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Understanding menstrual characteristics from the perspective of reproductive energetics: a study on the adolescent Oraon tribal populations

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ABSTRACT: The energetic costs of ovarian functions rely on the oxidizable fuels synthesized from carbohydrate, protein and fat that contribute to body's fat storage. Energy deficient diet in association with low body fat may disrupt normal ovulatory function and lead to several menstrual irregularities. We examined the association of nutritional status with menstrual characteristics among a group of adolescent Oraon tribal population of West Bengal, India. We selected 301 adolescent girls, aged 10-19 years. Information on socio-demographic status, menstrual characteristics and assessment of the dietary intake and nutritional status were collected following standard protocol. 'Healthy weight' participants more likely reported irregularity in periods and skipping of menstrual cycle and shorter cycle length. Multivariate analysis revealed PBF has inverse association with PMS, duration of discharge and skipping of cycle ($p<0.05$); carbohydrate intake has direct association with duration of menstrual discharge ($p<0.05$); increased dietary fat intake has direct association with skipping of cycle, but not with BMI ($p<0.05$); increase in MUAC has direct association with dysmenorrhoea ($p<0.05$). Conclusion: Our study indicates energy deficiency does alter the menstrual characteristics of the Oraon adolescent girls.

KEY WORDS: Menstrual characteristics, energetics, adolescent, Oraon

Introduction

The energetic costs of normal ovarian function, rely on the ability in saving oxidizable fuels in terms of nutrient transformations of physical, chemical and biological systems (Leonard and Ulijaszek 2002; Torre et al. 2014). Several studies revealed that at the time of physiological imbalance between reproductive needs and metabolism, ovarian function gets suppressed (Ellison 2001; Schneider 2004; Torre et al. 2011; Shapira 2013) as an energy-conserving adaptation (Myerson et al. 1991; Nattiv et al. 1994; Ellison 2003). It has been hypothesized that

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a critical amount of fat, relative to lean body mass is necessary for initiation of menses and maintaining ovulatory function (Bronson and Manning 1991; Reddy et al. 2005; Chavarro et al. 2015). Scholars argue that restricted positive energy balance during adolescent period of growth may result into low Body Mass Index (BMI) (Petridou et al. 1996; Key et al. 2001), which subsequently attributes to the ovarian hormone levels (Kirchengast and Huber 2004; Miller et al. 2004; Ziomkiewicz et al. 2008). Several studies suggest that women with low body fat percentages, owing to poor-calorie intake led to several menstrual irregularities, including short duration of menstrual bleeding, infrequent periods, abnormally painful periods, and even cessation of the cycle (Tena-Sempere 2007; Randhawa et al. 2016; Sherly 2017). Other studies reported a J-shaped relationship between BMI and ovulatory disorders, like painful, irregular and even absence of menstruation (Parimalavalli and Sangeetha 2011; Mukherjee 2014; Jena et al. 2017). A compelling evidence comes from a rural-urban study conducted among the Indian adolescents, where none of the girls with a normal BMI had symptoms of dysmenorrhea compared to those with a very low BMI, suggesting a below optimal functioning of the body (Madhubala & Jyoti 2013). Mukherjee et al. (2014) showed subcutaneous fat deposition and mid upper arm circumference (MUAC) remain significant determinants for irregular menstrual periods, skipping of menstrual cycles and number of days of menstrual discharge among the women athletes. Thus, fat distribution in the body, which is an indicator of energy balance may contribute in describing the menstrual characteristics of a population. Literature also suggests that an energy deficient or low caloric diet in association with low weight and/or low fat mass may disrupt normal ovulatory function (Pirke et al. 1986). The major source of bulk of energy consists of the "nutritional trinity", carbohydrate, protein and fat, which provides energy for body's vital processes and biosynthesis (Hoekstra 1963). Prolonged intake of low-carbohydrate diet may go about as a stressor, creating hypothalamic-pituitary-adrenal (HPA) axis dysfunction, which may encounter sporadic menstrual cycles, hypothalamic amenorrhea or menstrual disorders like premenstrual syndrome (PMS) (Jenkins et al. 2009; Mozaffarian et al. 2011; Roba et al. 2016). For instance, consumption of protein triggers energy metabolism that are under homeostatic controls (Pezeshki et al. 2016). Other studies reported effect of both protein and energy on ovulation rate (Memon et al. 1969 and Howland et al. 1966). For example, Bushman women ovulated only at a certain time of the year when food is plentiful (Vander Walt et al. 1978). In a developing country like India, adolescent girls, especially those belonging to socioeconomically backward community are more likely to be undernoursihed (National Institute of Nutrition 2002; Kaur et al., 2007; Choudhary et al. 2009). Therefore, the present study is an endeavour to examine the association of nutritional status with menstrual characteristics among a group of adolescent Oraon tribal population of West Bengal, India.

