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ORIGINAL RESEARCH

Association Between the Duration of the Second Stage of Labor and Postpartum Lateral Pelvic Tilt in Women with Singleton Cephalic Vaginal Delivery

Yang Xia[1], Hui Shao[2], Lie Wang[3], Junjiang Wu[3]

[1]Department of Radiation, Shaoxing Maternity and Child Health Care Hospital (Maternity and Child Health Care Affiliated Hospital, Shaoxing University), Shaoxing, Zhejiang Province, People's Republic of China; [2]Department of Infectology, Shaoxing Maternity and Child Health Care Hospital (Maternity and Child Health Care Affiliated Hospital, Shaoxing University), Shaoxing, Zhejiang Province, People's Republic of China; [3]Department of Obstetrics, Shaoxing Maternity and Child Health Care Hospital (Maternity and Child Health Care Affiliated Hospital, Shaoxing University), Shaoxing, Zhejiang Province, People's Republic of China

Correspondence: Junjiang Wu, Department of Obstetrics, Shaoxing Maternity and Child Health Care Hospital(Maternity and Child Health Care Affiliated Hospital, Shaoxing University), Shaoxing, Zhejiang Province, People's Republic of China, Email 15105850520@163.com

Objective: To investigate the association between the duration of the second stage of labor and postpartum lateral pelvic tilt and its underlying mechanisms in women with singleton cephalic vaginal deliveries.

Methods: In this retrospective cohort study, 4541 women with singleton cephalic vaginal deliveries were included. Participants were stratified by a second-stage duration cutoff of 1.5 hours, and 1:1 propensity score matching yielded 1406 matched pairs. Univariate and multivariate logistic regression were used to assess variable associations with lateral pelvic tilt. Three restricted multivariable logistic models evaluated the independent effect of second-stage duration, while restricted cubic splines tested for nonlinear relationships with postpartum lateral pelvic tilt. Subgroup analyses examined effect heterogeneity, and mediation models assessed the intermediary roles of delivery mode and oxytocin use.

Results: Both univariate and multivariate logistic regression analyses, including restricted multivariable models, consistently identified prolonged second-stage duration (≥1.5 hours) as an independent risk factor for lateral pelvic tilt (adjusted Odds Ratio [aOR] 1.34, 95% Confidence Interval [CI] 1.02–1.76, $P < 0.05$). Restricted cubic spline analysis revealed no significant nonlinear relationship ($P>0.05$). Subgroup analyses demonstrated enhanced associations among women undergoing operative vaginal delivery or receiving oxytocin. Mediation analysis confirmed delivery mode and oxytocin administration as significant mediating pathways, accounting for 11.07% and 13.09% of the total effect, respectively.

Conclusion: Prolonged second-stage labor constitutes an independent risk factor for postpartum lateral pelvic tilt, partially mediated through operative delivery and oxytocin administration. Early pelvic evaluation and targeted intervention are recommended for women experiencing extended second stage, particularly those requiring instrumental assistance or oxytocin augmentation.

Keywords: second stage of labor, pelvic lateral tilt, perinatal period, cephalic presentation, vaginal delivery

Introduction

The second stage of labor, defined as the period from complete cervical dilation to fetal delivery, represents a phase of intense mechanical stress on the maternal pelvic floor. A prolonged second stage is a well-established independent risk factor for postpartum pelvic floor dysfunction, including levator ani avulsion and subsequent pelvic organ prolapse.[1,2] While extensive research has elucidated its impact on soft tissues, the potential consequences for the bony pelvis and its biomechanical alignment remain largely unexplored. This gap is critical, as the pelvis serves as the foundational core structure linking the spine and lower extremities, and its stability is essential for posture, gait, and musculoskeletal health.

Pelvic obliquity, or lateral pelvic tilt, is a postural deviation characterized by an asymmetrical elevation of one iliac crest relative to the other. This condition is a recognized source of sacroiliac joint dysfunction, pregnancy-related pelvic girdle pain (PPP), low back pain, and functional leg-length discrepancy.[3–5] Critically, lateral pelvic tilt is not merely a transient

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postural issue but a biomechanical alteration with significant clinical implications. It disrupts the kinetic chain, potentially leading to compensatory scoliosis, chronic myofascial pain syndromes, and increased risk of osteoarthritis in the hip and knee joints over the long term.[6] In the postpartum context, the etiology of pelvic obliquity is often attributed to a combination of factors. Pre-existing musculoskeletal conditions (eg, scoliosis, leg length inequality, or pre-pregnancy sacroiliac joint dysfunction) and adaptive childcare postures (eg, habitual asymmetric baby carrying or feeding) are commonly cited.[7] However, the profound biomechanical forces inherent to childbirth itself represent a plausible yet under-investigated causative agent.[8] Prolonged fetal descent may lead to asymmetric neuromuscular fatigue and compensatory bearing-down efforts, while obstetric interventions such as instrumental delivery can impose direct, asymmetric forces on the sacroiliac joints and pubic symphysis, potentially resulting in joint dysfunction and malalignment.[9,10] Beyond pain, pelvic obliquity can significantly impair postpartum quality of life by causing functional limitations such as gait disturbances, difficulty in weight-bearing activities, challenges with childcare tasks, and chronic postural fatigue, which collectively contribute to prolonged recovery, maternal role strain, and increased healthcare utilization.[11]

Despite the plausible biomechanical connection between labor mechanisms and pelvic stability, current literature lacks direct evidence establishing the association between second-stage duration and postpartum pelvic obliquity. Existing research has primarily emphasized pain-related outcomes, failing to objectively quantify structural misalignment or control for the potential confounding effects of pre-pregnancy musculoskeletal status.[12] To isolate the effect of labor, it is methodologically crucial to account for these pre-existing factors through rigorous study design or statistical adjustment. Elucidating this relationship is essential for advancing the understanding of postpartum musculoskeletal disorders. Furthermore, understanding the specific biomechanical mechanism by which labor may induce pelvic obliquity is a critical step toward developing targeted preventive strategies and early rehabilitative interventions, which are vital for improving long-term musculoskeletal health and quality of life for postpartum women. Accordingly, this large-scale retrospective cohort study aims to investigate the association between second-stage labor duration and the incidence of postpartum pelvic obliquity in women with singleton cephalic deliveries, while employing statistical methods to account for key potential confounders.

