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Article

A biomechanical perspective on KAP characterization and intervention strategies for anxiety in pregnancy

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Abstract: In order to explore the biomechanical interactions between postural adaptation in pregnant women and the Knowledge-Attitude-Practice (KAP) model of prenatal anxiety in Southwest China, this cross-sectional study integrated psychometric assessments with kinematic analysis and conducted a survey among pregnant women in Nanchong between September and November 2022. A web-based questionnaire was employed to collect data on demographic characteristics, biomechanical features, prenatal anxiety KAP scores, and anxiety status. A total of 515 valid questionnaires were recovered, and 120 women (23.30%) had anxiety. The mean knowledge, attitude, and practice scores were 5.59 ± 2.73 (possible range: 0–9), 33.59 ± 4.36 (possible range: 10–50), and 21.85 ± 3.77 (possible range: 6–30). College or above education (OR = 3.66, 95% CI: 1.88–7.13, $P < 0.001$) and planned pregnancy (OR = 0.60, 95% CI: 0.37–0.99, $P = 0.046$) were independently associated with better knowledge. Without a history of adverse pregnancy (OR = 0.64, 95% CI: 0.42–0.95, $P = 0.029$) and freelancer (OR = 0.46, 95% CI: 0.26–0.80, $P = 0.007$) were independently associated with a favorable attitude. The knowledge (OR = 1.71, 95% CI: 1.01–2.89, $P = 0.047$) and attitude (OR = 0.54, 95% CI: 0.33–0.89, $P = 0.016$) were independently associated with anxiety. Pregnant women had a moderate KAP toward prenatal anxiety. It is recommended to learn about it and applying biomechanical knowledge to positive practices may help prevent prenatal anxiety.

Keywords: biomechanics; kinematic analysis; anxiety; prenatal; knowledge, attitudes, and practice; pregnant women; cross-sectional study

1. Introduction

Pregnancy is probably the most stressful event in a woman's life due to fears, the unknown, and expectations [1], and psychologists often describe pregnancy as an emotional crisis [2,3]. If the crisis is improperly managed/controlled, it can have a myriad of undesirable effects on the mother's and baby's health [4], such as, reduced physical mobility. The prevalence of anxiety disorder during pregnancy is 10% and 25% in developed and developing countries, respectively [4,5]. Severe anxiety and mood disorders during pregnancy can have adverse effects on the mother and baby 3, including impaired maternal-infant bonding and risks of maternal self-harm and neglect [6–8]. Prenatal anxiety can also affect the child's health [9].

The American College of Obstetricians and Gynecologists (ACOG) and the National Institute for Health and Clinical Excellence (NICE) recommend that obstetrician-gynecologists and other obstetrics care providers should screen patients

at least once during the prenatal period for depression and anxiety symptoms using standardized, validated tools, and the patients screened for depression or anxiety during pregnancy should receive additional screening during the comprehensive postpartum visit [10]. Physician-patient communication can influence prenatal stress [11,12]. The management depends upon anxiety severity and ranges from self-coping to medical interventions. Music therapy during pregnancy may reduce stress, anxiety, and depression [13], including in women with high-risk pregnancies [14]. Cognitive behavioral therapy (CBT), relaxation, and mindfulness therapy can be used to treat mild anxiety [15,16]. Moderate/severe anxiety requires pharmacotherapy and CBT, alone or in combination [15,16].

Biomechanical research in pregnancy typically involves the study of alterations in body structure, movement patterns, and hormonal influences. As pregnancy progresses, significant structural changes occur in the maternal body, such as an increase in uterine volume, an anterior shift of the center of gravity, and corresponding adaptive modifications in the pelvis and spine [17]. These changes not only modify the static posture of pregnant women but also profoundly affect their dynamic movement patterns, including adjustments in gait, balance, and muscular strength [18]. Research [19] has revealed that alterations in the distribution of the center of gravity and joint loading across different stages of pregnancy are associated with gait instability and increased lumbar burden, which in turn may elevate the physical strain and contribute to heightened anxiety.

Concurrently, fluctuations in hormone levels during pregnancy—particularly the marked elevations in relaxin, estrogen, and progesterone—directly influence ligament laxity and joint stability [20]. These hormonally mediated biochemical changes render the joints and ligaments more vulnerable to damage under increased load, thereby further impacting the motor function and safety of pregnant women. Moreover, hormones are recognized as one of the key factors in the development of anxiety disorders [21].