Materials and Methods

Study area and participants

The present study was carried out in the Jalpaiguri district of the State of West Bengal, India. The district of Jalpaiguri is situated at the foothills of the Himalaya Mountains. According to the last census report, around 7,31,704 tribal (indigenous) populations reside in this district, making it rank second with respect to the total tribal populations of this state (Jalpaiguri District Census Handbook 2011). The Oraon tribal population stands to be the largest tribal population of this district. The study area covered three *Gram Panchayets* (GPs) (rural administrative units), namely Rungamuttee, Damdim and Bagrakote that fall under Mal community development block of the district. The GPs were selected based on the numerical dominance of Oraon tribal population.

Study participants

The Chotanagpur Plateau of India is the original abode of the Oraons. During the colonial period, the predecessors of this group of Oraons migrated to the district of Jalpaiguri and joined the tea industry as labour force (Bhowmik et al. 1996; Chaudhury and Varma 2002; Ghosh 2014). Presently, around 3, 68,413 Oraon populations live in this district, out of which 3 1,76,929 were women (Census 2011).

We identified 307 adolescent girls [World Health Organizations (WHO) 1989] from the selected GPs, who fulfilled the criteria of our study by a door to door survey. The following were the criteria set for selecting our study participants: aged between 10 and 19 years, but attained menarche at least two years prior to the date of study, not reported to have suffered from any major gynaecological health problems and did not have any experience of sexual intercourse. Out of total 307 individuals, data from six participants could not be collected since two of them did not volunteer to participate at the time of collection of anthropometric data, three of them latter revealed about their sexual relationship and one was dropped for not being able to recall the food items consumed on the day preceding the day of the interview. Finally, data were collected from 301 Oraon adolescent girls.

Methods of data collection

A pre-tested structured schedule was used to collect information about their socio-demographic profile, menstrual characteristics and dietary intake. Anthropometric measurements were taken using standard protocol (Lohman et al. 1988).

Data Types

Socio-demographic data include age of the participants (in years) at the time of interview, educational and occupational status of the participants and of their parents, types of family and per capita monthly household expenditure [in Indian National Rupees (INR)]. Educational status was categorised as non-literate (never received any formal education), up to primary level (completed formal education up to standard four), up to upper-primary level (completed formal education up to standard eight), up to secondary level (completed formal education up to standard ten), above secondary level (received formal beyond standard ten). Menstrual characteristics included age at menarche, menstrual years (years passed since menarche), duration of menstrual discharge (number of days during which menstrual blood is discharged), number of days of peak discharge (number of days during which maximum amount of menstrual blood is discharged, as perceived by the participant), type of menstrual discharge (scanty, moderate and heavy amount of menstrual bleeding, as perceived by the participant), menstrual cycle length (in days) (period between the first day of menstrual bleeding and the day immediately prior to the next menstrual bleeding), regularity in menstrual periods(menstruation that took place on a monthly basis at a specific interval of time), skipping of cycle (skipping of menstrual cycle during a particular month or for some months) and the longest time without menstrual bleeding (following the record of skipping of menstrual cycle, the longest duration of the month or months reported of not experiencing any menstrual bleeding).

Data on duration and type of menstrual discharge, number of days of peak discharge and regularity of the menstrual cycle were collected on the basis of the reporting of the last three episodes of menstruation prior to the date of interview. Menstrual cycle length was estimated by calculating the mean value of the last three episodes of menstrual cycle length prior to the date of interview. Skipping of menstrual cycle(s) and the longest reported time without the menstrual bleeding was recorded on the basis of the history of the last one year period prior to the date of interview. Menstrual disorders included PMS and dysmenorrhea. PMS include symptoms like anxiety or irritation, mood swing, depression, insomnia, lack of interest in social interaction and difficulty in concentration, abdominal pain, musculoskeletal pain, fluid retention, breast tenderness, food craving, loss of appetite, digestive disorders, fatigue, dizziness and oily skin and acne. Dysmenorrhea was considered as painful abdominal cramping, musculoskeletal pain (muscle, joints, hips and pelvic pain, as assessed by the participants) at the time of menstrual bleeding. The participants were asked to recall if they have experienced any PMS and or dysmennorrhea related symptoms during the last three months period prior to the date of interview. Age at menarche was ascertained by asking the exact date, if couldn't recall, then the nearest month. Most of the participants recalled the menarcheal age by referring to their formal educational standards, i.e. in which class they studied at the time of onset of first menstrual bleeding. Few of the participants, who dropped their formal education prior to the reaching of menarche, recalled the exact year and the month by referring to certain memorable landmark events or some festivals around that time. Nutritional status of the participants was assessed by using anthropometric variables and dietary intake. Anthropometric variables like height (m), mid upper arm circumference (MUAC) (m), waist circumference (WC) (m) and hip circumference (HC) (m) were measured using standard protocol (Lohman *et al*. 1988). Height was measured using anthropometer. The participants were asked to stand erect, look straight on a levelled surface with heels together and toes apart, barefoot and with head oriented in the Frankfort horizontal (FH) plane. MUAC was measured with non stretched measuring tape by asking the participant to flex the bicep muscle while the tape was wrapped around the flexed bicep gently in the midway between the tip of acromian and olecranon process. WC was measured at a point midway between the lower border of the ribs and the highest point of iliac crest using the same non-stretchable tape in horizontal position, with the subject standing erect and looking straight forward. HC was also measured by applying the tape at the point yielding the maximum circumference or the widest part over the buttocks, between the greater trochanter (top of the thigh bone) and the lower buttock level, with the participant's legs together. Body weight (kg) and percent body fat (PBF) were recorded from the Omron Body Composition Monitor (model HBF-375) following the standard technique provided in the instruction manual. The participants were made to stand on barefoot on Omron Body Composition Monitor with extended arms straight at a 90°angle to the body. The digital display of the monitor showed the body weight (kg) and percent body fat (PBF) of the participants.

