.10 \pm 17.50	125.00	175.00
C (n = 12)			
Fat Free Mass (kg)	52.20 \pm 4.00	47.00	59.20
Muscle Mass (kg)	25.60 \pm 3.10	21.40	32.90
Fat Mass (kg)	13.20 \pm 3.10	8.50	18.80
Body Fat (%)	20.00 \pm 3.10	14.90	25.40
Volume of thigh (cm ³)	9185.90 \pm 1011.20	7281.80	10392.80
Number of exercise / week	4.40 \pm 1.80	2.00	9.00
Exercise duration / session (min.)	56.70 \pm 27.80	30.00	120.00
Heart Rate / Session (bpm)	137.18 \pm 9.70	123.00	154.00

The median (25th and 75th percentile) WT percent change over the study duration for the HP and C was: -1.43 % (-2.45 % and 6.38 %) and 0.30 % (0.13 % and 2.53 %), respectively. The median (25th and 75th percentile) BF % percent change for the HP and C was: -4.42 % (-9.18 % and 0.34 %) and 4.73 % (-3.44 % and 9.28 %), respectively. No significant within group mean differences were observed for WT (HP $p = 0.7$; C $p = 0.8$), BF % (HP $p = 0.97$; C $p = 0.6$), and FFM (HP $p = 0.6$; C $p = 0.98$).

Bone Mineral Density

Median values, 25th and 75th percentiles, ranges of the baseline BMD values (g / cm²) T-scores and Z-scores at the lumbar spine (L1-L4), total hip, and distal radius are presented in Table 2. Median lumbar spine and hip BMD were greater in the C (1.059 and 1.07 g / cm²) than in the HP (1.047 and 1.064 g / cm²). HP had one BMD measurement at the hip (1.357 g / cm²) that presented as an outlier (see Figure 1). There were no significant differences in mean lumbar spine, hip, or radial BMD values between the HP and C. However, the maximum value for all BMD measurement sites was greater in the HP.

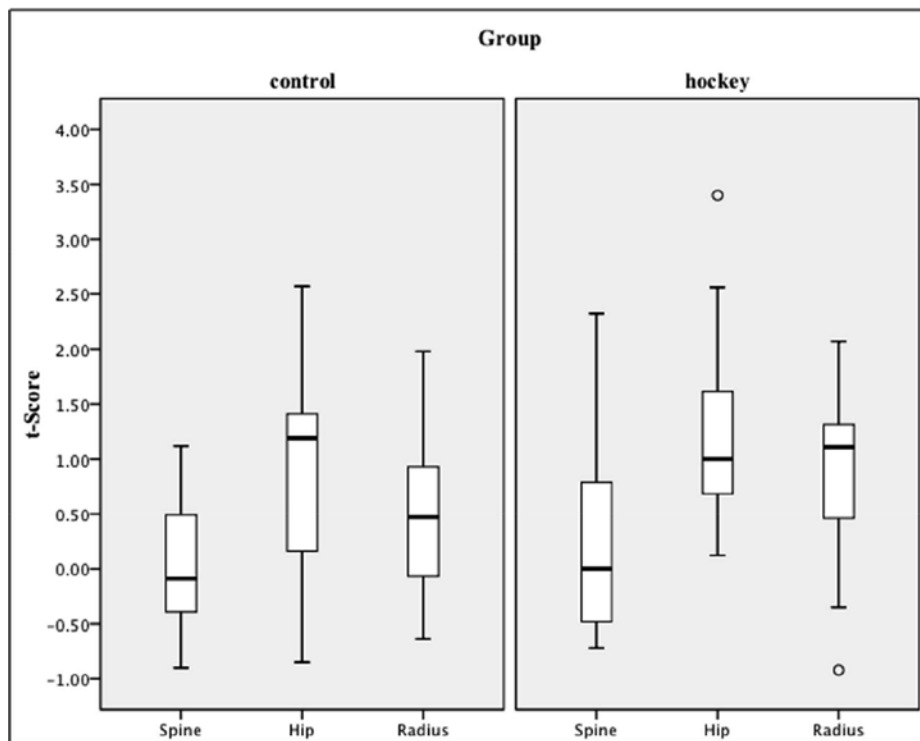
Median lumbar spine and hip T-scores were similar for HP and C. However median distal radius T-score was much larger for the HP (1.1) than C (0.5). The hip T-scores in the HP ranged from 0.1 to 3.4 as compared to a range of -0.9 to 2.6 in the C. The minimum lumbar spine (-0.7) and radial T-score (-0.9) in the HP and minimum T-score values at all sites in the C approached the WHO definition of osteopenia (-1.0 to -2.5). Figure 1 shows a comparison of HP and C T-scores values.