In summary, the biomechanical perspective not only enhances our understanding of the complex physiological and kinematic changes during pregnancy but also provides novel insights and methodologies for elucidating the etiology of prenatal anxiety, as well as for the management of maternal health, disease prevention, and rehabilitation.

The self-recognition and the self-management of prenatal stress before it is too late and professional help is necessary necessitate proper knowledge about the signs and symptoms of prenatal stress and the coping and management methods. Being aware of the possible complications and impacts can also help motivate women to take care of themselves and cultivate a calming attitude. Identifying the gaps in knowledge and the motivational factors could help design interventions to improve prenatal stress management.

A knowledge, attitudes, and practice (KAP) survey is a structured approach to investigate the knowledge level and behavior of specific individuals toward a specific subject. A KAP survey provides quantitative and qualitative data that can be used to identify gaps in knowledge and behavior toward the studied subject and design future teaching and training activities [22,23]. Recent studies examined anxiety and its influence factors among pregnant women during the COVID-19 pandemic [24,25],

and a previous study confirmed that improving the knowledge of complications is associated with less prenatal anxiety [26]. Still, the KAP toward prenatal anxiety among pregnant women in China remains unknown.

Therefore, this study aimed to investigate the KAP of pregnant women in the Nanchong area (Southwest China) for prenatal anxiety.

2. Materials and methods

2.1. Study design and participants

This cross-sectional study was conducted among pregnant women in Nanchong between September and November 2022, and incorporates biomechanically relevant investigations in it. Biomechanics-related data collection in the form of a questionnaire. The inclusion criteria were 1) pregnant women with a gestational age of 12–38 weeks, 2) no history of psychiatric disorder, and 3) voluntary participation in this study. The exclusion criteria were 1) severe infection during pregnancy and 2) known fetal malformations. The questionnaires were handed and collected through "Sojump" (www.wjx.cn), a platform made to design and distribute online forms and questionnaires. The researchers sent the questionnaire link or QR code to pregnant women through social media, and the participants could scan the QR code or click on the link to complete the questionnaires. The valid questionnaires were those with no missing answers, without an obvious filling pattern (e.g., all first choices), and that took > 3 min to complete. A given IP address could only submit one questionnaire.

This work has been carried out in accordance with the Declaration of Helsinki (2000) of the World Medical Association. This study was approved by the Medical Ethics Committee of the Affiliated Hospital of North Sichuan Medical College (2022ER323-1). All participants provided written informed consent before completing the survey.

2.2. Questionnaire

The questionnaire was developed in three phases, and face and content validity were assessed [27]. The first phase was a literature review that was performed in PubMed, EMBASE, and Web of Science from their inception to January 2022. The keywords were "knowledge", "attitude", "practice", "pregnancy", "biomechanics", "body posture", "movement patterns", "hormones", "stress", and "prenatal stress". The Boolean operators AND and OR were used to increase the sensitivity and specificity of the search. In phase II, the questionnaire was designed by the investigators based on previous studies on prenatal stress [28,29]. In phase III, the questionnaire was distributed to a small number of women (50 copies) to determine face and content validity, revealing a reliability of 0.792.

The final questionnaire was in Chinese and included four dimensions: demographic data (age, gestational age, number of gestation, adverse maternal history, place of residence, nationality, education level, type of occupation, income level, comorbidities, type of medical insurance, and unplanned pregnancy), as well as the knowledge dimension, attitude dimension, and practice dimension, which incorporate biomechanics, for a total of 4 dimensions. There were 11 items in the knowledge

dimension; 1 point was awarded for correct answers in knowledge dimensions, and 0 points were awarded for incorrect answers. Question 9 was used to screen valid questionnaires. The total score ranged from 0 to 9 points. The attitude dimension contained 11 questions answered using a five-point Likert scale. Among them, items A5, A6, A9 and A11 were positive from strongly agree (5 points) to strongly disagree (1 point), while the other questions were negative from strongly agree (1 point) to strongly disagree (5 points). The total score ranged from 10 to 50 points. The practice dimension consisted of 7 items answered using a five-point Likert scale, from always (5 points) to never (1 point). The total score ranged from 6 to 30 points.