Anthropometric indices

- Body mass index (BMI) was calculated by using the standard formula: BMI (kg/m^2) = Weight (kg)/Height^2 (m^2). BMI was classified based on their age following the classification of WHO (1996): a BMI less than 5th percentile was classified as 'underweight', 5th to <85th percentile as 'healthy weight', 85th to <95th percentile as overweight and ≥95th percentile as obese. The participants were categorised into 'underweight' and ''healthy weight''. The participants under ''healthy weight'' category includes all those whose BMI values fall are 5th percentile and beyond.
- Waist-hip ratio (WHR) was calculated (WHO 2000) using the formula: WHR = WC (m)/HC (m).
- The following equations of VanItallie et al. (1990) were utilized to assess the proportion of Fat mass (FM) and Fat mass index (FMI):
- (i) FM (kg) = (PBF/100) × weight (kg); (ii) FMI (kg/m^2) = FM (kg) / Height^2 (m^2).

Assessment of energy, carbohydrate, protein and fat consumption

Dietary intake of the participants was assessed using 24 hour recall method. Participants were asked to report the types of food items consumed on the day immediately preceding the date of data collection. We did not include the participants who were on sick diet or attended feast on the day preceding the date of study. Daily intake of both cooked and uncooked food items (gram/day) were collected using 'portion size' method as suggested in National Institute of Nutrition (NIN) (2011) dietary guidelines. While measuring the raw uncooked food ingredients, pictures of different portion sizes of various raw food items (snapped from the local market) were presented before the participants and for the cooked items, standard measuring "cups" (of various sizes) were used.

Intake of raw equivalents of different foods for each major consumed item by the participant on the preceding day of interview was calculated using the following formulae (NIN 2009).

$$\text{conversion factor (CF) for a given ingredient in a preparation} = \frac{\text{weight of that raw food used in the preparation}}{\text{total cooked quantity of that}}$$

$$\text{raw equivalent of a given food ingredient consumed by an individual} = \text{conversion factor of the food item} \times \text{volume of cooked food consumed}$$

Later, all the consumed raw foods were converted to weight (grams) on the basis of density (Food and Agriculture Organization, FAO)/In foods density database version 2.0, 2012) and thereafter assessment were made on the amount of carbohydrate (grams), protein (grams), fat (grams) and energy (Kcal) of each raw food item based on the NIN guideline (2017). We did not find the reference of conversion of some of the food items reported to have been consumed by the participants following NIN guideline (2017). In such cases we followed the references of conversion described by Ghosh-Jerath (2015) and Verma et al. (2015). The total energy consumption by a participant was estimated by summing the amount of carbohydrate, protein and fat, derived from the consumed food items by the participants on the day preceding the date of interview. The entire data were collected by one of the authors (JT) during the winter months, November to February, 2016–2018. These four winter months were chosen to minimise the seasonal variation in food intake.