Methods

The Study Setting and Design

This was a single-center, retrospective cohort study conducted at the Department of Obstetrics and Gynecology, Shaoxing Maternity and Child Health Care Hospital, Shaoxing, Zhejiang Province, China. The hospital is a tertiary care specialized maternity center serving a diverse urban and suburban population in Eastern China. The study utilized routinely collected clinical data from the hospital's electronic health record system.

The Study Population

The study included a total of 4,541 women with singleton cephalic presentations who underwent vaginal delivery at our institution between January 2024 and August 2025. Among them, 750 women were diagnosed with pelvic obliquity at the 42-day postpartum examination, while 3,791 women did not develop this condition. Representative X-ray images of patients with and without pelvic obliquity are presented in Figure 1. Lateral pelvic tilt was diagnosed based on the concurrent presence of all the following criteria: (1) radiographic evidence of pelvic obliquity on anteroposterior pelvic X-ray during the 42-day postpartum examination; (2) patient reports of persistent unilateral pain in the pelvic girdle, lower back, or groin region that developed between delivery and the 42-day postpartum examination, accompanied by gait abnormalities (eg, limping or instability) or functional leg-length discrepancy; and (3) physical examination findings of asymmetrical height between the bilateral posterior superior iliac spines (PSIS) or anterior superior iliac spines (ASIS) in a standing position. Therefore, participants were included in the lateral pelvic tilt group only if they fulfilled all three criteria, ensuring a high-specificity case definition. Figure 2 presents the participant screening and study inclusion flowchart, detailing the selection process from initial eligibility assessment to final analytical cohort formation.

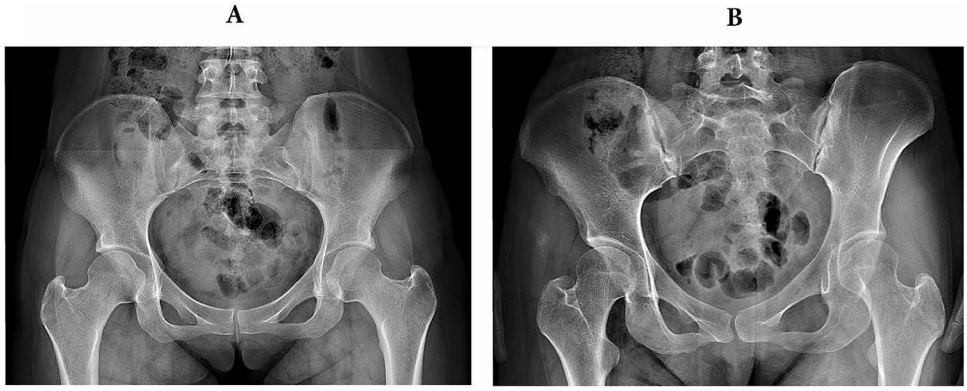

Figure 1 Postpartum pelvic X-ray comparisons. (**A**) Normal: Radiograph illustrating symmetric pelvic anatomy. (**B**) Obliquity: Radiograph illustrating characteristic asymmetry of the iliac wings, ischial spines, and obturator foramina, with lateral deviation of the sacrococcygeal axis.

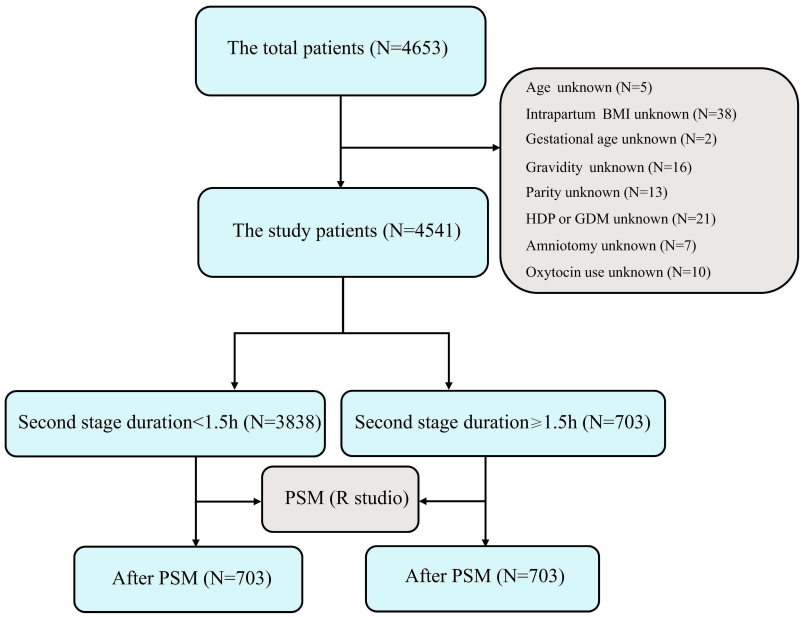

Figure 2 Flowchart of participant screening and study inclusion process.

Data Collection

We conducted a retrospective analysis of clinically routine data extracted from electronic medical records, nursing documentation, and postpartum health examination systems to examine maternal baseline characteristics. The extracted variables included maternal age, intrapartum body mass index (BMI), gestational age, gravidity, parity, neonatal birth weight, infant sex, gestational diabetes mellitus (GDM), hypertensive disorders of pregnancy (HDP), mode of vaginal delivery (spontaneous or operative), amniotomy, oxytocin use, duration of the second stage of labor, and presence of lateral pelvic tilt at the 42-day postpartum examination. Notably, retrospective data on pain recordings or specific gait abnormalities during pregnancy were not systematically available and thus were not included as covariates. In this study, the duration of the second stage of labor, initially a continuous variable, was dichotomized using a cutoff of 1.5 hours. This threshold was selected based on a dual rationale: (1) its alignment with established clinical benchmarks for defining prolonged labor, and (2) its approximation of the 75th percentile (Q75) of the second-stage duration distribution within our study cohort.[13] All data were meticulously reviewed by a team of experienced senior obstetricians and midwives to ensure accuracy. Given the relatively low proportion of missing data (<5% of cases), a complete-case analysis approach was adopted, whereby records with any missing variables were excluded from the final analysis.