Table 2: Bone mineral baseline values by site and group

	Median	Percentile		Range	Median	Percentile		Range
		25 th	75 th			25 th	75 th	
Hockey (n = 11)					Control (n = 12)			
Lumbar spine L1-L4								
BMD g/cm²	1.047	0.993	1.149	0.968 - 1.273	1.059	1.001	1.112	0.948 - 1.251
T-Score	0.0	-0.5	0.1	-0.7 - 2.3	0.1	-0.4	0.7	-0.9 - 1.9
Z-score	0.2	-0.4	1.1	-0.5 - 2.4	0.2	-0.2	0.9	-0.9 - 2.1
Total Hip								
BMD g/cm²	1.064	1.007	1.116	0.956 - 1.357	1.07	0.982	1.12	0.838 - 1.257
T-Score	1.0	0.5	1.8	0.1 - 3.4	1.0	0.3	1.5	-0.9 - 2.6
Z-score	1.1	0.5	2.6	0.1 - 3.4	1.2	0.5	1.4	-0.9 - 2.6
Distal radius								
BMD g/cm²	0.639	0.602	0.651	0.529 - 0.691	0.606	0.602	0.651	0.545 - 0.686
T-Score	1.1	0.4	1.3	-0.9 - 2.0	0.5	0.5	1.3	-0.6 - 1.9
Z-score	1.3	0.7	1.4	0.5 - 2.0	0.3	0.7	1.4	-0.5 - 1.9

Note: Outlier Total Hip HP 1.357 g/cm²

Figure 1: Baseline BMD T-Scores at three sites for Control and Hockey Players.



Energy Expenditure

Table 3 lists the mean group values of EPA, REE, TEF and TEE for the HP and C. The mean HP-TEE was greater than C-TEE due to the varying contributions of EPA, TEF, and REE. EPA and TEF were greater in the HP than the C. The mean REE was greater for C. Values of EPA, REE, and TEF for both HP and C were verified to be within recommended theoretical percentages of TEE.

The median EI (25th and 75th percentile) values for the HP and C were: 1880.3 (1714.6 and 2080.85) and 1799.2 (1509.1 and 2038.5) kcal / day, respectively (see Table 4). One HP had an average daily energy intake of 1065.6 kcal / day and was represented as an outlier. The median (25th and 75th percentile) TEE for the HP and C groups were 2854.2 (2802.8 and 3080.28) and 2544.01 (2440.08 and 2659.55) kcal / day respectively. The frequency distribution for HP-TEE is left skewed. Daily mean caloric intakes for the HP and C were 11 % (HP -1026.52 ± 450.1 kcal / day) and 15

Table 3: Components of mean (SD (\pm)) Total Daily Energy Expenditure by group

kcal / day	HP n = 12			C n = 12		
	Mean, SD	Min	Max	Mean, SD	Min	Max
EPA	1116.48 \pm 79.30	985.71	1234.42	741.75 \pm 39.50	690.10	810.68
REE	1594.98 \pm 113.30	1408.16	1763.46	1648.33 \pm 87.80	1533.56	1801.52
TEF	189.80 \pm 13.50	167.57	209.85	167.30 \pm 8.90	155.66	182.85
TEE	2901.26 \pm 206.10	2561.44	3207.73	2557.38 \pm 136.1	2379.32	2795.06

Note: Estimated Energy of Physical Activity (EPA), Resting Energy Expenditure (REE), Thermic Effect of Food (TEF) and derived Total Daily Energy Expenditure (TEE)