Statistical analysis

Descriptive statistics were used to estimate the socio-demographic as well as nutritional status of the participants. We examined the distribution of the continuous data using the Kolmogorov-Smirnov test and found that the variables like age of the participants at the time of interview, age at menarche, menstrual duration, number of days of peak discharge, menstrual cycle length followed normal distribution and hence mean and standard deviation values of these variables were calculated. Variables like weight, MUAC, BMI, PBF, FMI, WHR resting metabolism, consumption quantity of carbohydrate, protein and fat, total calorie intake and monthly household expenditure showed skewed distribution; therefore the median values along with its lower and upper limits were estimated for these variables. Socio-demographic factors like educational status of the participants and that of their parents, occupational types of their parents, family type and menstrual characteristics of the participants (like menstrual discharge, regularity in the menstrual cycle, skipping of menstrual cycle, PMS and symptoms related to dysmenorrhoea) were expressed in frequency and percentage values. Bivariate statistics, like independent sample t-test and chi square test were used to examine the association of 'underweight' and 'healthy weight' categories with menstrual characteristics that are categorical in nature. Stepwise linear regression was applied to find out the determinants of menstrual cycle length, duration of menstrual discharge and number of days of peak menstrual discharge. The significant associates of the final model were presented in the result. For all the dependent variables, socio-demographic factors parameters (educational status of the participants and of their parents, occupational types of the parents and monthly household expenditure); menstrual characteristics (age at menarche, menstrual years, duration of bleeding, number of days of peak discharge, cycle length, irregularity of periods, skipping of cycle, PMS and dysmenorrhoea); anthropometric variables (MUAC, BMI, PBF, FMI and WHR); and nutrient intake (consumption quantity of carbohydrate, protein and fat) were considered as the independent associates. The collinearity between the independent variables was measured with the help of condition index. Stepwise logistic regression (backward conditional) was applied to identify the determinants of irregular menstrual cycle, skipping of cycle, experience of any PMS and dysmenorrhoea. We used the same independent variables (as used in stepwise linear regression model) as the possible associate variables. The analyses of the data were done using the Statistical Package for Social Sciences version18.0 (SPSS Inc., Chicago IL, USA). And *p*-values less than equal to 0.05 (two-tailed) were considered statistically significant.

Ethical considerations

Prior to data collection, the purpose and nature of the study were explained to the participants. The study was approved by Institutional Ethical Committee, University of Calcutta (026/17-18/1699).

Results

Socio demographic status of the participants shows that participants were aged between 14 and 19 years, with the mean age of 16.35± 1.82 years. Half of the participants studied up to secondary level and one fourth of them up to primary level. Most of the parents of the participants were non literate and were engaged as skilled/unskilled labours in tea production industry. The median monthly household expenditure was found to be 4200.00 INR (Table 1). The median values of MUAC, BMI and percent body fat (PBF) showed that the participants were on the edge of undernourishment. The median values of consumption of macronutrients like carbohydrate, protein and fat were 312.47 gm, 55.01 gm and 18.07 gm respectively and the median intake of daily energy was found to be inadequate than that of the required and recommended daily allowances (RDA) (Table 2). The relationship between BMI and menstrual characteristics (Table 3) shows that the mean age at menarche was slightly higher among the 'underweight' participants compared to that of their 'healthy weight' counterparts. The lowest and the highest ages at menarche were 11 years and 16 years respectively (irrespective of their BMI status). The mean duration of the menstrual bleeding (days) was similar for both the groups but the mean duration of days for peak discharge tended to be higher among the 'healthy weight' participants compared to those who were 'underweight'. 'Healthy weight' participants had comparatively shorter mean interval between two consecutive menstrual cycles than that of their 'underweight' counterparts. While majority of the 'healthy participants' experienced irregular period, the incidence of skipping of menstrual cycle and duration of absence of menstrual period (for more than two months) were higher among the 'underweight' participants . None of the menstrual characteristics has been found to differ significantly between 'underweight' and ''healthy weight'' participants. The same table also shows that the prevalence of PMS and dysmenorrhoea were high among all the participants; however, the prevalence of PMS was higher among the 'healthy participants' than the 'underweight participants'. Barring the prevalence of two of the dysmenorrhoeal symptoms (abdominal pain and musculoskeletal pain), vaginal pain during passing of urine was significantly higher among the 'healthy participants' compared to the 'underweight participants' ($p \leq 0.05$). Linear regression analyses (Table 4) revealed that participants with increase in age at menarche ($p \leq 0.05$) and with increased incidence of skipping of menstrual cycle ($p \leq 0.001$) were more likely to have

Table 1. Socio-demographic variables of the participants

Variables	Mean and frequencies (N=301)
Mean age of the participants (years)	16.35±1.82
Participants' educational status	
Up to primary level	7 (2.30)
Up to upper primary level	79 (26.20)
Up to secondary level	158 (52.50)
Up to higher secondary level	45 (15.00)
Above higher secondary level	12 (4.00)
Fathers' educational status (n=260)†	
Non literate	110 (42.30)
Up to primary level	42 (16.20)
Up to upper primary level	55 (21.20)
Up to secondary level	38 (14.60)
Above secondary level	15 (5.80)
Mothers' educational status (n=286)†	
Non literate	209 (73.10)
Up to primary level	22 (7.70)
Up to upper primary level	26 (9.10)
Above secondary level	29 (9.63)
Fathers' occupational status (n=260)†	
Non-working	17 (6.50)
Skilled and unskilled labour	227 (87.30)
Service	16 (6.20)
Mothers' occupational status (n=286)†	
Non-working	24 (8.40)
Skilled and unskilled labour	254 (88.80)
Service and business	8 (2.70)
Types of family	
Nuclear family	205 (68.10)
Joint family	96 (31.90)
Median monthly household expenditure (in Indian rupees)	4200.00 (1500–12000)

Figures in parenthesis indicates percentage
†Fathers of 41 participants' and mothers of 15 participants were found to be deceased and hence not included in the analyses.