The participants were evaluated for anxiety using the Self-Rating Anxiety Scale (SAS), with a total of 20 questions, with 15 increasing anxiety level questions and five decreasing anxiety questions [30]. Each question was scored between 1 and 4 points, and the total score after adding the scores of all questions was multiplied by 1.25 to get the standard scores. Participants with standard scores > 50 had anxiety symptoms. The SAS has satisfactory psychometric properties, including internal consistency (Cronbach's α = 0.82), concurrent validity, and discrimination between anxiety and other psychiatric disorders [31].

2.3. Statistical analysis

STATA 17.0 (STATA Corp., College Station, TX, USA) was used for statistical analysis. The continuous data were tested for normal distribution using the Kolmogorov-Smirnov test. The continuous data with a normal distribution were presented as means ± standard deviations and analyzed using Student's t-test or one-way ANOVA. Categorical data were presented as *n* (%) and analyzed using the chi-square test. Correlations between knowledge, attitudes, and practice scores for the included biomechanics survey were analyzed using the Pearson correlation test. Multifactorial logistic regression analyses were performed with knowledge scores, attitude scores, practice scores (converted to a binary variable based on 70% of the subjects' scores), and anxiety, which took into account the effects of biomechanics, as dependent variables. The variables with $P < 0.05$ in univariable analyses were included in the multivariable logistic regression. A structural equation model (SEM) analysis was performed to examine the relationships among KAP dimensions. The SEM was based on the following hypotheses, which were based on the KAP theory 17,18: H1) knowledge directly influences attitudes; H2) knowledge directly influences practice; H3: attitude directly influences practice. A two-sided $P < 0.05$ was considered statistically significant.

3. Results

3.1. Demographical characteristics

A total of 559 questionnaires were distributed, and 515 valid questionnaires were recovered, with an effective rate of 92.13%. Among them, 120 (23.30%) suffered from anxiety. Most women were 25.1–30 years of age (49.32%), were at <25 gestational weeks (57.26%), were not at their first pregnancy (57.77%), had no history of adverse pregnancy (57.57%), were of Han ethnicity (99.22%), lived in urban areas (76.89%),

were employed (41.55%), had a junior college education or above (67.77%), had a monthly income <5000 (46.41%), had no comorbidities (92.04%), had medical insurance (98.06%) and had a planned pregnancy (55.92%) (**Table 1**). Compared with women not at their first pregnancy, those at their first pregnancy were younger ($P < 0.001$), had a smaller frequency of previous adverse pregnancy events ($P < 0.001$), showed differences in occupation ($P = 0.045$), and had a higher education ($P = 0.001$), but there were no differences in the frequency of anxiety ($P = 0.395$) (**Table 2**).

Table 1. Demographic characteristics and KAP scores of participants.

Variables	*n* (%)	Knowledge scores		Attitude scores		Practice scores	
		Mean ± SD	*P*	Mean ± SD	*P*	Mean ± SD	*P*
Total scores	515 (100.00)	5.59 ± 2.73		33.59 ± 4.36		21.85 ± 3.77	
Anxiety			< 0.001		< 0.001		0.139
Yes	120 (23.30)	6.37 ± 2.47		31.97 ± 4.06		21.38 ± 3.97	
No	395 (76.70)	5.35 ± 2.76		34.08 ± 4.34		22.00 ± 3.71	
Age			0.264		0.468		< 0.001
≤ 25	68 (13.20)	5.40 ± 3.21		32.97 ± 4.53		20.19 ± 3.99	
25–30	254 (49.32)	5.79 ± 2.63		33.61 ± 4.30		22.18 ± 3.79	
> 30	193 (37.48)	5.39 ± 2.66		33.77 ± 4.38		22.01 ± 3.54	
Gestational age (weeks)			0.261		0.151		0.531
≤ 25	288 (57.26)	5.75 ± 2.63		33.79 ± 4.23		21.95 ± 3.73	
> 25	215 (42.74)	5.41 ± 2.82		33.23 ± 4.47		21.66 ± 3.84	
Gestational history			0.475		0.407		0.002
First	212 (42.23)	5.72 ± 2.67		33.21 ± 4.23		21.19 ± 3.78	
Non-first	290 (57.77)	5.54 ± 2.72		33.77 ± 4.33		22.29 ± 3.74	
Adverse pregnancy history			0.865		0.050		0.262
Yes	213 (42.43)	5.63 ± 2.54		33.22 ± 4.17		22.12 ± 3.73	

Table 2. Characteristics of the participants according to para.