Table 4. HP and C Mean daily Energy Balance (calculated)

kcal / day	Mean \pm SD	
	Hockey n = 12	Control n = 12
Daily Energy Intake	1882.89 \pm 366.37	1777.31 \pm 328.62
Range	1065 to 2419	1212 to 2219
Total Energy Expenditure	2901.26 \pm 206.1	2557.38 \pm 136.06
Mean Energy Balance	-1018.37 \pm 464.9	-780.07 \pm 310.62

Note: Mean EB per day calculated as the difference between mean daily caloric intake (EI) and estimated total daily energy expenditure (TEE).

% (C -780.00 \pm 310.19 kcal / day) less than that recommended by Health and Welfare Canada (1990) for females aged 16 to 49 years (2100 kcal / day).

There was a small difference of 105.5 kcal / day in daily EI between the HP and C but the number of exercise sessions per week and calculated mean HR per exercise session were also different. Thus, TEE between the HP and C was different and may have contributed to the difference in EB between the groups. Both groups maintained a state of negative EB for the study period as indicated by the mean TEE which exceeded daily caloric intake for both HP and C (see Table 4). The frequency distribution of HP-EB was symmetrical about the median and the median (25th and 75th percentile) was - 984.71 (- 1223.8 and - 767.7) kcal / day. The frequency distribution for C-EB

was right skewed and the median (25th and 75th percentile) was - 681.72 (- 1046.57 and - 595.25) kcal / day. Energy balance remained in a negative state despite corrections for errors (self-report corrected factor ~30 %) in estimating daily EI such that mean corrected EB for the HP and C was -641.8 and -424.6 kcal / day, respectively.

Menstrual Cycle Characteristics

Out of a possible 78 cycles for the HP and 72 cycles for the C, only 22 HP and 51 C cycles were included in the analysis due to incomplete data. The HP and C median (25th and 75th percentile) LP lengths were 9.0 (9 and 11) and 9.4 (8.3 and 10.5) days, respectively. Mean LP length for the C (9.4 ± 1.9) was slightly less than the HP (9.9 ± 1.7) days. Both groups were classified as having SLP (<10 days).

Table 5 indicates that three HP and three C had less than 25 % of eligible cycles defined as anovulatory. Five C and two HP had 25 to 50 % of eligible cycles designated as anovulatory. Two HP and two C had 51 to 75 % of eligible cycles considered anovu-

Table 5. Anovulatory cycle comparison between Hockey Players and Controls

HP ID	Cycle Tally	Cycles	% Anovulatory	C ID	Cycle Tally	Cycles	% Anovulatory
1	1	1	100	13	0	5	0
2	2	5	40	14	3	6	50
3	3	4	75	15	0	5	0
4	2	3	67	16	1	3	33
5	missing	missing	missing	17	4	6	67
6	missing	missing	missing	18	1	3	33
7	0	2	0	19	4	6	67
8	1	3	33	20	2	4	50
9	0	2	0	21	3	3	100
10	missing	missing	missing	22	1	1	100
11	1	1	0	23	1	5	25
12	2	2	100	24	0	5	0
Total	11	22	50%	Total	22	51	43.1%

Note: ID = subject number; cycle tally = number of anovulatory cycles out of total eligible cycles per subject; Cycles = Total number of eligible cycles; Anovulatory = Total anovulatory cycles; Percent = Total percent of anovulatory cycles per group.

latory. Finally, 75 to 100 % of eligible cycles were defined as anovulatory in two C and two HP. Thus, 11 out of 22 or 50 % of the HP eligible cycles were defined as anovulatory. Similarly, 43.1 % or 22 out of 51 C eligible cycles were defined as anovulatory.

DISCUSSION

In this paper, we describe menstrual disturbances across two groups: athletes (HP) and young university aged women (C) through the determination of MC and LP length, and occurrence of anovulatory cycles. Baseline BMD measurements were collected for comparison by group and with population based diagnostic reference standards (T-Scores). Descriptive data on EI, TEE, EB and body composition percent change over a 9-month study period were calculated and summarized.

