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ABSTRACT

Background: Primary dysmenorrhea is associated with pain and neuromuscular alterations that may influence functional movement patterns. Lumbopelvic motion plays a crucial role during forward bending by ensuring coordinated interaction between lumbar spine flexion and anterior pelvic tilt. However, its phase-wise alteration across the menstrual cycle remains insufficiently explored.

Objective: To quantify phase-dependent alterations in lumbopelvic ratio during forward bending among college students with primary dysmenorrhea.

Methodology: A prospective repeated-measures observational study was conducted on 88 female college students with primary dysmenorrhea. We assessed lumbar flexion and anterior pelvic tilt during the menstrual, follicular, ovulatory, and luteal phases using standardised inclinometric techniques. We analysed data using the Friedman test, post hoc comparisons, and Spearman rank correlation.

Results: Lumbar flexion differed significantly across phases (Friedman χ^2= 212.86, $p<0.001$, Kendall's W=0.806), with the lowest value during the menstrual phase (39.17° ± 0.56 SE) and significantly increased during the follicular (47.01° ± 0.60 SE) and luteal phases (47.25° ± 0.58 SE). Anterior pelvic tilt also differed significantly across phases, although the magnitude of the phase effect was smaller than that observed for lumbar flexion. (χ^2= 94.71, $p<0.001$, Kendall's W=0.359). The lumbopelvic (L/P) ratio also differed significantly across phases (Friedman χ^2 = 109.46, $p < 0.001$, Kendall's W=0.415), with the lowest value during the menstrual phase (1.016±0.017 SE), while the contribution of lumbar motion compared to pelvic motion increased during the other three phases.

Conclusion: Significant phase-dependent variations were observed in lumbar flexion, anterior pelvic tilt, and the lumbopelvic ratio during forward bending in women with primary dysmenorrhea. The L/P ratio was lowest during menstruation and remained higher during the follicular, ovulatory, and luteal phases. These findings support consideration of menstrual phase when assessing lumbopelvic movement in women with primary dysmenorrhea.

Keywords: Primary Dysmenorrhea, Lumbopelvic Kinematics, Biomechanics, Forward Bending, Lumbar Flexion, Pelvic Tilt.

INTRODUCTION

Forward bending is a fundamental functional movement requiring coordinated interaction between the lumbar spine and pelvis. This coordinated motion, referred to as lumbopelvic motion, ensures efficient load distribution and minimizes mechanical stress on spinal structures. Lumbar range of motion is the difference between the maximum and minimum angles attained during motion. In healthy individuals (mean age: 21.4±1.9 years), the lumbar flexion ROM value is 69.9±14.5 degrees. [1,26,31] Pelvic tilt means the pelvic motion in the sagittal plane. A line drawn from the ASIS to PSIS that forms an angle with respect to the horizontal plane is used to assess the pelvic tilt. Pelvic tilt can be measured in both static and dynamic positions. An anterior pelvic tilt occurs when the ASIS rotates inferiorly in relation to the PSIS, and a posterior pelvic tilt occurs when the ASIS rotates superiorly in relation to the PSIS. In the standing position, the average anterior pelvic tilt among healthy female college students is 12.2 +/- 5.2 degrees on the right side and 11.8 +/- 4.5 degrees on the left. [29] Lumbo-pelvic ratio (L/P ratio) is total lumbar flexion divided by anterior pelvic tilt in the sagittal plane. Dual bubble inclinometers are used to measure lumbar flexion. Although several methods exist for evaluating pelvic tilt, a handheld inclinometer with smartphone software application (Bubble level and clinometer) remains one of the most accessible and reliable tools for clinical measurement. [15,32] During forward bending, the disruption of the coordinated movement between lumbar flexion and pelvic tilt can occur due to musculoskeletal disorders like LBP, muscle tightness, and neuromuscular imbalance. [28]

Pain and movement are universal experiences that affect people. Multiple theories explain the relationship between pain and movement. According to the vicious cycle theory, regardless of the task, pain increases muscle activity. Hyperactivity of the muscles causes ischemia and metabolite accumulation, which increases pain. According to the pain adaptation theory, pain inhibits muscle activity of agonist muscles and facilitates antagonist muscles, which is nonpainful. Pain can cause a wide variety of movement alterations, from minor motor compensations during task completion to muscle spasms to total avoidance of unpleasant movements. Recent studies suggest that individuals with acute low back pain can achieve a small range of motion in lumbar flexion and greater motion of pelvic tilt during forward bending compared with normal individuals. [20,28,34]

Menstruation is described as the periodic bleeding that takes place from the uterine corpus between menarche and menopause. The menstrual cycle is the regular cyclic changes of the female reproductive system that prepare the body periodically for ovulation and potential pregnancy. The normal menstrual frequency is defined by the International Federation of Gynecology and Obstetrics (FIGO) as cycles occurring at intervals of 24 to 38 days. The normal duration of menstruation is defined as bleeding lasting for 8 days or less. The average duration of a menstrual cycle is 28 days, which may vary between 25 and 30 days. [5,21]

The menstrual cycle is composed of four phases: menstruation, follicular, ovulation & luteal phase. Menstruation (Day 1-5): The shedding of the uterine lining, which results in menstrual bleeding. Follicular phase (Day 1-14): Hormones stimulate the development of follicles in the

ovaries, each containing an egg. Ovulation (Day 14): A mature egg is released from the ovary and can potentially be fertilized by sperm. The ovulation phase can be detected through the calendar method or basal body temperature (BBT). BBT is an approximate phase-identification method, not hormonal confirmation. The BBT rises 0.5°–1° F during the ovulation phase. A sustained rise in temperature supports retrospective identification of ovulation. Luteal phase (Day 15-28): After ovulation, the ruptured follicle transforms into the corpus luteum, which releases progesterone to prepare the uterus for pregnancy. [5,9,21,30]