Variables	First pregnancy, *n* (%)	Non-first pregnancy, *n* (%)	*P*
	n = 212	*n* = 290	
Anxiety			0.395
Yes	54 (25.47)	64 (22.07)	
No	158 (74.53)	226 (77.93)	
Age			< 0.001
≤ 25	45 (21.23)	22 (7.59)	
25–30	129 (60.85)	120 (41.38)	
> 30	38 (17.92)	148 (51.03)	
Gestational age (weeks)			0.846
≤ 25	121 (57.62)	164 (56.75)	
> 25	89 (42.38)	125 (43.25)	
Adverse pregnancy history			<0.001
Yes	18 (8.46)	192 (66.21)	

Table 2. (*Continued*).

Variables	First pregnancy, *n* (%)	Non-first pregnancy, *n* (%)	*P*
	n = 212	*n* = 290	
No	193 (91.04)	95 (32.76)	
Nationality			0.480
Han	210 (99.06)	288 (99.31)	
Others	2 (0.94)	2 (0.69)	
Residence			0.087
Urban	171 (80.66)	215 (74.14)	
Non-urban	41 (19.34)	75 (25.86)	
Occupation			0.045
Employed	90 (42.45)	118 (40.69)	
Freelancer	35 (16.51)	70 (24.14)	
Unemployed (housewife/househusband, student)	37 (17.45)	57 (19.65)	
Others	50 (23.58)	45 (15.52)	
Education			0.001
High school or below	51 (24.06)	110 (37.93)	
Junior college or above	161 (75.94)	180 (62.07)	
Monthly income (Yuan)			0.205
≤ 5000	110 (52.36)	127 (43.79)	
5000–10,000	75 (35.38)	112 (38.62)	
10,000–20,000	17 (8.02)	35 (12.07)	
> 20,000	9 (4.25)	16 (5.52)	
Comorbidities			0.155
Yes	13 (6.13)	28 (9.66)	
No	199 (93.87)	262 (90.34)	
Medical insurance			0.885
Yes	208 (98.11)	284 (97.93)	
No	4 (1.89)	6 (2.07)	
Unplanned pregnancy			0.869
Yes	92 (43.40)	128 (44.14)	
No	120 (56.60)	162 (55.86)	

3.2. Biomechanical perspectives on participants' knowledge, attitudes, and practices regarding prenatal anxiety

The mean knowledge score was 5.59 ± 2.73 (total score: 9, 62.11%), indicating moderate knowledge. The knowledge score significantly differed among women with different statuses of anxiety ($P < 0.001$), occupation ($P = 0.018$), and education ($P < 0.001$) (**Table 1**). The items with the lowest rates of correct answers were K4 ("Prenatal anxiety may cause symptoms such as increased heart rate, chest tightness, shortness of breath, flushing or pale skin, sweating and even malignant pregnancy vomiting"; 37.86%), K3 ("Frequent solitude may worsen symptoms of prenatal anxiety"; 43.30%), K11 ("Postural correction during pregnancy may relieve

psychological stress"; 45.83%) (**Table 3**).

Table 3. The participant's response to the knowledge items.

Knowledge	Correct, *n* (%)
1. The anxious emotions before childbirth are common and normal.	301 (58.45)
2. The manifestations of prenatal anxiety include emotional changes such as sleep disorders, sensitivity and suspiciousness, and behavioral changes such as increased daily small movements.	276 (53.59)
3. Frequent solitude may worsen symptoms of prenatal anxiety.	223 (43.30)
4. Prenatal anxiety may cause symptoms such as increased heart rate, chest tightness, shortness of breath, flushing or pale skin, sweating, and even malignant pregnancy vomiting.	195 (37.86)
5. Treating complications and keeping in touch with doctors can help relieve prenatal anxiety.	339 (65.83)
6. In addition to self-regulation, social support is also important for relieving prenatal anxiety.	394 (76.50)
7. Learning prenatal knowledge can help relieve prenatal anxiety.	430 (83.50)
8. Psychological counseling, muscle relaxation training, etc., help relieve prenatal anxiety.	421 (81.75)
10. Prenatal anxiety may lead to adverse pregnancy events such as intrauterine hypoxia, dystocia, and delayed labor.	300 (58.25)
Posture correction during pregnancy may ease psychological stress	236 (45.83)

The mean attitude score was 33.59 ± 4.36 (total score: 50, 67.18%), indicating moderate attitudes. The attitude score significantly differed among women with different statuses of anxiety ($P < 0.001$), history of adverse pregnancy ($P = 0.050$), and occupation ($P = 0.028$) (**Table 1**). The items with the poorer attitudes were A5 ("I know enough about prenatal anxiety"), A4 ("I worry that the process of delivery is very painful"), A7 ("I think prenatal anxiety is difficult to control well through psychological adjustment"), and A2 ("I am worried that my child will have congenital malformations") (**Table 4**).