Statistical Analysis

We performed comprehensive descriptive analyses for all study participants. Continuous variables are presented as mean ± standard deviation (SD) and were compared using *t*-tests, while categorical variables are expressed as percentages and were analyzed using chi-square tests. To enhance statistical power and minimize bias in this observational study, we employed propensity score matching with a 1:1 nearest-neighbor algorithm and a caliper width of 0.2.[14,15] Following matching, the standardized difference was used to evaluate balance between groups, with an absolute value below 10% indicating adequate balance in baseline characteristics. Both univariate and multivariate logistic regression analyses were conducted before and after propensity score matching to examine the association between second-stage labor duration and the occurrence of postpartum pelvic obliquity. Restricted cubic spline analysis was further performed to explore potential linear and nonlinear relationships between second-stage duration and pelvic obliquity. Subgroup analyses were carried out according to maternal age, intrapartum BMI, gestational age, parity, gravidity, pregnancy comorbidities, mode of delivery, neonatal birth weight, infant sex, amniotomy, and oxytocin use. For mediation analysis, we applied a Bayesian mediation analysis approach, which is widely used in observational studies to improve statistical power and reduce bias.[16,17] A p-value < 0.05 was considered statistically significant. All statistical analyses were performed using R software (version 4.4.1).

Results

Balance of Baseline Characteristics Before and After Propensity Score Matching in the Study Cohort

The study included a total of 4541 parturients (Table 1), among whom 3,838 (84.52%) had a second stage duration (SSD) of <1.5 hours and 703 (15.48%) had an SSD of ≥1.5 hours. Prior to 1:1 propensity score matching (PSM), significant differences ($p < 0.001$) were observed between the two groups in terms of maternal age, gestational age, neonatal birth weight, gravidity, parity, mode of delivery, and oxytocin use. Specifically, compared to the SSD <1.5-hour group, the SSD ≥1.5-hour group consisted of younger women (28.76 ± 3.14 years vs 29.29 ± 3.70 years), had a higher gestational age (39.46 ± 1.04 weeks vs 39.18 ± 1.22 weeks), delivered newborns with higher birth weight (3.34 ± 0.35 kg vs 3.27 ± 0.39 kg), and included a significantly greater proportion of primiparas (97.72% vs 72.49%). Additionally, the rate of operative vaginal delivery was significantly higher in the prolonged SSD group than in the control group (28.02% vs 10.53%). After PSM, 703 patients were included in each group, and all matched covariates (including age, intrapartum BMI, gestational age, neonatal birth weight, gravidity, parity, hypertensive disorders of pregnancy or diabetes mellitus, mode of delivery, infant sex, amniotomy, and oxytocin use) achieved good balance, with no statistically significant differences between groups ($p > 0.05$). Figure 3A illustrates the distribution of data before and after matching, while Figure 3B presents the standardized mean differences (SMD). All SMD values were below 0.1, indicating well-balanced baseline characteristics between the two groups after matching.

Univariate and Multivariate Logistic Regression Analysis of the Association Between Second Stage Duration and Lateral Pelvic Tilt

To examine the association between second-stage duration and other covariates with postpartum lateral pelvic tilt (LPT), we performed univariate and multivariate logistic regression analyses before and after propensity score matching (PSM) (Table 2). All variables were included in the multivariate model for adjustment. Before matching, univariate analysis indicated that mode of delivery (operative vaginal delivery vs spontaneous vaginal delivery: OR 1.36, 95% CI 1.10–1.69), oxytocin use (yes vs no: OR 1.28, 95% CI 1.08–1.53), and prolonged second-stage duration (SSD ≥1.5 h vs <1.5 h: OR 1.39, 95% CI 1.13–1.70) were significant risk factors for LPT ($P < 0.05$), while higher intrapartum BMI (OR 0.97, 95% CI 0.94–0.99) and multiparity (OR 0.80, 95% CI 0.66–0.97) showed protective effects. In the multivariate analysis, prolonged second-stage duration remained independently associated with an increased risk of LPT (aOR 1.23, 95% CI 1.01–1.52). Operative vaginal delivery (aOR 1.26, 95% CI 1.01–1.58) and oxytocin use (aOR 1.27, 95% CI 1.06–1.52) were also independent risk factors, whereas amniotomy (aOR 0.84, 95% CI 0.71–0.99) was associated with risk reduction. After matching, multivariate analysis continued to show a significant association between prolonged second-stage duration and LPT (aOR 1.34, 95% CI 1.02–1.76). Moreover, the effect sizes for operative

Table 1 Baseline Characteristics of the Study Population Before and After Propensity Score Matching