Dysmenorrhea is menstrual pain over lower abdomen, which can be radiating to the inner thighs and lower back. There are two types of dysmenorrhea: primary dysmenorrhea & secondary dysmenorrhea. Primary dysmenorrhea, characterized by painful menstruation without underlying pathology, is associated with increased prostaglandin activity leading to uterine contractions and pain. Secondary dysmenorrhea is menstrual pain resulting from an underlying pathology, including endometriosis, fibroids, adenomyosis, endometrial polyps, interstitial cystitis, pelvic inflammatory disease, and possibly the use of an intrauterine contraceptive device. [2,6,10] The pathophysiology of primary dysmenorrhea has not been fully explained, but recent evidence suggests that it is associated with excessive endometrial prostaglandin (PG) synthesis. In the late stage of the luteal phase, corpus luteum regression (luteolysis) happens, which reduces the levels of progesterone and estrogen and triggers menstruation. During menstruation, the endometrium sloughing release prostaglandins PGF2α, PGE2, and vasopressin in menstrual fluid. The excessive levels of prostaglandins PGF2α, PGE2, and vasopressin lead to increased myometrial contractility and intrauterine pressure, which produce vasoconstriction of the uterine artery. This vasoconstriction causes ischemia of the uterus and formation of anaerobic metabolites. It causes hypersensitization of nociceptive nerve fibres, which produces pain. [12,23] The pain mainly occurs in the lower abdomen, but in most of the cases, pain is found in the lower abdomen along with the lower back, pelvic region and thigh area, with some associated symptoms like nausea, vomiting, fever, headache, fatigue and dizziness. Beyond visceral discomfort, primary dysmenorrhea has been shown to influence musculoskeletal function through altered neuromuscular control, protective muscle guarding, and central pain modulation mechanisms. These affect functional movements and activities during menstruation, which decrease the quality of life. Primary dysmenorrhea is seen in adolescent girls. The symptoms start 6 months to 24 months after the onset of menarche. The symptoms peak at the age of 20-24 years and gradually decrease at the age of 30 or after the first pregnancy. [6,33,35] To quantify pain intensity, a variety of validated outcome measures are available; however, the Numerical Rating Scale (NRS) is considered one of the most reliable and sensitive tools for assessing pain severity in individuals with primary dysmenorrhea. [7] The prevalence of dysmenorrhea among young women, school-aged & university-aged, ranges from 41- 91.5%, and 29% of them experience severe pain. In India, the prevalence of dysmenorrhea is 50% to 80%. The worldwide prevalence of primary dysmenorrhea is 66.1%. The prevalence of primary dysmenorrhea is between 50 to 87.8 % in India. [6,33,35]

Some studies have found that pain affects movement. When pain increases, movement becomes reduced. LBP has a direct correlation with forward bending disruption. Pain-related adaptations may disrupt normal movement patterns, particularly in trunk biomechanics. Individuals experiencing pain often demonstrate increased reliance on specific segments, altered motor recruitment patterns, and reduced movement variability. In this context, dysmenorrhea may influence lumbopelvic ratio during functional tasks such as forward bending. Studies have

demonstrated reduced spinal mobility in women with primary dysmenorrhea, specifically decreased sacral mobility in the sagittal plane and reduced thoracic and lumbar mobility in the frontal plane; it is reasonable to consider how these mobility limitations may influence functional lumbopelvic movement patterns. [32] Some studies have found that women with dysmenorrhea had reduced spinal mobility despite no change in static spinal posture. [15] Another study reported decreased lumbopelvic muscle endurance, reduced muscle thickness, and diminished pelvic mobility in women with dysmenorrhea compared with controls. However, these studies largely focus on static or low-level functional assessments, leaving a critical gap in understanding how dynamic, phasic coordination between the lumbar spine and pelvis (lumbopelvic motion) is disrupted during movement in women with dysmenorrhea. Moreover, lumbopelvic misalignment has been correlated with dysmenorrhea symptoms, such as in a study using Formetric 4D alignment and ultrasound-measured abdominal muscle thickness.[14] Previous studies have primarily compared spinal mobility, pelvic alignment, and lumbopelvic muscle characteristics between women with primary dysmenorrhea and healthy controls. Despite growing interest in women's health and biomechanics, limited research has explored the effect of menstrual phases on lumbopelvic kinematics. Although previous studies have examined spinal mobility, pelvic alignment and muscle endurance in women with primary dysmenorrhea, dynamic lumbopelvic kinematics during functional forward bending across menstrual phases remains unexplored. Understanding these alterations is essential for developing physiotherapy interventions targeting movement dysfunction in this population.

Since activities of daily living frequently require coordinated lumbar flexion, it is clinically relevant to determine whether individuals with primary dysmenorrhea exhibit greater pelvic motion relative to lumbar motion, or conversely, a lumbar-dominant movement strategy during forward bending. From a clinical perspective, physiotherapists must comprehend these changed movement patterns. Targeted therapies can be guided by determining whether those with primary dysmenorrhea exhibit reduced lumbopelvic coordination. To restore normal biomechanics and enhance functional performance, individualized therapeutic approaches may include movement re-education, core stability exercises, flexibility training, and pain management techniques tailored to the identified impairments. Exploring this lumbopelvic contribution may help clarify how altered mobility profiles affect functional biomechanics in this population. [12,20,22,25]

METHODOLOGY

Study Design: Prospective repeated-measures observational study

Study duration: 10 months

Sample size calculation: The sample size was calculated using G*Power version 3.1 for a repeated-measures observational design with four within-subject measurements across the menstrual cycle phases. Assuming a small effect size (f = 0.15), a power of 95%, and a significance level of 0.05, the minimum required sample size was estimated to be 88 participants.