Table 4. The participant's response to the attitude items.

Attitude, *n* (%)	Strongly agree	Agree	Neutrality	Disagree	Strongly disagree
1. I worry that fertility will affect my career.	26 (5.05)	69 (13.40)	189 (36.70)	188 (36.50)	43 (8.35)
2. I am worried that my child will have congenital malformations.	58 (11.26)	146 (28.35)	171 (33.20)	104 (20.19)	36 (6.99)
3. I'm worried that I won't be able to be a qualified mother.	23 (4.47)	121 (23.50)	155 (30.10)	169 (32.82)	47 (9.13)
4. I worry that the process of delivery is very painful.	94 (18.25)	219 (42.52)	132 (25.63)	51 (9.90)	19 (3.69)
5. I know enough about prenatal anxiety.	29 (5.63)	129 (25.05)	252 (48.93)	92 (17.86)	13 (17.86)
6. Relieving prenatal anxiety is important for the successful delivery.	163 (31.65)	262 (50.87)	74 (14.37)	12 (2.33)	4 (0.78)
7. I think prenatal anxiety is difficult to control well through psychological adjustment, etc.	60 (11.65)	131 (25.44)	139 (26.99)	157 (30.49)	28 (5.44)
8. It's a shame to go to the doctor due to prenatal anxiety.	4 (0.78)	10 (1.94)	54 (10.49)	341 (66.21)	106 (20.58)
9. I think my family members pay enough care for me.	155 (30.10)	269 (52.23)	71 (13.79)	18 (3.50)	2 (0.39)
10. I think that my family members are too caring for me, which puts me under huge stress.	11 (2.14)	40 (7.77)	136 (26.41)	283 (54.95)	45 (8.74)
I believe that improving physical force lines can be effective in reducing anxiety levels.	133 (25.53)	232 (45.05)	93 (16.12)	38 (7.38)	19 (3.69)

The mean practice score was 21.85 ± 3.77 (total score: 30, 72.83%), indicating moderate practice. The practice score significantly differed among women with

different statuses of age ($P < 0.001$), pregnancy history ($P = 0.002$), residence ($P = 0.046$), occupation ($P < 0.001$), education ($P < 0.001$), and medical insurance ($P = 0.012$) (**Table 1**). The items with the poorer practice were P2 ("I will learn the knowledge about pregnancy and delivery by consulting with doctors"), P1 ("I will exchange pregnancy and delivery experiences with other pregnant women or relatives and friends who have had delivery experience") and P7 ("I take the initiative to adjust my daily posture through professional guidance") (**Table 5**).

Table 5. The participant's response to the practice items.

Practice, n (%)	Always	Usually	Sometimes	Occasionally	Never
1. I will exchange pregnancy and delivery experiences with other pregnant women or relatives and friends who have had delivery experience.	74 (14.37)	176 (34.17)	106 (20.58)	152 (29.51)	7 (1.36)
2. I will learn the knowledge about pregnancy and delivery by consulting with doctors.	61 (11.84)	135 (26.21)	143 (27.77)	165 (32.04)	11 (2.14)
3. I will maintain a healthy routine and eating habits.	83 (16.12)	229 (44.47)	179 (34.76)	24 (4.66)	0
4. I will keep the habit of going out for a walk.	73 (14.17)	184 (35.73)	162 (31.46)	92 (17.86)	4 (0.78)
5. I will seek help from doctors in time when I have symptoms.	137 (26.60)	217 (42.14)	92 (17.86)	65 (12.62)	4 (0.78)
6. I will ensure the health of my child through pregnancy tests.	284 (55.15)	187 (36.31)	30 (5.83)	10 (1.94)	4 (0.78)
I take the initiative to adjust my daily posture through professional guidance.	89 (17.28)	162 (31.46)	102 (19.81)	149 (28.93)	13 (2.52)