Table 2. Distribution of the anthropometric variables and nutrients intake

Variables	Median	Lower limit	Upper limit
Weight (kg)	42.40	30.10	59.30
Mid Upper Arm Circumference (meter)	0.21	0.17	0.81
Body Mass Index	18.40	14.20	23.97
Percent Body Fat	22.80	12.80	34.80
Fat Mass Index	4.28	1.90	8.27
Waist Hip Ratio	0.77	0.66	2.04
Carbohydrate consumption per day (gram)	312.47	63.11	597.66
Protein consumption per day (gram)	55.01	12.50	218.47
Fat consumption per day (gram)	18.07	6.61	90.99
Total energy consumption per day (Kcal)	1813.76	435.78	3909.86

longer menstrual cycle length. But reverse is the relationship between menstrual cycle length and incidence of PMS ($p \leq 0.05$). Similarly, duration of menstrual discharge was found to be significantly associated with factors like mothers' occupational status ($p \leq 0.05$), number of days of peak discharge ($p<0.01$), PBF ($p \leq 0.05$) and consumption of carbohydrate ($p<0.01$). Number of days of peak discharge on the other hand, was significantly associated with fathers' ed-

Table 3. Distribution of participants for reported menstrual variables against Body Mass Index status

Variables		'Underweight' n=60	'Healthy weight' n=241	*t*-value, χ^2 *p*-value
Mean age at menarche (years)		13.32±1.21	13.29±1.15	t =0.16, p=0.88
Median age at menarche (years)		13.00 (11–16)ᵠ	13.00 (11–16)ᵠ	–
Mean Length of the menstrual cycle (days)		30.30±7.08	29.94±7.01	t=0.36, p= 0.67
Mean duration of menstrual bleeding (days)		4.37±1.30	4.37±1.33	t=0.01, p= 0.70
Mean number of days of peak discharge		1.43±0.59	1.47±0.67	t=0.42, p= 0.36
Menstrual flow on peak discharge days	Light	0 (0.00)	4 (1.66)	
	Medium	20 (33.33)	71 (29.46)	χ^2= 1.27, p=0.53
	Heavy	40 (66.67)	166 (68.88)	
Skipping of cycle (last one year)		20 (33.33)	77 (31.95)	χ^2=0.02, p=0.55
Longest time without menstrual bleeding (months)		2.13±1.56	1.75±1.45	t =0.99, p=0.43
Irregularity in menstrual cycle		17 (28.33)	76 (31.54)	χ^2= 0.23, p=0.76
Premenstrual syndrome (PMS)		50 (83.33)	220 (91.29)	χ^2= 3.29, p=0.09
Anxiety/depression		26 (52.00)	113 (51.36)	χ^2=0.01, p=0.94
Anger/irritability		16 (32.00)	86 (39.09)	χ^2=0.87, p=0.35
Mood swing		13 (26.00)	81 (36.82)	χ^2=0.14, p=0.71
Insomnia		10 (20.00)	61 (27.73)	χ^2=1.26, p=0.26
Lack of interest in social interaction		17 (34.00)	74 (33.64)	χ^2=0.02, p=0.96
Difficulty in concentration		20 (40.00)	100 (45.45)	χ^2=0.49, p=0.48
Abdominal pain		26 (52.00)	124 (56.36)	χ^2=0.31, p=0.58
Musculoskeletal pain		28 (56.00)	110 (50.00)	χ^2=0.59, p=0.44
Fluid retention		12 (24.00)	34 (15.45)	χ^2=2.11, p=0.15
Brest tenderness		11 (22.00)	34 (15.45)	χ^2=1.26, p=0.26
Food craving		17 (34.00)	70 (31.82)	χ^2=0.09, p=0.77
Loss of appetite		19 (38.00)	63 (28.64)	χ^2=1.69, p=0.19
Digestive disorders		13 (26.00)	49 (22.27)	χ^2=0.32, p=0.57
Fatigue		18 (36.00)	90 (40.91)	χ^2=0.41, p=0.52
Dizziness		14 (28.00)	56 (25.45)	χ^2=0.14, p=0.71
Oily skin/acne		16 (32.00)	66 (30.00)	χ^2=0.08, p=0.78
Dysmenorrhoeal problems		47 (78.33)	188 (78.01)	χ^2= 0.003, p=0.96
Abdominal pain		41 (87.23)	154 (81.05)	χ^2=0.75, p=0.39
Musculoskeletal pain		47 (100.00)	182 (95.79)	χ^2=1.54, p=0.22
Vaginal pain during and after passing urine		11 (23.40)	73 (38.42)	χ^2=3.90, $p \leq 0.05$

Figures in parenthesis indicates percentage.
ᵠ – median values with upper and lower limits in parenthesis.