Bone Mineral Density Measurements

BMD is an important component of bone strength and is considered the best method for diagnosis of osteopenia and osteoporosis. The maximum value for all BMD sites measured was greater in the HP, however, the median lumbar spine and hip values were slightly greater in the C. The median hip T-score may have been larger for the C because of the wider range in hip T-Scores (0.1 to 3.4) in HP when compared to C (–0.9 to 2.6). Surprisingly, the minimum values in HP's lumbar spine and radial T-score and C's lumbar spine, hip and radial T-score all approached the WHO definition of osteopenia. These results contrast with our hypothesis stating baseline BMD values at the spine, hip, and radial site in the HP would be greater than BMD values for population reference standards.

These BMD results are supported by Henderson, Price, Cole, Gutheridge, & Bhagat (1995) who reported normal values for mean BMD at the spine and proximal femur (Caucasian women, 20 to 50 years of age) to be $1.03 \pm 0.113 \text{ g / cm}^2$ and $1.00 \pm 0.114 \text{ g / cm}^2$, respectively. Mean BMD at the radius ($0.69 \pm 0.13 \text{ g / cm}^2$) reported by Faulkner et al. (1996) and Warren et al. (1991) is higher than mean radial BMD value for the HP and C in the current study. In studies of BMD in female runners, Drinkwater et al. (1984) and Rencken, Chesnut, and Drinkwater (1996) observed a significant difference in BMD at the lumbar spine for amenorrheic athletes (1.12 g / cm^2) when compared with matched eumenorrheic controls (1.30 g / cm^2). HP and C BMD at the lumbar spine were less than those reported in the Drinkwater et al. (1984) and Rencken et al. (1996) studies (HP = $1.066 \pm 0.098 \text{ g/cm}^2$; C = $1.069 \pm 0.086 \text{ g / cm}^2$). These comparisons are made with caution as measurement techniques may have been different and there was an mean age difference between our group (HP, 21.1 ± 3.4 ; C, 21.4 ± 2.8 years) and Drinkwater et al. (1984) (amenorrheic athletes 24.9 ± 1.3 years; eumenorrheic athletes 25.5 ± 1.4 years). It is possible that our HP and C may not be at their peak BMD for the lumbar spine due to their younger age (Recker et al., 1992).

Increased BMD in female athletes is reported to be dependent on the pattern of weight bearing activity and this effect is specific to the skeletal region stimulated by the activity. Specifically, increased BMD at the lumbar spine and lower body has been reported in male and female runners and weight lifters whereas increases at the distal radius have been reported for gymnasts and tennis players when compared to sedentary controls (Dalsky, 1990; Kannus, Haapasalo, & Sankelo, 1995; Petit, Prior, & Barr, 1999). Ice hockey players are assumed to experience constant skeletal loading at the hip during the motion of skating and loading of the upper body through the hands and wrists during stick handling. Thus, the research of Dalsky (1990), Kannus, Haapasalo, & Sankelo (1995), and Petit et al. (1999) into the activity specific accrual of bone mineral content would support increased mean BMD at these sites when compared to C. In this study, weight bearing sites specific to ice hockey did not manifest bone mass accrual specific to the activity pattern in the HP group when compared with the C. However, HP₁ (25.2 years old) and HP₉ (20.3 years old) did have T-scores at the hip that were greater than 2.5 SD above the mean peak bone mass or young normal values for population reference standards. HP₉ also had a radial T-score greater than 2 SD above the peak bone mass or young normal values for population reference standards.