Study population: Women college students with primary dysmenorrhea

Sampling Technique: Convenience sampling

Study setting: The sample was from Brainware University, Kolkata

Inclusion Criteria:

Age: 20 -25 years

Primary dysmenorrhea was identified based on a documented medical diagnosis and clinical history of recurrent menstrual pain in the absence of clinically diagnosed secondary pelvic pathology.

Students who agreed to participate in the study,

NRS > 4 (Moderate to severe),

Menstrual cycle: Regular

Dysmenorrhea with associated symptoms & medication history.

Exclusion criteria:

Known gynecological conditions associated with secondary dysmenorrhea, including endometriosis, adenomyosis, uterine fibroids, or other clinically diagnosed pelvic pathology,

Known case of any musculoskeletal & neurological disorders,

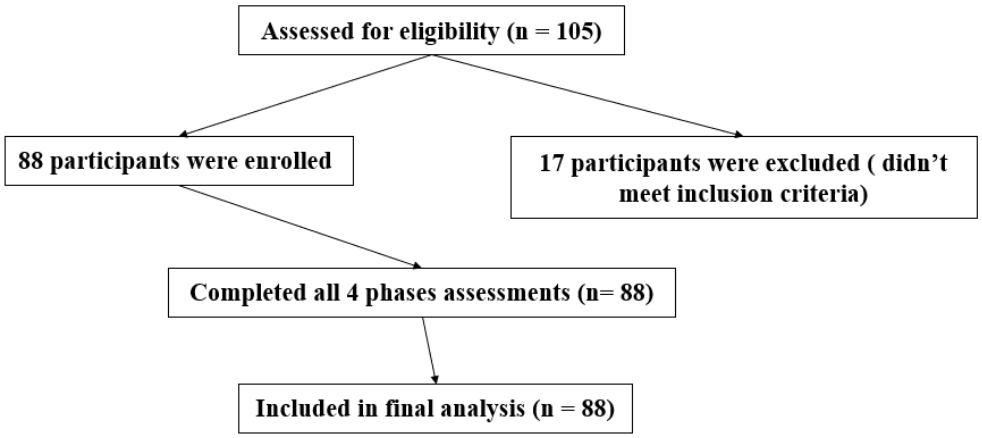
Known case of any spinal dysfunction & deformity,

Recent injury & surgery,

Recent history of systemic disease,

Students who did not agree to participate in the study.

Participant flow: Of the 105 participants assessed for eligibility, 17 were excluded for not meeting the predefined inclusion criteria. The remaining 88 participants were enrolled and completed all four assessment phases. Consequently, the final analysis included data from all 88 participants (Fig. 1).



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Fig. 1 Flow diagram showing participant recruitment, eligibility assessment, enrollment, and inclusion in the final analysis.

MATERIALS USED

All equipment and materials were procured from standard manufacturers to ensure reliability and accuracy of measurements. The study utilised a comprehensive array of specialised equipment, including:

Stadiometer: It was used for precise height measurement.

Digital Weighing Machine: Used to measure body weight.

NRS Scale: It is a valid and reliable patient-reported outcome measure for assessing dysmenorrhea-related pain intensity, which has 83% sensitivity & 86% specificity.

Thermometer: It was used to measure BBT to detect the ovulation phase.

Measuring Tape: It was used to measure distance accurately during Lumbar Flexion measurement.

Baseline Bubble Inclinometer: It is a validated clinical measurement method to measure joint range of motion. This device was used to measure lumbar flexion ROM by using the PSIS-to-15 cm cephalad method. It has 0.78 to 0.88 ICC for intra-rater reliability and 0.66 ICC for inter-rater reliability.

Wooden caliper with smartphone software (Bubble Level and Clinometers): A mobile inclinometer is used to measure pelvic tilt. It uses three carved wooden pieces - two of which serve as caliper ends and one of which functions as an immobile arm. A smartphone with the app "Bubble Level and Clinometers" is put on the middle arm. It is a reliable clinical measurement tool to measure Anterior Pelvic Tilt, which has intra-rater reliability C-alpha = 0.98; ICC = 0.96.