Table 4. Determinants of menstrual characteristics: Linear regression (stepwise)

Dependent variables	Independent variables	β	SE	*p*-value	R^2
Menstrual cycle length	Age at menarche	1.07	0.48	0.03	0.13
	Skipping of cycle	4.92	1.20	0.001	
	Premenstrual syndrome	−4.12	2.05	0.05	
Duration of discharge	Mothers' occupational status: Non-working (Reference group)				0.14
	Skilled and unskilled labour	−0.61	0.30	0.04	
	Number of days of peak discharge	0.44	0.16	0.01	
	Percent Body Fat	−0.06	0.03	0.02	
	Carbohydrate consumption	1.82	0.58	0.002	
Number of days of peak discharge	Father's educational status	0.02	0.01	0.04	0.06
	Duration of discharge	0.09	0.03	0.01	

Table 5. Determinants of menstrual disorders: Stepwise (backward conditional) logistic regression

Dependent variables	Independent variables	OR	95% CI		*p*-value	R^2
			Lower	Upper		
Irregularity of periods	Menstrual years	1.19	0.98	1.46	0.09	0.19
	Cycle length	1.05	0.99	1.10	0.06	
	Skipping of cycle: No (Reference group)					
	Yes	3.31	1.59	6.90	0.001	
	Dysmenorrhoea: No (Reference group)					
	Yes	0.41	0.17	0.94	0.04	
	Fat consumption	2.60	0.84	8.04	0.10	
Skipping of cycle	Menstrual cycle length	1.11	1.04	1.18	0.002	0.35
	Regularity of cycle: Regular (Reference group)					
	Irregular	3.96	1.80	8.73	0.001	
	Dysmenorrhoea: No (Reference group)					
	Yes	5.49	1.82	16.54	0.002	
	Percent Body Fat	0.41	0.17	0.96	0.04	
	Body Mass Index	0.30	0.09	0.96	0.04	
	Fat consumption	3.07	0.87	10.87	0.05	
Premenstrual syndrome	Participants' educational status	0.72	0.50	1.04	0.08	0.39
	Menstrual cycle length	0.89	0.81	0.97	0.005	
	Skipping of menstrual cycle: No (Reference group)					
	Yes	4.44	0.76	26.09	0.10	
	Dysmenorrhoea: No (Reference group)					
	Yes	5.74	1.25	26.48	0.03	
	Percent Body Fat	0.40	0.23	0.69	0.001	
	Fat consumption	0.05	0.004	0.66	0.02	
Dysmenorrhoea	Regularity of menstrual cycle: Regular (Reference group)					0.16
	Irregular	0.43	0.19	0.98	0.05	
	Skipping of menstrual cycle: No (Reference group)					
	Yes	4.94	1.80	13.57	0.002	
	Mid Upper Arm Circumference	1.03	1.003	1.05	0.03	

ucational status ($p \leq 0.05$) and duration of discharge ($p<0.01$). The R^2 values could explain 13%, 14% and 6% of the variance for menstrual cycle length, duration of discharge and number of days of peak discharge respectively. Results of the final step of logistic regression (stepwise backward elimination) (Table 5) shows that the likelihood of having irregular periods significantly increased among those with history of skipping of menstrual cycle (OR 3.31, $p=0.001$), but significantly decreased among those with history of dysmenorrhoea (OR=0.41, $p=0.04$). In addition, the likelihood of skipping menstrual cycle significantly increased with increase in menstrual cycle length (OR=1.11, $p=0.002$), for those with history of irregular menstrual cycle (OR=3.96, $p=0.001$) and dysmenorrhoea (OR=5.49, $p=0.002$) and with regularl dietary fat consumption (OR=3.07, $p=0.05$); however, the trend is reversed with an increase in PBF (OR=0.41, $p=0.04$) and BMI (OR=0.30, $p=0.04$). Regression analysis further shows menstrual problems like the chance of experiencing PMS significantly increased among those with history of dysmenorrhoea (OR=5.74, p=0.03), but decreased with increase in menstrual cycle length (OR=0.89, $p=0.005$), PBF (OR=0.40, $p=0.001$) and fat consumption (OR=0.05, $p=0.02$). The incidence of dysmenorrhea significantly increased with increase in skipping of menstrual cycle (OR=4.94, $p=0.002$) and MUAC (OR=1.31, $p=0.03$), but decreased among those with irregular menstrual cycle (OR=0.43, $p=0.05$). The R^2 values indicate that the models could explain 19%, 35% 39% and 16% of the variance for irregularity of periods, skipping of cycles, PMS and dysmenorrhoea respectively.