Variable	Before PSM				After PSM			
	Total (N = 4541)	SSD < 1.5h (N = 3838)	SSD ≥1.5h (N = 703)	P	Total (N = 1406)	SSD < 1.5h (N =703)	SSD ≥1.5h (N = 703)	P
Age, Mean ± SD	29.21 ± 3.62	29.29 ± 3.70	28.76 ± 3.14	<0.001	28.78 ± 3.16	28.81 ± 3.19	28.76 ± 3.14	0.742
Intrapartum BMI, Mean ± SD	26.48 ± 3.28	26.51 ± 3.27	26.33 ± 3.30	0.184	26.27 ± 3.19	26.22 ± 3.08	26.33 ± 3.30	0.032
Gestational age, Mean ± SD	39.23 ± 1.20	39.18 ± 1.22	39.46 ± 1.04	<0.001	39.46 ± 1.05	39.47 ± 1.05	39.46 ± 1.04	0.760
Infant birth weight, Mean ± SD	3.28 ± 0.39	3.27 ± 0.39	3.34 ± 0.35	<0.001	3.34 ± 0.35	3.33 ± 0.35	3.34 ± 0.35	0.037
Gravidity, n (%)				<0.001				0.415
< 3	3758 (82.76)	3103 (80.85)	655 (93.17)		1302 (92.6)	647 (92.03)	655 (93.17)	
≥ 3	783 (17.24)	735 (19.15)	48 (6.83)		104 (7.4)	56 (7.97)	48 (6.83)	
Parity, n (%)				<0.001				0.573
Primipara	3469 (76.39)	2782 (72.49)	687 (97.72)		1377 (97.94)	690 (98.15)	687 (97.72)	
Multipara	1072 (23.61)	1056 (27.51)	16 (2.28)		29 (2.06)	13 (1.85)	16 (2.28)	
HDP or GDM, n (%)				0.380				0.911
No	2892 (63.69)	2434 (63.42)	458 (65.15)		918 (65.29)	460 (65.43)	458 (65.15)	
Yes	1649 (36.31)	1404 (36.58)	245 (34.85)		488 (34.71)	243 (34.57)	245 (34.85)	
Mode of delivery, n (%)				<0.001				0.905
SVD	3940 (86.77)	3434 (89.47)	506 (71.98)		1014 (72.12)	508 (72.26)	506 (71.98)	
OVD	601 (13.23)	404 (10.53)	197 (28.02)		392 (27.88)	195 (27.74)	197 (28.02)	
Infant sex, n (%)				0.568				0.669
Male infant	2358 (51.93)	1986 (51.75)	372 (52.92)		736 (52.35)	364 (51.78)	372 (52.92)	
Female infant	2183 (48.07)	1852 (48.25)	331 (47.08)		670 (47.65)	339 (48.22)	331 (47.08)	
Amniotomy, n (%)				0.091				0.516
No	1801 (39.66)	1502 (39.13)	299 (42.53)		586 (41.68)	287 (40.83)	299 (42.53)	
Yes	2740 (60.34)	2336 (60.87)	404 (57.47)		820 (58.32)	416 (59.17)	404 (57.47)	
Oxytocin use, n (%)				<0.001				0.885
No	1419 (31.25)	1305 (34.00)	114 (16.22)		230 (16.36)	116 (16.50)	114 (16.22)	
Yes	3122 (68.75)	2533 (66.00)	589 (83.78)		1176 (83.64)	587 (83.50)	589 (83.78)	

Abbreviations: SSD, Second Stage Duration; HDP, Hypertensive Disorders of Pregnancy; GDM, Gestational Diabetes Mellitus; SVD, Spontaneous Vaginal Delivery; OVD, Operative Vaginal Delivery.

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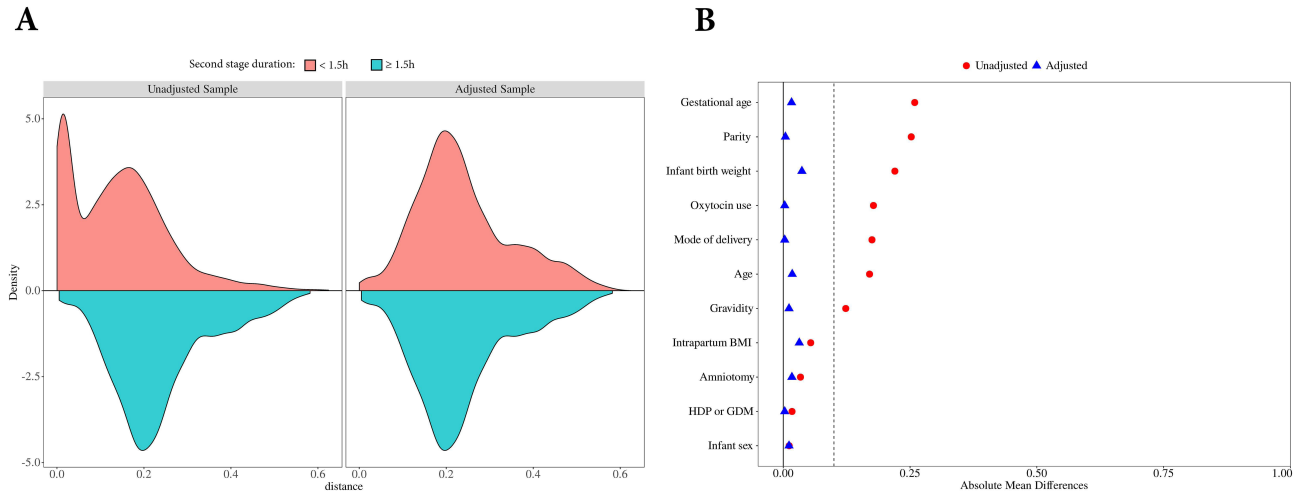

Figure 3 (**A**) illustrates the data distribution before and after PSM, while (**B**) presents the standardized mean difference (SMDs) values before and after matching. The results provided an intuitive visualization of balance improvement across all variables, clearly demonstrating that all post-PSM SMDs were below 0.1.

vaginal delivery (aOR 1.49, 95% CI 1.10–2.00) and oxytocin use (aOR 2.15, 95% CI 1.38–3.35) were even higher than before matching and remained statistically significant. Intrapartum BMI (aOR 0.95, 95% CI 0.90–0.99) and amniotomy (aOR 0.74, 95% CI 0.55–0.99) also demonstrated independent protective effects. In summary, a second-stage duration of ≥1.5 hours is an independent risk factor for postpartum lateral pelvic tilt. Operative vaginal delivery and oxytocin use are also significantly associated with an increased risk of LPT.