PROCEDURE

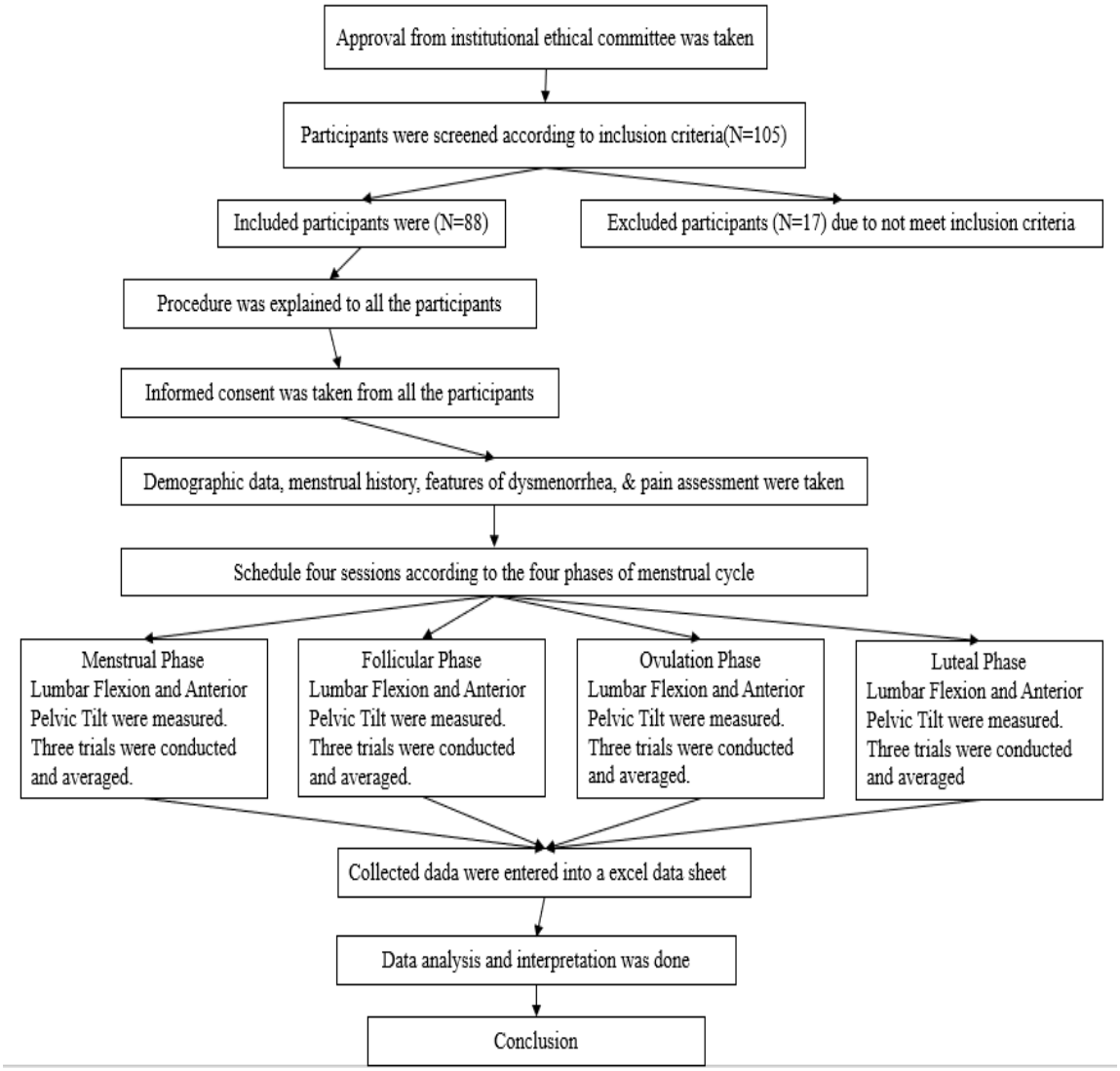
This study was approved by the Departmental Research Committee of Brainware University (Approval No. BWU/AHS/NOC/DSC/2026/004) and was conducted according to the ethical standards of the 1964 Declaration of Helsinki and its later amendments. We obtained written informed consent from all participants. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

This study was conducted as a prospective repeated-measures observational study over ten months period at Brainware University, Kolkata. The study population consisted of female college students aged 20-25 who were diagnosed with primary dysmenorrhea. Assuming a small effect size (f = 0.15), a power of 95%, and a significance level of 0.05, the final included sample size was 88 female college students with primary dysmenorrhea. A convenience sampling technique was used to recruit participants. The study included women between the ages of 20 and 25 who agreed to participate, had regular menstrual cycles, and experienced moderate to severe menstrual pain (NRS > 4). Individuals with musculoskeletal or neurological

abnormalities, spinal deformities, recent injuries or surgeries, systemic diseases, secondary dysmenorrhea associated with clinically diagnosed pelvic pathology, including endometriosis, adenomyosis, uterine fibroids, or other relevant gynecological conditions or who disagreed to participate were excluded. The purpose of the study was explained to the enrolled participants before starting the data collection. Demographic information and menstrual history, such as age at menarche, features of dysmenorrhea, the length of the menstrual cycle, blood flow, and the most recent menstrual period, were gathered in order to perform screening. The Numeric Rating Scale (NRS) was used to measure menstrual pain intensity. Participants were assessed across four phases of the menstrual cycle (menstrual, follicular, ovulatory, and luteal phase). Menstrual cycle phases were estimated using menstrual history, cycle calendars and basal body temperature patterns. Ovulation was not confirmed using biochemical hormonal assays or ultrasonography. Each participant underwent four separate sessions aligned with cycle phases. All assessments were performed by a single examiner in the morning time of the day to minimize potential inter-examiner and diurnal variations in measurements. Before commencing every session, the phase was evaluated, participants wore well-fitting garments, and anatomical landmarks including S2, 15 cm above S2, ASIS, and PSIS were identified and marked. During every session, lumbar flexion and anterior pelvic tilt were assessed. Lumbar flexion was measured using a dual-bubble inclinometer placed at S2 and 15 cm above, while subjects bent forward with knee extended from a standing position (Fig. 2A). The ROM was calculated by subtracting the degrees on the S2 inclinometer from the degrees on the upper inclinometer, and the average of three trials was taken. Anterior pelvic tilt was measured with a wooden caliper device and a smartphone clinometer app (Fig. 2B), with measurements recorded during forward bending after placing the caliper over the ASIS and PSIS landmarks. Three trials were performed, and the mean value was used for analysis. All the collected data were entered into an Excel data sheet for final statistical analysis.