Evidence of low bone mass (negative T-score values) was present in both groups: HP (5 lumbar spine -0.4 to -0.7 SD; 2 radial -0.4 and -0.9 SD); and C (6 lumbar spine -0.1 to -1.0; 2 hip -0.2 and -0.9 SD; and 3 radial -0.1 to -0.6 SD). These results raise specific concerns as Johnston and Slemenda (1991) estimate that the risk of fracture increases by 50-100 % for each decrease of 1 SD in BMD. In addition, Riggs et al. (1981) report the 90th percentile for vertebral BMD for patients with nontraumatic vertebral fractures to be 0.965 g / cm². HP₃ (18.1 yrs old) and HP₄ (20.9 yrs old) had mean lumbar spine BMD values of 0.968 g / cm² and 0.972 g / cm², respectively. C₂₃ (29.6 yrs old) had a mean spinal BMD of 0.948 g / cm² which is less than the threshold below which the risk for non-traumatic vertebral fractures increases. Thus, each of these individuals with spinal BMD values nearing the fracture threshold and those having T-score values approaching -1 SD may be at risk for future fracture, indicating the potential need for monitoring and preventative education.

Several contributing variables have been emphasized in studies investigating osteoporosis or low BMD in female athletes. Henderson et al. (1995) suggest that BMD in young women is associated with their weight and muscle strength but not dietary intakes. Rencken et al. (1996) suggests amenorrhea and weight have a significant impact on BMD at the lumbar spine, trochanter, intertrochanteric region, and tibial shaft in amenorrheic, aerobically trained athletes. Further, these researchers recognize age of menarche as a significant predictor of lumbar spine BMD, suggesting that the later the age of menarche, the lower the lumbar spine BMD. Low calcium intakes (< 1000 mg / day), prolonged hypoestrogenism, occurrence of menstrual disturbances (specifically amenorrhea, SLP, and anovulatory cycles), have been recognized to differentially impact skeletal sites leading to low BMD values in female athletes (Drinkwater et al., 1984; Drinkwater, Bruemner, & Chesnut, 1990; Heaney,

1982; Prior et al., 1990; Warren et al., 1991). Although the current study neither attempted to measure circulating estrogen levels nor determine age of menarche, mean reported calcium levels were less than 1000 mg/day in both the HP (870.53 ± 250.99 mg / day) and C (785.33 ± 217.15 mg / day) and may partially contribute to the lack of bone-trophic effect for weight bearing activity (Heaney, 1982).

Nutritional Status, Energy Balance and Body Composition Changes

The identification of caloric restriction or lack of nutrition is important in all athletes because of the effect, both positive and negative, this may have on sport performance and subsequent health. The general perception is that female athletes involved in aesthetic or weight dependent sports, restrict caloric intake and become energy deficient. Although female hockey players do not fit the typical risk profile for the Triad with respect to body composition (e.g. low body weight and low fat mass), they are involved in intense physical training.

Median EI values for the HP and C were 1882.89 ± 366.37 and 1777.31 ± 328.62 kcal / day, respectively. These values are less than our previous EI research with varsity soccer (1850.70 ± 417.40 kcal/day), basketball (2639.50 ± 586.21 kcal/day) and volleyball players (2134.80 ± 286.00 kcal/day) (Doyle-Baker, MacDonald, Hewitt, & Harris, 2000). They are also less than the 2100 kcal / day RNI (Required Nutrient Intake) by Health and Welfare Canada (1990). Jones, Martin, Wanfang, and Boyd (1997) suggest that Health Canada's RNI values for women aged 25 to 49 years (2100 kcal / day) are substantially below the true requirement level of the population age based subgroup. Thus, if the reported daily EI for the HP and C are below the current recommendations by 11 % and 15 %, respectively, this may be the first indication of the inadequacy of dietary caloric intake occurring.

Despite the indications of low caloric intake, it is important to consider that under-reporting due to day to day variation in energy status, the disturbance of normal dietary practices, food recall problems, and errors related to analysing EI or calculating EE using activity records or generalized equations, contributes to a decrease in the accuracy of determining the energy requirement for a population. Specifically, when 7- day diet records were compared to the "gold standard" DLW method of determining EI and EE, errors in estimating EI of up to ± 30 % of actual need have been reported (deVries, Zock, Mensink, & Katan, 1994; Mahalko & Johnson, 1980; Sawaya, Tucker, & Tsay, 1996; Todd, Herdes, & Calloway, 1983). We calculated an error estimate of 20 % of actual energy need reported to determine a closer approximation of the daily caloric intake considering all possible sources of error. The mean corrected daily caloric intake (HP 2259.47; C 2132.77 kcal / day) would increase their totals to the current age specific RNI.