Table 2 Univariate and Multivariate Logistic Regression Analysis of Second Stage Duration and Lateral Pelvic Tilt

Variable	Before PSM				After PSM			
	Univariate Logistic		Multivariable Logistic		Univariate Logistic		Multivariable Logistic	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Age	1.00 (0.98–1.02)	0.982	1.01 (0.98–1.03)	0.501	1.04 (1.01–1.09)	0.043	1.05 (1.01–1.09)	0.050
Intrapartum BMI	0.97 (0.94–0.99)	0.005	0.96 (0.94–0.99)	0.005	0.96 (0.92–1.00)	0.079	0.95 (0.90–0.99)	0.017
Gestational age	1.02 (0.95–1.09)	0.561	1.03 (0.95–1.11)	0.528	1.01 (0.89–1.15)	0.901	1.04 (0.89–1.21)	0.645
Infant birth weight	0.98 (0.80–1.19)	0.808	1.00 (0.77–1.29)	0.985	1.07 (0.73–1.58)	0.725	1.23 (0.78–1.92)	0.369
Gravidity								
< 3	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
≥ 3	0.84 (0.67–1.04)	0.105	0.94 (0.72–1.23)	0.649	0.98 (0.59–1.65)	0.951	1.06 (0.61–1.85)	0.841
Parity								
Primipara	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Multipara	0.80 (0.66–0.97)	0.024	0.93 (0.72–1.20)	0.575	0.70 (0.24–2.03)	0.512	0.58 (0.18–1.86)	0.361
HDP or GDM								
No	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Yes	0.98 (0.83–1.15)	0.781	1.03 (0.87–1.22)	0.722	1.17 (0.89–1.55)	0.263	1.30 (0.97–1.73)	0.078
Mode of delivery								
SVD	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
OVD	1.36 (1.10–1.69)	0.005	1.26 (1.01–1.58)	0.041	1.45 (1.09–1.93)	0.012	1.49 (1.10–2.00)	0.009
Infant sex								
Male infant	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Female infant	1.00 (0.86–1.17)	0.971	1.01 (0.86–1.18)	0.927	0.98 (0.75–1.29)	0.902	0.98 (0.74–1.29)	0.859

(*Continued*)

Table 2 (Continued).

Variable	Before PSM				After PSM			
	Univariate Logistic		Multivariable Logistic		Univariate Logistic		Multivariable Logistic	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Amniotomy								
No	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Yes	0.88 (0.75–1.03)	0.110	0.84 (0.71–0.99)	0.038	0.85 (0.65–1.11)	0.229	0.74 (0.55–0.99)	0.041
Oxytocin use								
No	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
Yes	1.28 (1.08–1.53)	0.005	1.27 (1.06–1.52)	0.011	2.05 (1.32–3.18)	0.001	2.15 (1.38–3.35)	<0.001
Second stage duration								
< 1.5 h	1.00 (Reference)		1.00 (Reference)		1.00 (Reference)		1.00 (Reference)	
≥ 1.5 h	1.39 (1.13–1.70)	0.001	1.23 (1.01–1.52)	0.049	1.33 (1.01–1.74)	0.040	1.34 (1.02–1.76)	0.039

Abbreviations: HDP, Hypertensive Disorders of Pregnancy; GDM, Gestational Diabetes Mellitus; SVD, Spontaneous Vaginal Delivery; OVD, Operative Vaginal Delivery.

Hierarchical Regression Analysis of Second Stage Duration and Lateral Pelvic Tilt

We constructed three progressively adjusted multivariate logistic regression models (Table 3). Model 1 was an unadjusted crude mo Model 2 was adjusted for basic demographic and neonatal characteristics (maternal age, intrapartum BMI, gestational age, and neonatal birth weight); Model 3 was further fully adjusted for obstetric-related variables (gravidity, parity, hypertensive disorders of pregnancy or diabetes mellitus, mode of delivery, infant sex, amniotomy, and oxytocin use). Before PSM, the crude model (Model 1) showed that prolonged second-stage duration (SSD ≥1.5 h) was significantly associated with the risk of lateral pelvic tilt (OR = 1.39, 95% CI: 1.13–1.70, p = 0.001). After adjusting for demographic and neonatal characteristics in Model 2, the association was only slightly attenuated (OR = 1.38, 95% CI: 1.12–1.69, p = 0.002). When further adjusting for obstetric confounders in Model 3, prolonged SSD remained an independent risk factor for lateral pelvic tilt, although the effect size was reduced (aOR = 1.23, 95% CI: 1.01–1.52, p = 0.049). After PSM, the results of the three models demonstrated good consistency and stronger robustness. In Model 1, the OR for SSD ≥1.5 h was 1.33 (95% CI: 1.01–1.74, p = 0.040). In both the adjusted Model 2 (aOR = 1.34, 95% CI: 1.02–1.76, p = 0.036) and the fully adjusted Model 3 (aOR = 1.34, 95% CI: 1.02–1.76, p = 0.039), the effect estimates remained stable and statistically significant. In summary, these analyses confirm that a second-stage duration of ≥1.5 hours is an independent risk factor for postpartum lateral pelvic tilt, and this association remains stable after controlling for multiple potential confounding factors.

Table 3 Multi-Model Logistic Regression Analysis of Second Stage Duration and Lateral Pelvic Tilt

Model	Second Stage Duration	Before PSM		After PSM	
		OR (95% CI)	P	OR (95% CI)	P
Model 1	< 1.5 h	1.00 (Reference)		1.00 (Reference)	
	≥ 1.5 h	1.39 (1.13–1.70)	0.001	1.33 (1.01–1.74)	0.040
Model 2	< 1.5 h	1.00 (Reference)		1.00 (Reference)	
	≥ 1.5 h	1.38 (1.12–1.69)	0.002	1.34 (1.02–1.76)	0.036
Model 3	< 1.5 h	1.00 (Reference)		1.00 (Reference)	
	≥ 1.5 h	1.23 (1.01–1.52)	0.049	1.34 (1.02–1.76)	0.039

Notes: Model1: Crude. Model2: Adjust: Age, Intrapartum BMI, Gestational age, Infant birth weight. Model3: Adjust: Age, Intrapartum BMI, Gestational age, Infant birth weight, Gravidity, Parity, HDP or GDM, Mode of delivery, Infant sex, Amniotomy, Oxytocin use.