Fig 2. Measurement of Lumbopelvic motion (A) Lumbar flexion measurement using a Dual Bubble Inclinometer. (B) Anterior pelvic tilt measurement using a wooden calliper with smartphone software (Bubble Level and Clinometers).



Scheme 1. Representation of experimental design

OUTCOME MEASURES

Pain Intensity Measurement:

Asked the individuals to rate their pain between 0 and 10 by using the Numeric Rating Scale (NRS); where 0 means no pain, 1-3 means mild pain, 4-6 means moderate pain, 7-9 means severe pain, and 10 means the worst pain imaginable. [7]

Lumber Flexion Measurement (°):

Instrument: Dual Bubble Inclinometer (PIC)

Method: PSIS to 15 cm cephalad

Procedure: Asked the individual to assume a standing position with feet shoulder width apart, knees straight, heels flat on the floor and arms at shoulder level (90° shoulder flexion). Marked the lower landmark at the level of S2 by palpating both PSIS and the upper landmark

by measuring 15 cm above S2. Placed both inclinometers on their landmark and both inclinometers were zeroed at the upright starting posture. Participants were instructed to bend forward to their maximum comfortable range while maintaining the knees in extension. Calculate the ROM by subtracting the degrees on the S2 inclinometer from the degrees on the other inclinometer. [18]

Anterior Pelvic Tilt Measurement (°):

Instrumentation: A mobile inclinometer was used to measure pelvic tilt. It used three carved wooden pieces -two of which serve as caliper ends and one of which functions as an immobile arm. A smartphone with the app "Bubble Level and Clinometers" was put on the middle arm.

Procedure: Asked the individual to assume a standing position with feet shoulder width apart, heels flat on the floor and arms crossed over the chest. Palpated the ASIS and PSIS on both sides for landmarks. Used self-adhesive stickers for marking. caliper tips were pressed together to a firm resistance after being positioned over the landmarks. Stabilized the stationary arm through the hands. Then asked the individual to bend forward as far as possible while keeping the knee straight. Measured the angle at the end of motion. Anterior pelvic tilt was measured bilaterally, and the mean of the right and left measurements was used as the participant-level pelvic tilt value. [3]

STATISTICAL ANALYSIS

All data collected in this study were analyzed using the software IBM SPSS v31. To test the normality Shapiro wilk test was used. Descriptive statistics were presented as mean and standard deviation for normally distributed variables and as median and interquartile range for non-normally distributed variables. Categorical variables were summarized using frequencies and percentages. For non-normally distributed variables, the Friedman test was used as a non-parametric test. Pairwise post-hoc comparisons were performed using Wilcoxon signed-rank tests with Bonferroni adjustment to determine pairwise differences between phases where applicable. Spearman rank correlation was used to examine associations between lumbar flexion, anterior pelvic tilt, and pain intensity. Statistical significance was set at $p < 0.05$.

RESULTS

Results of Application of Method and Sample Characteristics:

A total of 88 participants completed the full assessment protocol, including anthropometric measurements, phase-wise lumbar flexion and anterior pelvic tilt measurements during forward bending. All the participants adhered to the standardized protocols. The sample consisted of 88 female students with primary dysmenorrhea from Brainware University, with ages ranging from 20 to 25 years, where the mean age was 21.15 ± 1.18 years, and the mean BMI was 22.52 ± 3.54 kg/m². Out of 88 participants, 57 participants reported moderate menstrual flow, and 67 participants reported no routine medication use for pain; the mean menstrual pain intensity was 6.85 ± 1.37 on the NRS. All participants met inclusion criteria and demonstrated no exclusionary condition that would affect the research. Participant compliance was excellent, with all individuals completing the required assessment in four phases. No adverse event was reported during the study period. Representation of participant characteristics is described in detail in Table 1.

Table 1. Representation of participant characteristics. Data are presented as mean ± SD.

Characteristic	Value
Sample size	88
Age (years)	21.15 ± 1.18
BMI (KG/M²)	22.52 ± 3.54
BMI category	Underweight: 8; Normal: 63; Overweight: 14; Obesity class I: 3
Cycle regularity	Regular: 88
Blood flow	Light: 11; Moderate: 57; Heavy: 20
Medication use	No: 67; Occasionally: 10; Every cycle: 11
Menstrual pain intensity (NRS)	6.85 ± 1.37

Descriptive Analysis:

Lumbar Flexion: The analysis of lumbar flexion showed clear variations based on the phase. The mean lumbar flexion was lowest during the menstrual phase at 39.17° ± 0.56 SE, with a median of 40° and mode of 35°. There was a significant increase during the follicular phase, reaching 47.01° ± 0.60 SE, followed by a slight decrease during the ovulation phase to ≈ 44.94° ± 0.54 SE. Lumbar flexion increased again in the luteal phase to ≈ 47.25° ± 0.58 SE, which was similar to the follicular phase (Table 2). A mean increase of approximately +2.3° was observed from the ovulatory to luteal phase, indicating enhanced lumbar contribution. These results suggest restricted lumbar movement during menstruation and improved mobility during non-menstrual phases (Fig. 3).

Anterior Pelvic Tilt: Anterior pelvic tilt (APT) was shown to significantly decrease during the menstrual period, with a mean value of around 38.85°, which was significantly lower than the other phases. The follicular, ovulation, and luteal phases, on the other hand, showed comparatively steady and consistent APT values, all of which ranged closely between 41.5° and 41.7°, indicating little fluctuation during these periods (Table 2). Furthermore, the menstrual period showed the highest standard deviation (3.55), indicating increased inter-individual variability in pelvic posture, potentially as a result of variations in neuromuscular control or pain severity during menstruation. Overall, the APT values demonstrated a wide range, from a minimum of 24.5° noted during the follicular phase to a maximum of 45° noted during the menstrual, follicular, and luteal phases, underscoring the participants' varying pelvic alignment (Fig. 3).