Energy Balance

Long term negative EB (EE exceeds EI) leads to a decrease in utilizable metabolic fuels, disrupted LH pulsatility, and subsequent alterations to thyroid metabolism and basal metabolic rate (Loucks & Heath, 1994; Loucks & Verdun, 1998; Loucks, Verdun, & Heath et al., 1998; Wade, Schneider, & Li, 1996). The “energy availability hypothesis” suggests that the GnRH pulse generator is disrupted by an unidentified signal that dietary intake is inadequate for the energy cost of reproduction and locomotion (Loucks et al., 1998).

On average, HP and C maintained a state of negative EB as indicated by their mean TEE exceeded their daily caloric intake. These results are comparable to those reported by Drinkwater et al. (1984), who reported that EB in a group of amenorrheic athletes was significantly lower than in an eumenorrheic group. In the Drinkwater, et al. (1984) study, EI were not different, but training was significantly more rigorous in the amenorrheic group. In our study, the HP and C were divided by exercise and not based on their menstrual status. There was a small difference of 105.5 kcal / day in daily EI between the groups and the HP had more rigorous training based on the number of exercise sessions per week and calculated mean HRs per exercise session which were different. Thus, TEE between HP and C was different and should have contributed to higher EI in HP and a difference in EB. However, both groups experienced a negative state despite corrections for errors in estimating daily EI; mean corrected EB for the HP and C was -641.80 and -424.60 kcal / day, respectively.

The EB findings are practically important in consideration of the research of Loucks (1996) who suggests that exercise contributes to menstrual disturbances only when the EE is not adequately replenished. This is supported in our study as although the exercise sessions per week and exercise intensity differed between HP and C both experienced similar MC aberrations, possibly because of negative EB. In a series of well controlled studies Loucks and coworkers (Loucks & Heath, 1994; Loucks & Verdun, 1998; Loucks, Verdun & Heath, 1998), suggest energy deficits are associated with significant suppression of triiodothyronine (a regulator of metabolic rate) and disruption of LH pulsatile secretion (a strong indicator of reproductive performance). Further, they suggest that the degree of disruption in LH pulse amplitude and frequency is in direct relation to the duration of energy depletion. Since successful reproductive function requires appropriate hormonal stimulation, individuals experiencing disruptions in LH pulsatility may experience a range of menstrual disturbances including amenorrhea, oligoamenorrhea, SLP, and anovulation. Our results may be suggestive of this phenomena since a state of negative EB was consistently maintained throughout the study and menstrual disturbances in the form of SLP, oligoamenorrhea, and anovulation did occur in both the HP and C.

Body Composition

Even though both the HP and C maintained a state of negative EB for the study period, percent changes in WT, BF, and FFM were very small (HP -1.43% , -4.42% , 0.82% ; C 0.30% , 4.73% , -0.15%) respectively. This finding supports the hypothesis that HP would be in a state of negative energy balance in the absence of any change in body composition.

Menstrual disturbances can occur with or without weight loss (Yen, 1998). The general perception that changes in weight or body composition, specifically BF %, are an impetus to the onset of menstrual disturbances in female athletes has been challenged by several studies that have failed to correlate reproductive function and body composition (DeCree, 1998; l'Anson, Foster, & Foxcroft, 1991; Sanborn, Albrecht, & Wagner, 1987; Sinning & Little, 1987). Specifically, reproductive function has been linked to general availability of metabolic fuels (Loucks & Callister, 1993; Loucks & Heath, 1994; Loucks, Verdun, & Heath, 1998; Wade & Schneider, 1992). The results of the current study may lend support to the work of several researchers investigating the role that EA plays in regulating metabolism and producing a “hypometabolic state” in which available energy is stored or partitioned to only essential functions (Laughlin & Yen, 1996).