Subgroup Analyses Before and After Propensity Score Matching

To evaluate the robustness and potential effect modification of the association between second-stage duration and lateral pelvic tilt, we conducted systematic subgroup analyses. The results demonstrated a significant association between second-stage duration and lateral pelvic tilt risk before PSM (Figure 4A; OR = 1.39, 95% CI: 1.13–1.70). This association was consistent across multiple subgroups, with particularly pronounced effect sizes observed among women aged ≥30 years, those with hypertensive disorders of pregnancy or diabetes mellitus, and those who underwent operative vaginal delivery (OR = 1.61 and 1.91, respectively). Notably, a negative association was observed in the subgroup without oxytocin use (OR = 0.37, 95% CI: 0.17–0.81), and interaction testing suggested that oxytocin use may be an important effect modifier (P for interaction < 0.05). After PSM (Figure 4B), the overall association remained significant (OR = 1.33, 95% CI: 1.01–1.74). The operative vaginal delivery subgroup continued to show the strongest risk effect (OR = 1.83, 95% CI: 1.13–2.97), while the subgroup with neonatal birth weight ≥3 kg also exhibited a significant association (OR = 1.42, 95% CI: 1.06–1.91). The protective effect in the no-oxytocin subgroup persisted (OR = 0.36, 95% CI: 0.14–0.89). Comprehensive analysis indicates that the positive association between prolonged second-stage duration and lateral pelvic tilt is most pronounced and stable in women undergoing operative vaginal delivery, those receiving oxytocin, and those delivering newborns with higher birth weight. A significant interaction exists between oxytocin use and prolonged second-stage duration, collectively influencing the risk of lateral pelvic tilt.

Restricted Cubic Spline Analysis of the Relationship Between Second Stage Duration and Lateral Pelvic Tilt

Restricted cubic spline analysis revealed a significant overall association between second-stage duration and lateral pelvic tilt in the unadjusted model before PSM (Figure 5A; P overall < 0.001), with no significant nonlinear trend (P nonlinear = 0.086). The fully adjusted model before PSM also showed a significant overall association (Figure 5B; P overall = 0.013) without significant nonlinearity (P nonlinear = 0.444). After PSM, the unadjusted model maintained a significant overall association (Figure 5C; P overall = 0.003) with no significant nonlinear trend (P nonlinear = 0.101). Similarly, the fully adjusted model after PSM demonstrated a significant overall association (Figure 5D; P overall = 0.023) with no statistically

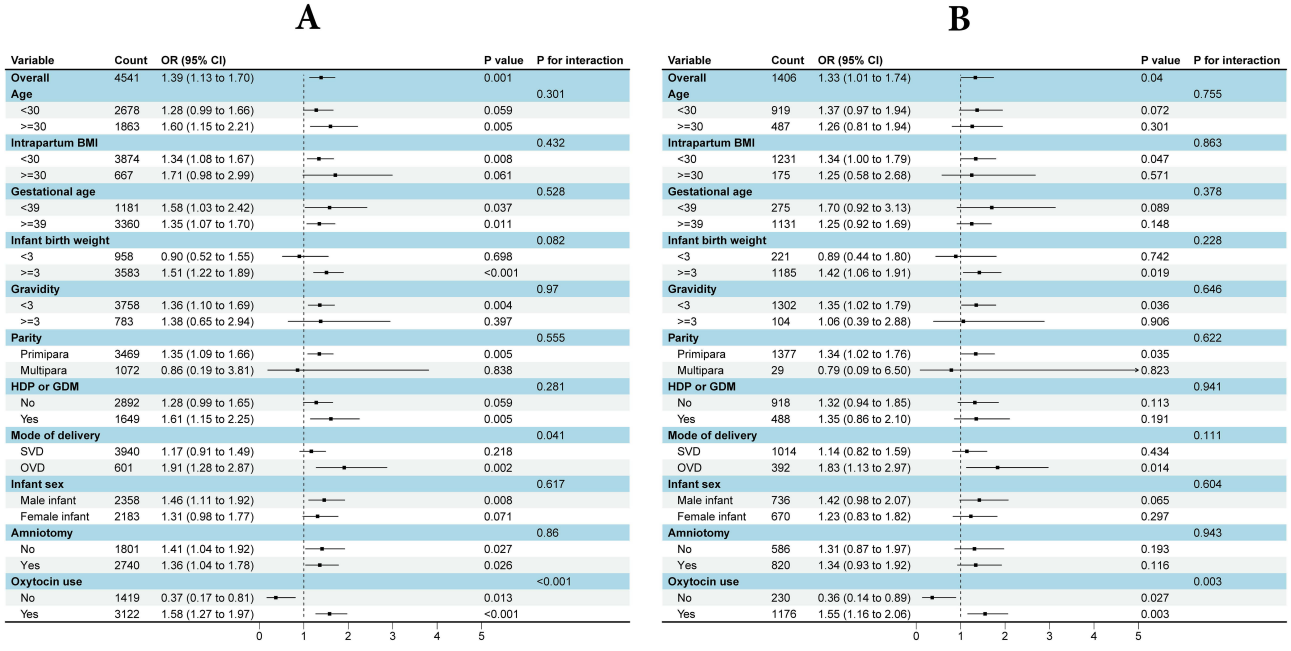

Figure 4 (**A**) Before PSM, subgroup analysis of the relationship between second stage duration and lateral pelvic Tilt. (**B**) After PSM, subgroup analysis of the relationship between second stage duration and lateral pelvic Tilt.