Table 2. Phase-wise mean ± SE, 95% CI and median (IQR) of Lumbar flexion & Anterior Pelvic Tilt

Phase	Lumbar flexion Mean ± SE (95% CI)	Lumbar flexion median (IQR)	Anterior pelvic tilt Mean ± SE (95% CI)	Anterior pelvic tilt median (IQR)
Menstrual	39.17° ± 0.56	40° (35°-45°)	38.85° ± 0.38	39.50° (37.38°-41°)

	(38.06° – 40.28°)		(38.10° – 39.60°)	
Follicular	47.01° ± 0.60	48 ° (45°-50°)	41.63 ± 0.32	42° (41°-44°)
	45.82° – 48.21°)		(40.99° – 42.27°)	
Ovulation	44.94° ± 0.54	45° (40°-48°)	41.55 ± 0.35	42° (41°-44°)
	(43.88° – 46.01°)		(40.85° – 42.25°)	
Luteal	47.25° ± 0.58	48° (45°-50°)	41.70 ± 0.31	42° (41°-43.50°)
	(46.09° – 48.41°)		(41.09° – 42.32°)	

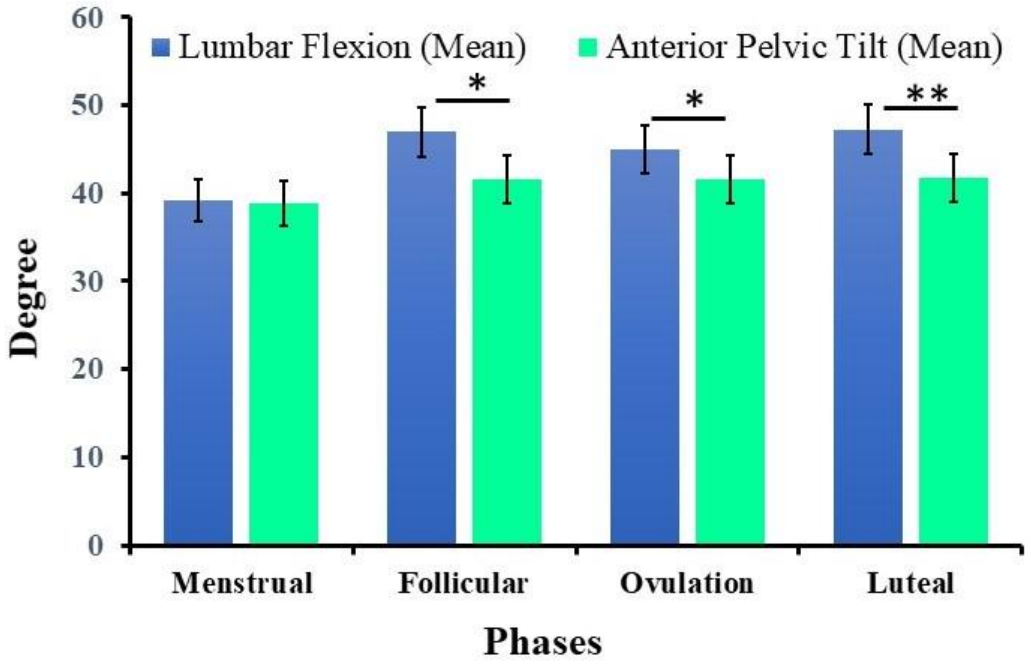


Fig. 3 Chart of Phase-wise Comparison of Mean Lumbar Flexion and Anterior Pelvic Tilt. Data are represented as Mean ± SE; *p<0.05, **p<0.01

Lumbopelvic Ratio (L/P): The L/P ratio was lowest during menstruation at 1.016±0.017 (95% CI: 0.981 – 1.051), indicating a relatively greater proportional contribution of pelvic motion compared with lumbar motion, whereas higher ratios during the follicular phase at 1.134, ovulatory at 1.088, and luteal phases at 1.137 indicated a relatively greater lumbar contribution (Table 3; Fig. 4).

Table 3. Represents the phase-wise mean ± SE and 95% CI of Lumbopelvic Ratio

Phase	Lumbopelvic Ratio	95% CI
Menstrual	1.016±0.017	0.981 – 1.051
Follicular	1.134±0.016	1.102 – 1.165
Ovulation	1.088±0.016	1.057 – 1.120
Luteal	1.137±0.015	1.106 – 1.168