Discussion

From the perspective of life history theory, energetic trade-offs between reproductive functions and other metabolic allocations for survival is the central understanding of 'reproductive effort' (Stearns 1992; Ellison 2003). It is argued that ovarian functions, in terms of production of major steroid hormones that controls the ovarian cycle are sensitive to energy availability (Ellison 2001). In India, almost a quarter of the population comprises adolescents (Agarwal et al., 2010) and 47 per cent of them are undernourished [United Nations Children's Fund (UNICEF 2011)]. Studies also show that reproductive morbidity is higher among these undernourished adolescents (Dasgupta et al. 2008; Mohite et al. 2013). This problem is more pronounced among the adolescents hailing from socially backward groups like scheduled castes and tribes, who are the worst sufferer of the ravages of energy deficiency (NIN, 2002). Our study clearly indicates nutritional energy deficiency among the Oraon adolescent participants in terms of daily energy consumption (deficient by 21% from the recommended dietary allowances suggested by NIN 2010), body fat (median is on the edge of 'critical fat value' for normal ovulatory functions: Frisch et al. 1973) and BMI (median is on the edge of being 'underweight': WHO 1996).

The effect of restricted energy availability on menstrual functions appears to be burdensome when energetic constraints are high (Bullen et al. 1985; Prior et al. 1982). The fat cells release leptin hormone, which is required at a specific level to send signal to the hypothalamus for carrying out menstrual activity (Obert et al. 2016; Osman 2016). Individuals with low body fat percentages potentially cause hormonal disturbance, leading to leading to longer menstrual cycles, irregular periods, painful periods and even cessation of the cycle (Tena-Sempere 2014; Randhawa et al. 2016; Sherly 2017). For example, lower level of body mass due to negative energy balance will cause low levels of estradiol and therefore interruption in menstrual cycle length (Kirchengast and Huber 2004; Miller et al. 2004; Ziomkiewicz et al. 2008). In the same vein, we also found that 'underweight' participants have longer cycle length and more frequently skipped their cycle than that of the 'healthy weight' participants. Alongside, we also found percent body fat (PBF) as well as BMI decreased the chance of menstrual cycle skipping.

It may be argued that nutritional factors do play a role in the maturation of hypothalamic–pituitary–ovarian axis (Treloar et al. 1967; Vollman 1977), which in turn regularize the cycle length. The effect of unbalanced nutrition on the menstrual cycle has largely been investigated in epidemiological studies. For example, a low caloric diet may rapidly create disturbances in the pulsatility of gonadotrophic hormones, thereby induce cycle disorders and ovarian dysfunction (Pirke et al. 1986; Frisch 1978, 1988; Schweiger et al. 1987). But our study denotes that irregularity in periods was comparatively high among the 'healthy weight' than that of the 'underweight' participants, which is consistent with the finding of a Bangladesh based study (Hossain et al. 2011). We also found dietary fat consumption is inversely related to skipping skipping of menstrual cycle. A high level of body fat storage due to the intake of higher amount of dietary fat may decrease the excretion of urinary progesterone metabolite and reduce serum and urinary luteinizing hormone (LH) levels. This may subsequently affect the normal functioning of ovary, oocyte, and corpus luteum leading to skipped cycle (Kuokkanen et al. 2016).