DeCree (1998) documented alterations to the thyroid axis in individuals experiencing energy deficits linked to menstrual disturbances. Such alterations lead to reduced BBT and reduced metabolic rate. The athletes in this current study did experience asymptomatic menstrual disturbances in the absence of significant changes in WT, FFM, and BF %. Although, thyroid levels were not measured, these results potentially lend support to future research directed at determining the possible mechanism behind menstrual disturbances, specifically SLP, oligo amenorrhea, and anovulation, and a reduction in metabolic rate leading to maintenance of body composition. Further, the lack of body composition change in this study supports the need to expand the present Triad model (its association with amenorrhea, eating disorders, and loss of weight) to adopt the understanding that menstrual disturbances do occur in active individuals who do not experience the symptomatic changes in body composition associated with amenorrhea in anorexia nervosa.

Menstrual Disturbances

HP and C mean menstrual cycle lengths were similar and were within the defined normal menstrual cycle length of 21–36 days. Maximum MC lengths are suggestive of the occurrence of oligomenorrhea (cycles greater than 36 days) in both groups (Abraham, 1978). Similarly, the minimum MC length are indicative of polymenorrhea (cycles length of less than 21 days) occurring in HP (Abraham, 1978). Mean LP length in days for the C was slightly less than that of the HP, yet both groups are classified as having SLP (< 10 days). These results support the hypothesis that the HP group would

exhibit a longer MC length when compared with C. However, the data do not support the hypotheses that the HP group would exhibit SLP (< 10 days) and a greater number of anovulatory cycles when compared with C.

Luteal function was disturbed in 55 of 150 eligible cycles (sum of all SLP and anovulatory cycles) or in 36.70 % of recorded cycles in the HP and C combined. Specifically, anovulation occurred in 50.00 % of HP and 43.10 % of C cycles. Similar to the study by Prior et al., (1990) disruptions to the LP occurred in both highly active HP (10.30 ± 4.10 sessions / week) and in the recreationally active C (4.40 ± 1.80 sessions / week). Although, Prior et al (1990) did not mention energy status, the HP and C in this study were in a state of negative EB and this may be impacting GnRH responsiveness and LH pulsatility possibly leading to altered menstrual function. The results of this study may support the work of Loucks et al. (1998) who concluded that low EA, not stress of exercise or athletic involvement, alters LH pulsatility in exercising women. Thus, there is a potential that these “apparently healthy” HP and C may be exposed to the detrimental effects of low reproductive hormones without their knowledge.

Limitations

We realize that this study had a large participant burden as our original recruitment at the outset of the study exceeded the sample size calculation. However, the BBT method coupled with keeping a MC diary was time intensive for the HP with only a 28 % completion rate versus 70 % with the C. In addition, differences may be present but obscured due to errors inherent in the estimation of EB and / or because the C were university students and thus not a true “sedentary” control group. While EA did change, the effects on MC may not occur for months, and an effect on BMD may not occur for years (Drinkwater, Nilson, Ott, & Chesnut 1986; Hanley, 1996).

CONCLUSIONS

In conclusion, the prospective, descriptive nature of our study was designed to increase awareness regarding the presence of menstrual disturbances in a select population of female ice hockey players and to potentially highlight the need for intervention in this sub-population of female athletes related to future BMD loss. Despite the errors inherent in indirect measurement of energy status and menstrual cyclicity, the results of our study do add to the literature which now identifies a strong relationship between reproductive endocrinology, EB and BMD. We hypothesized that neither intensity of exercise nor body composition independently would disrupt menstrual function; rather, inadequate dietary replenishing of expended energy leading to long term negative EB would explain the occurrence of menstrual disturbances. Of course, this is well known today, but we did due diligence at the time of the study and contacted several research-

ers to ensure that we were identifying a plausible trend (Personal Communication, D. A., Haney; A. B. Loucks; V. Harber; and J. C. Prior, October 2000).

In 2014, the IOC published a consensus statement: beyond the Female Athlete Triad and introduced a more comprehensive term that employs a multi-disciplinary approach across all athletes. This reframing resulted in a new model renamed, Relative Energy Deficiency in Sport (RED-S), which is caused by energy deficiency relative to the balance between dietary EI and EE (Mountjoy et al., 2014).

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