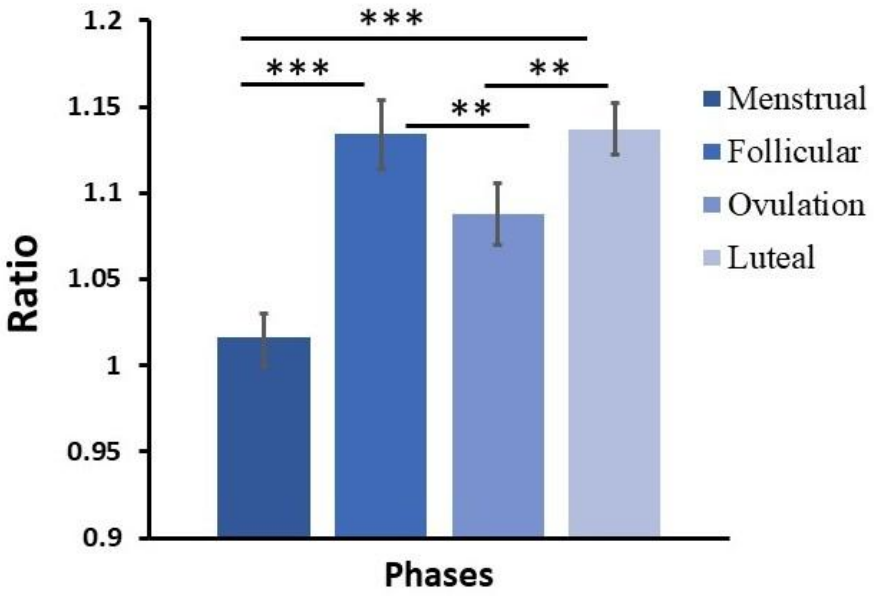


Fig 4. Phase-wise comparison of Lumbopelvic (L/P) Ratio. Data are represented as Mean ± SE; **p<0.01, ***p<0.001

Shapiro Wilk Test:
Normality was assessed using the Shapiro–Wilk test. All phase-specific distributions demonstrated significant departures from normality; therefore, non-parametric repeated-measures analyses were used.

Friedman Test:
Friedman analysis demonstrated a statistically significant phase effect for lumbar flexion (χ^2 = 212.86, $p < 0.001$), anterior pelvic tilt (χ^2 = 94.71, $p < 0.001$) and lumbopelvic (L/P) ratio (χ^2 = 109.46, $p < 0.001$) (Table 4).

Table 4. Represents the Inferential Statistics.

Outcome	Friedman χ^2	p	Kendall W	Significant pairwise Comparisons
Lumbar Flexion	212.86	<0.001	0.806	Menstrual vs Follicular, Menstrual vs Ovulatory, Menstrual vs Luteal, Follicular vs Ovulatory, Ovulatory vs Luteal
Anterior Pelvic Tilt	94.71	<0.001	0.359	Menstrual vs Follicular, Menstrual vs Ovulatory, Menstrual vs Luteal
L/P Ratio	109.46	<0.001	0.415	Menstrual vs Follicular, Menstrual vs Ovulatory, Menstrual vs Luteal, Follicular vs Ovulatory, Ovulatory vs Luteal

Bonferroni-Adjusted Post-hoc Comparisons:

Bonferroni-adjusted post-hoc comparisons (Table 5) revealed significant differences in lumbar flexion between the menstrual and follicular, menstrual and ovulatory, menstrual and luteal, follicular and ovulatory, and ovulatory and luteal phases (all $p < 0.001$). No significant difference was observed between the follicular and luteal phases ($p = 1.000$). For anterior pelvic tilt, we observed significant differences between the menstrual phase and the follicular, ovulatory, and luteal phases (all $p < 0.001$). However, no significant differences were found between the follicular and ovulatory phases ($p = 1.000$), follicular and luteal phases ($p = 1.000$), or ovulatory and luteal phases ($p = 0.614$).

Table 5. Represents the Bonferroni-adjusted post-hoc comparisons.

Variable	Pairwise comparison	Difference	Bonferroni-adjusted p
Lumbar flexion	Menstrual vs Follicular	+0.118	<0.001
Lumbar flexion	Menstrual vs Ovulatory	+0.072	<0.001
Lumbar flexion	Menstrual vs Luteal	+0.121	<0.001
Lumbar flexion	Follicular vs Ovulatory	-0.046	<0.001
Lumbar flexion	Follicular vs Luteal	+0.003	1.000
Lumbar flexion	Ovulatory vs Luteal	+0.049	<0.001
Anterior pelvic tilt	Menstrual vs Follicular		<0.001
Anterior pelvic tilt	Menstrual vs Ovulatory		<0.001
Anterior pelvic tilt	Menstrual vs Luteal		<0.001
Anterior pelvic tilt	Follicular vs Ovulatory		1.000
Anterior pelvic tilt	Follicular vs Luteal		1.000
Anterior pelvic tilt	Ovulatory vs Luteal		0.614

Spearman Rank Correlation analysis:

Spearman correlation analysis demonstrated weak, non-significant associations between lumbar flexion and anterior pelvic tilt across the menstrual ($\rho = 0.062$, $p = 0.567$), follicular ($\rho = 0.179$, $p = 0.095$), ovulatory ($\rho = 0.147$, $p = 0.172$), and luteal phases ($\rho = 0.092$, $p = 0.394$) (Table 6).

Pain intensity was not significantly associated with lumbar flexion ($\rho = -0.087$, $p = 0.419$) or anterior pelvic tilt ($\rho = 0.042$, $p = 0.695$) during menstruation, indicating that movement alteration may not be explained by pain intensity alone.

Table 6. Represents the Spearman Rank Correlation analysis between Lumbar flexion and anterior pelvic tilt in different phases of the menstrual cycle.

Correlation	Spearman rho	p value

Lumbar flexion and anterior pelvic tilt (Menstrual Phase)	+ 0.062	0.567
Lumbar flexion and anterior pelvic tilt (Follicular Phase)	+ 0.179	0.095
Lumbar flexion and anterior pelvic tilt (Ovulation Phase)	+ 0.147	0.172
Lumbar flexion and anterior pelvic tilt (Luteal Phase)	+ 0.092	0.394
Pain intensity vs menstrual lumbar flexion	− 0.087	0.419
Pain intensity vs menstrual anterior pelvic tilt	+ 0.042	0.695

DISCUSSION

The present study found significant phase-dependent changes in lumbopelvic motion during forward bending among college students with primary dysmenorrhea. Strong statistical evidence of different movement patterns across the menstrual cycle was confirmed, as Friedman analysis demonstrated statistically significant phase-related differences in lumbar flexion and anterior pelvic tilt (both $p < 0.001$). Statistical analysis revealed that during the menstrual phase, lumbar flexion, anterior pelvic tilt and lumbopelvic ratio were reduced significantly, followed by restoration of mobility during other phases. Anterior pelvic tilt during menstruation had a larger standard deviation (3.55), indicating more individual variability. The lumbopelvic ratio was highest in the luteal phase. This variability may reflect individual differences in movement strategy and pain-related responses, although neuromuscular control was not directly assessed.