The results of our study show that percent body fat and carbohydrate intake remained significant associates of duration of menstrual discharge as found by Stokic et al. (2005). According to 'Frisch hypothesis', a critical amount of fat is necessary not only for menarche (17% body fat), but also to maintain normal menstrual periodicity (22% body fat) (Frisch et al. 1973; Frisch 1976). During each menstrual cycle, endometrium proliferates to develop high secretary capacity and an elaborate microvasculature (Johnson and Everitt, 1988; Ferin et al. 1993). Continuous metabolism of energy is required to sustain the process of endometrium proliferation (Price et al. 1981; Strassmann et al. 1996, 1997). Therefore, energetic source like carbohydrate plays a crucial role for duration of menstrual bleeding. A large number of participants have experienced PMS, especially those who are from 'healthy weight' category, contradicting the country's scenario which denotes 20% prevalence of PMS in India (Joshi et al. 2010). However, Nourjah (2008) observed that the intensity of PMS may vary and as many as 80% of women of reproductive age may experience premenstrual emotional and physical changes. Our study revealed the lowered risk of PMS with increasing dietary fat consumption, which supports some previous results (Houghton 2016 and Gold et al. 2007). PMS and attribution of dietary fat also denotes a duel hypothesis. During the luteal phase of menstrual cycle, the demand for energy increases for individuals with PMS due to a rise in metabolic rate (Vlitos and Davies 1996; Bussell 2014). It is well known that dietary fats provide a source of energy and a source of essential fatty acids like, omega-3 and omega-6 (Lee 1997). Studies also suggest that some women with premenstrual syndrome have elevated prolactin levels and few of them are abnormally sensible to normal quantities of prolactin (Horrobin 1983 and Filho et al. 2011). Prostaglandin E1, derived from dietary essential fatty acids, is able to attenuate the biologic actions of prolactin and that in the absence of prostaglandin E1 prolactin has exaggerated effects resulting in PMS. On the contrary, most of the literature including Nagata et al. (2004) and American College of Obstetricians and Gynaecologists (2015) recommend reducing fat intake to treat PMS. Dietary fats may affect a woman's cytokine, hormone levels (Houghton and Bertone-Johnson 2015) and also act as pro-inflammatory factors increasing C-reactive protein (CRP) concentrations (Aeberli et al. 2006; Santos et al. 2013). A higher CRP and other inflammatory cytokine levels may cause PMS (Bertone-Johnson et al. 2014; Houghton et al. 2017). Although the aetiology of PMS has not been elucidated, yet it has been suggested that PMS is multifactorial and risk factors like age, family history, lifestyle and consumption of micronutrients may also determine the experience of PMS (Kandeepan et al. 2013; Mohamadirizi and Kordi 2015). Many researchers suggested that vitamin rich food may reduce premenstrual symptoms like irritability, constipation and edema that may rise days before the onset of menstruation (Bendich 2000; Niemeier et al. 2006). Our study participants, owing to their socioeconomic and cultural background mostly consume leafy vegetables [rai saag (*Brassica juncea*), pui saag (*Basella alba*), kochu saag (*Colocasia anti-quorum*), muli saag (*Raphanus sativus*), palang saag (*Spinacia oleracea*), beng saag (*Centella asiatica*), muchari saag (*Hygrophila polysperma*), bhatua saag (*Chenopodium album*), katai saag (*Vangueria spinosus*), kukri saag (*Dryopteris cochleata*)] that are enriched with vitamins and micronutrients (data not presented). These leafy vegetables are abundant in the locality, and the consumption of these food items may be linked with the aetiology of PMS. The most widely accepted explanation for the pathogenesis of primary dysmenorrhea is the overproduction of uterine prostaglandins. Enhanced release of prostaglandins, allegedly from disintegrating cells during endometrial sloughing, is believed to cause myometrial hypercontractility, resulting in ischemia and hypoxia of the uterine muscle, and, ultimately, menstrual pain (Dawood 1987; Iacovides et al. 2015). A complex interaction between both low and high body fat and steroid hormones attributes to dysmenorrhoea (Scott and Johnston 1982; Ju et al. 2015). Our result connotes a higher prevalence of dysmenorrhea among the 'underweight' participants compared to 'healthy weight' corroborating with the existing literature (Chauhan and Kala 2012; Hirata et al. 2002 and Tangchai et al. 2004). Perhaps progesterone affects the synthesis of prostaglandins and their attachment to myometrium receptors (Wang et al. 2004). A low level of energetic balance may alter the level of sexual steroid hormones and thereby disrupt the function of hypothalamic-pituitary-ovarian axis (Gagua et al. 2012), causing menstrual pain (Bajalan et al. 2019). Multivariate analyses of our study revealed an increased risk of dysmenorrhoea with an increase in MUAC. Many studies (Craig et al. 2014; Chaput et al. 2016; Jaiswal et al. 2017) have suggested increased MUAC as an indicator of obesity, thus a higher energetic balance. It has been hypothesised that adiposity may influence endometrial thickness by its estrogen-mediated effect (Jungheim et al. 2012). Studies show that an increase in body weight reduces sex-hormone binding globulin (SHBG). The function of SHBG is to bind oestrogen. A reduced SHBG elevates serum oestrogen level, which in turn prompts proliferation of endometrial tissues that produce prostaglandins, resulting in dysmenorrhea (Barnard etal. 2000; Ju et al. 2015). The crossover clinical trial by Barnard et al. (2000) also found that an intervention with a low fat vegetarian diet during two consecutive menstrual cycles' diminished duration and severity of dysmenorrhea.

The findings of the present study should be viewed under certain limitations. Data on energy expenditure by means of physical activity would have provided a better picture of energy availability of the participants and its effect on menstrual functions. Since ovarian functions are energetically demanding for a human female, menstrual cycle is expected to be sensitive to the factors influencing energy availability and metabolism. Therefore, any alteration in the energetic homeostasis is closely associated with the changes in reproductive axis. Our study reinforces this concept that energy availability determines the menstrual characteristics. Thus, trading off energy allocation to reproductive effort, especially for the vulnerable group like tribal adolescents, are likely to affect their continuum of ovarian function (Ellison 2008).

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Authors' contributions

JT has contributed fifty percent by collecting and anlysing the data and in partially drafting the manuscript; MG has contributed thirty percent by drafting the manuscript; SR has contributed twenty percent by designing the study and reviewing the manuscript.

Conflict of interest

The authors report no conflicts of interest.

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