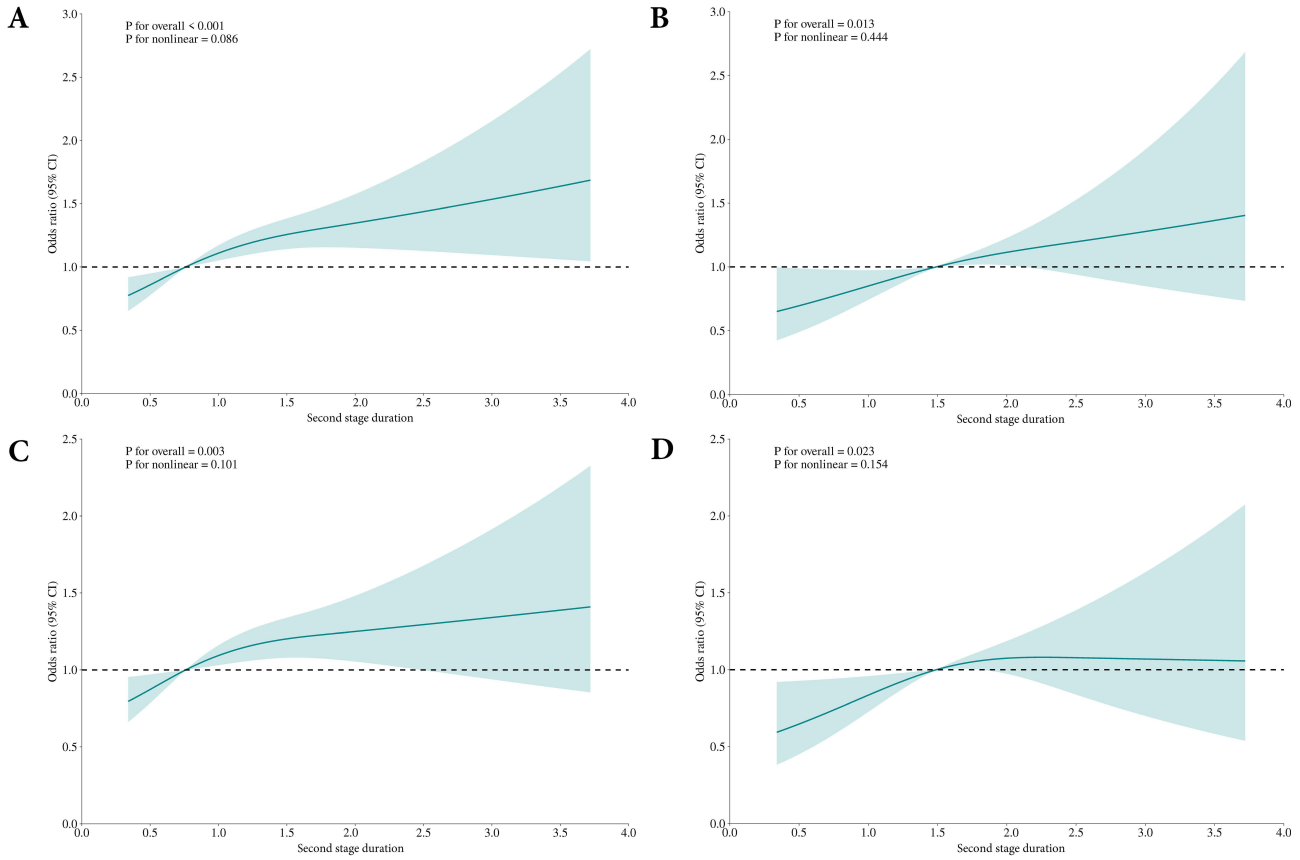

Figure 5 (**A**) Before PSM, RCS analysis of the association between second-stage duration and lateral pelvic tilt, based on the unadjusted Model 1. (**B**) Before PSM, RCS analysis of the association between second-stage duration and lateral pelvic tilt, based on the fully adjusted Model 3. (**C**) After PSM, RCS analysis of the association between second-stage duration and lateral pelvic tilt, based on the unadjusted Model 1. (**D**) After PSM, RCS analysis of the association between second-stage duration and lateral pelvic tilt, based on the fully adjusted Model 3.

significant nonlinear relationship (P nonlinear = 0.154). All models consistently indicated a significant dose-response relationship between second-stage duration and lateral pelvic tilt risk. This association consistently followed a linear pattern, with no significant nonlinear trends detected under any analytical conditions.

Mediation Effect Analysis

To investigate the underlying mechanisms through which second-stage duration affects lateral pelvic tilt, we performed mediation analysis focusing on the potential mediating roles of delivery mode and oxytocin use. The results (Figure 6A) demonstrated a significant mediating effect of delivery mode in the association between second-stage duration and lateral pelvic tilt, with a mediation effect value of 0.005 (95% CI: 0.002–0.009, $P < 0.05$), accounting for 11.072% of the total effect (0.040). After controlling for this mediation pathway, the direct effect of second-stage duration remained significant (effect value = 0.035, 95% CI: 0.004–0.072, $P < 0.05$). Similarly (Figure 6B), oxytocin use also exhibited a significant mediating effect, with an effect value of 0.005 (95% CI: 0.002–0.008, $P < 0.05$), explaining 13.089% of the total effect (0.041). After accounting for this pathway, the direct effect of second-stage duration continued to be significant (effect value = 0.036, 95% CI: 0.005–0.073, $P < 0.05$). In summary, the effect of second-stage duration on lateral pelvic tilt is partially mediated through specific delivery modes and oxytocin use, with these two pathways explaining approximately 11% and 13% of the total effect, respectively, while the majority of the effect remains direct.

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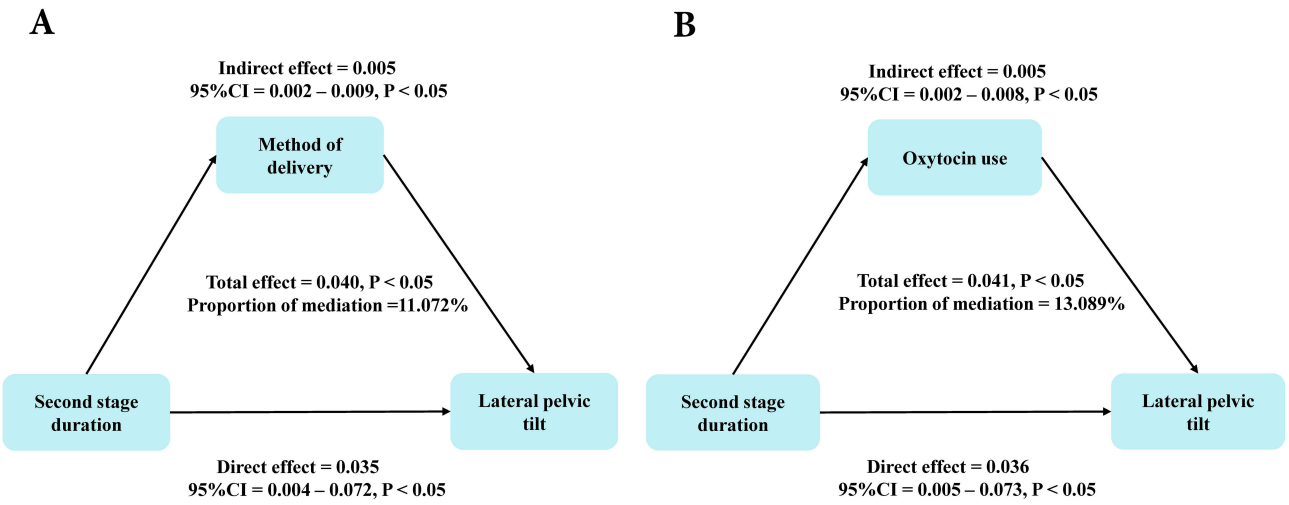