The reduction in lumbar flexion during menstruation is clinically meaningful because forward bending requires adequate spinal mobility and coordination with pelvic rotation. Pain-related motor adaptation may explain the observed pattern. Menstrual pain may be accompanied by protective movement strategies or altered muscle recruitment, which could contribute to reduced comfortable trunk excursion; however, these mechanisms were not directly assessed in the present study. Such guarding can reduce movement amplitude and alter coordination, even when the pain source is visceral rather than musculoskeletal. [11,17,20]

Anterior pelvic tilt also showed a significant phase effect, with lower values during menstruation and relatively stable values during the remaining phases. This suggests that menstrual-phase pain may restrict pelvic contribution during forward bending. Reduced pelvic motion may increase dependence on compensatory lumbar or hip strategies in some participants; however, the weak correlations between lumbar flexion and anterior pelvic tilt indicate considerable individual variability in movement strategies.

The weak association between pain intensity and movement variables {lumbar flexion ($r = -0.076$) and anterior pelvic tilt ($r = 0.085$)} suggest that Pain intensity was not significantly associated with lumbar flexion or anterior pelvic tilt. Other contributors may include neuromuscular control, pain tolerance, autonomic response, tissue sensitivity, physical activity level, and hormonal effects on connective tissue compliance. Neuromuscular control plays a major role in altered movement, where pain changes the timing of muscle activation and central motor planning. Pain-related alterations in motor control may influence the timing and coordination of trunk and pelvic musculature, potentially contributing to altered lumbopelvic

movement. However, muscle activation was not assessed in the present study. These neuromuscular adaptations may contribute to the observed alterations. The increased lumbar flexion observed in the follicular and luteal phases may reflect reduced pain-related guarding and changes in tissue extensibility, although hormonal levels were not directly measured in this study. [4,8,22,23,24]

Hormonal fluctuations across the menstrual cycle may influence connective-tissue properties and neuromuscular function and could potentially contribute to the observed phase-dependent changes. However, because hormonal concentrations and tissue laxity were not measured, this explanation remains speculative. [21,27,30]

These findings suggest that primary dysmenorrhea may be associated with phase-dependent alterations in functional lumbopelvic movement. These findings have practical implications for women's health physiotherapy. These findings suggest that menstrual phase should be considered when interpreting biomechanical assessments in women with primary dysmenorrhea. These findings may help inform future phase-sensitive rehabilitation research. This phase-sensitive approach may help reduce recurrent movement restriction and prevent secondary musculoskeletal complaints. [10,12]

The study has some limitations. It did not include a non-dysmenorrheic control group, menstrual phases were not confirmed using hormonal assays, and kinematics were assessed using clinical inclinometric methods rather than three-dimensional motion analysis. Basal Body Temperature (BBT), which was used to determine the ovulation phase, has low accuracy level and BBT fluctuations can be influenced by numerous factors, including fever, inflammation, stress, alcohol consumption, thermometer quality, and sleep disturbance.[9] The sample was limited to young college students from a single setting, and pain intensity was self-reported. Therefore, generalization to broader age groups or clinical populations should be made cautiously. Convenience sampling may also have introduced selection bias

Future studies should include a matched control group, hormonal verification of menstrual phases, electromyographic assessment of trunk and pelvic muscle activation, and three-dimensional motion analysis. Longitudinal interventional trials are recommended to evaluate whether phase-specific physiotherapy, motor-control training, and pain management strategies can normalize lumbopelvic ratio and improve functional outcomes in individuals with primary dysmenorrhea.

CONCLUSION

This study concludes that Women with primary dysmenorrhea demonstrated significant phase-dependent variation in lumbar flexion during forward bending, with the lowest lumbar flexion during menstruation. Anterior pelvic tilt also differed across phases, although the magnitude of change was smaller. The lumbopelvic ratio was closest to unity during menstruation and increased during the follicular and luteal phases. The absence of significant correlations between menstrual pain intensity and movement variables suggests that pain intensity alone may not account for the observed movement adaptations. These findings provide a rationale for future studies investigating whether menstrual-phase considerations should be incorporated into rehabilitation assessment and intervention for women with primary dysmenorrhea.

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Ethics Approval: This study was approved by the Departmental Research Committee of Brainware University (Approval No. BWU/AHS/NOC/DSC/2026/004) and was conducted according to the ethical standards of the 1964 Declaration of Helsinki.

Consent to Participate: Informed consent was obtained from all individual participants before data collection.

Consent for Publication: All the participants provided informed consent regarding the publication of collected data and study findings.

Data availability statements: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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Authors' Contributions:

Utpala Biswas: Conceptualization, Investigation, Data Collection, Writing-original draft.

Priyanka Nahak: Validation, Data Curation, Review and editing.

Diya Bhattacharyya: Statistical Analysis, Validation and Review.

Kundan Das Ukil (Corresponding Author): Methodology, Supervision, Final draft writing, review, and editing.

REPORTING GUIDELINE

STROBE Checklist: The STROBE checklist was used to evaluate the quality of this observational study.

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