Figure 6 Examining the relationship between the mode of delivery (**A**) and oxytocin use (**B**) as mediators of second stage duration and lateral pelvic tilt.

Discussion

This study presents a systematic investigation into the association between the duration of the second stage of labor and postpartum lateral pelvic tilt. We identified a prolonged second stage as an independent risk factor for this condition, a novel finding that offers relevant insights for clinical postpartum rehabilitation. Multi-model logistic regression confirmed a significantly elevated risk of lateral pelvic tilt when the second stage lasted ≥1.5 hours. This finding is consistent with the work of Aldabe et al, which underscored the considerable influence of intrapartum mechanical factors on postpartum pelvic stability.[18] Moreover, a significant linear dose-response relationship was observed between the duration of the second stage and the degree of lateral pelvic tilt, aligning with recent reports by Gutke et al suggesting a continuous relationship between labor duration and pelvic biomechanical alterations.[19] Subgroup analyses further revealed that this association was strongest in women who underwent operative vaginal delivery or received oxytocin, thereby corroborating the hypothesis put forward by Kearney et al that asymmetric traction during instrumental delivery can directly induce changes in pelvic biomechanics.[20] From a biomechanical standpoint, the hypothesized mechanism can be elucidated through both musculoskeletal and neurological pathways. Musculoskeletally, prolonged bearing-down efforts, especially if asymmetrical, can lead to differential fatigue and strain in the pelvic floor muscles (eg, levator ani) and supporting ligaments (eg, sacroiliac and sacrotuberous ligaments), resulting in a functional leg-length discrepancy and iliac crest elevation. Neurologically, sustained mechanical compression and ischemia during prolonged descent may affect the lumbosacral plexus or superior gluteal nerve, compromising motor control to the gluteus medius and minimus —key stabilizers of pelvic alignment.[21] This neuromuscular dysfunction could manifest as a Trendelenburg-like gait and sustained postural compensation, ultimately crystallizing as a structural lateral pelvic tilt.[22]

Through mediation analysis, we further elucidated specific mechanisms by which the second stage influences lateral pelvic tilt. Delivery mode and oxytocin use were found to mediate 11.07% and 13.09% of the total effect, respectively. These observations are supported by multiple studies. Research by Nicola et al indicated that oxytocin-induced strong contractions significantly increase stress loading on pelvic ligaments,[23,24] while Hilde et al confirmed a close relationship between delivery mode and pelvic stability.[25,26] Notably, our study identified a significant interaction between oxytocin use and prolonged second stage, likely because oxytocin-induced intense contractions combined with prolonged labor jointly exacerbate mechanical strain on pelvic tissues. From a clinical perspective, the findings of this study carry important practical implications. Based on our results, we recommend implementing early pelvic assessment for women experiencing prolonged second stage of labor, particularly those requiring operative vaginal delivery or oxytocin administration. This risk stratification approach aligns with the postpartum pelvic health management concepts proposed in previous studies. Chen et al have emphasized the importance of postpartum pelvic assessment,[27] while Bazi et al have

demonstrated the effectiveness of early intervention in preventing long-term pelvic complications.[28] Furthermore, existing evidence supports the necessity of targeted interventions for high-risk populations.[29]

Our study has several methodological strengths. We implemented a range of statistical techniques—propensity score matching, multi-model logistic regression, restricted cubic splines, and mediation analysis—that cross-validated one another, thereby strengthening the robustness of our conclusions.[30] This multifaceted strategy highlights the critical role of multi-model methodology in modern obstetric studies.[31] Nonetheless, some limitations warrant acknowledgment. First, the retrospective nature of this work means that residual confounding factors cannot be fully dismissed. Second, the results from our single-center cohort may not be fully generalizable. Future investigations should therefore focus on: uncovering further mediating factors like nerve injury or inflammatory responses; launching multicenter prospective studies to confirm our observations; and conducting long-term follow-ups to determine the durability of early interventional effects on pelvic function.

Conclusion

This research systematically investigated the association between a prolonged second stage of labor and postpartum lateral pelvic tilt in women with singleton cephalic presentations undergoing vaginal delivery. The study revealed that a -prolonged second stage significantly increased the risk of lateral pelvic tilt. This association was particularly pronounced among women who underwent operative vaginal delivery or received oxytocin augmentation. These findings provide important evidence for the clinical identification of high-risk populations. It is recommended that women with a -prolonged second stage, especially those who also undergo operative vaginal delivery or receive oxytocin, be considered a high-risk group for lateral pelvic tilt and receive targeted pelvic assessment and early rehabilitative intervention.

Abbreviations

SSD, Second Stage Duration; LPT, lateral pelvic tilt; HDP, Hypertensive Disorders of Pregnancy; GDM, Gestational Diabetes Mellitus; BMI, body mass index; SVD, Spontaneous Vaginal Delivery; OVD, Operative Vaginal Delivery; PSM, propensity score matching.

Data Sharing Statement

Relevant data from this study can be obtained from the corresponding author.

Ethics Statement

This retrospective study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Shaoxing Maternal and Child Health Hospital (IRB-AF-023-01.5). The research involved analysis of anonymized medical records and did not include human participants or animal trials. The ethics committee waived the requirement for informed consent given the retrospective nature of the study. All data were handled in compliance with institutional guidelines and regulations for patient data confidentiality.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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