3.3. Biomechanical perspectives on risk factors associated with KAP and antenatal anxiety

Pearson's correlation tests showed the knowledge scores were correlated with the practice scores ($r = 0.161$, $P < 0.001$), and the attitude scores were correlated with the practice scores ($r = 0.260$, $P < 0.001$) (**Table 6**). Education (college or above vs. high school or below, OR = 3.66, 95% CI: 1.88–7.13, $P < 0.001$) and planned pregnancy (OR = 0.60, 95% CI: 0.37–0.99, $P = 0.046$) were independently associated with better knowledge. Adverse pregnancy history (No vs. Yes, OR = 0.64, 95% CI: 0.42–0.95, $P = 0.029$) and occupation (Freelancer vs. Employed, OR = 0.46, 95% CI: 0.26–0.80, $P = 0.007$) were independently associated with favorable attitudes. A better knowledge (OR = 2.02, 95% CI: 1.16–3.51, $P = 0.013$), a favorable attitude (OR = 2.63, 95% CI: 1.67–4.14, $P < 0.001$), and occupation (Freelancer vs. Employed, OR = 0.38, 95% CI: 0.19–0.75, $P = 0.005$; Unemployed vs. Employed, OR = 0.43, 95% CI: 0.21–0.90, $P = 0.025$; Others vs. Employed, OR = 0.39, 95% CI: 0.19–0.80, $P = 0.010$) were independently associated with more active practice. A better knowledge (OR = 1.71, 95% CI: 1.01–2.89, $P = 0.047$) was independently associated with a higher risk of anxiety, while a favorable attitude (OR = 0.54, 95% CI: 0.33–0.89, $P = 0.016$) was independently associated with a lower risk of anxiety (**Table 7**).

Table 7. Multivariable logistic regression for knowledge, attitude, practice, and prenatal anxiety.

Dependent variables	Independent variables	OR (95% CI)	*P*
Knowledge			
	Education		
	High school or below	Ref.	
	Junior college or above	3.66 (1.88, 7.13)	< 0.001
	Unplanned pregnancy		
	No	Ref.	
	Yes	0.60 (0.37, 0.99)	0.046
Attitude			
	Knowledge		
	≤ 70%	Ref.	
	> 70%	1.28 (0.77, 2.13)	0.342
	Adverse pregnancy history		
	Yes	Ref.	
	No	0.64 (0.42, 0.95)	0.029
	Occupation		
	Employed	Ref	
	Freelancer	0.46 (0.26, 0.80)	0.007
	Unemployed	0.65 (0.37, 1.14)	0.133
	Others	0.87 (0.52, 1.47)	0.609
Practice			
	Knowledge		
	≤ 70%	Ref.	
	> 70%	2.02 (1.16, 3.51)	0.013
	Attitude		
	≤ 70%	Ref.	
	> 70%	2.63 (1.67, 4.14)	< 0.001
	Age		
	≤ 25	Ref.	
	25–30	2.11 (0.90, 4.92)	0.085
	> 30	1.82 (0.76, 4.38)	0.179
	Occupation		
	Employed	Ref.	
	Freelancer	0.38 (0.19, 0.75)	0.005
	Unemployed	0.43 (0.21, 0.90)	0.025
	Other	0.39 (0.19, 0.80)	0.010
	Education		
	High school or below	Ref.	
	Junior college or above	1.19 (0.64, 2.23)	0.579

Table 7. (*Continued*).

Dependent variables	Independent variables	OR (95% CI)	*P*
Prenatal anxiety			
	Knowledge		
	≤ 70%	Ref.	
	> 70%	1.71 (1.01, 2.89)	0.047
	Attitude		
	≤ 70%	Ref.	
	> 70%	0.54 (0.33, 0.89)	0.016
	Practice		
	≤ 70%	Ref.	
	> 70%	0.93 (0.55, 1.58)	0.788

3.4. Structural equation modeling

The SEM is presented in **Figure 1**. Knowledge directly negatively influenced attitudes ($\beta = -0.472$, $P < 0.001$) but directly positively influenced practice ($\beta = 0.566$, $P < 0.001$). Attitudes directly influenced practice ($\beta = 0.126$, $P = 0.004$) (**Table 8**). **Table 9** shows that the fit of the model was good.

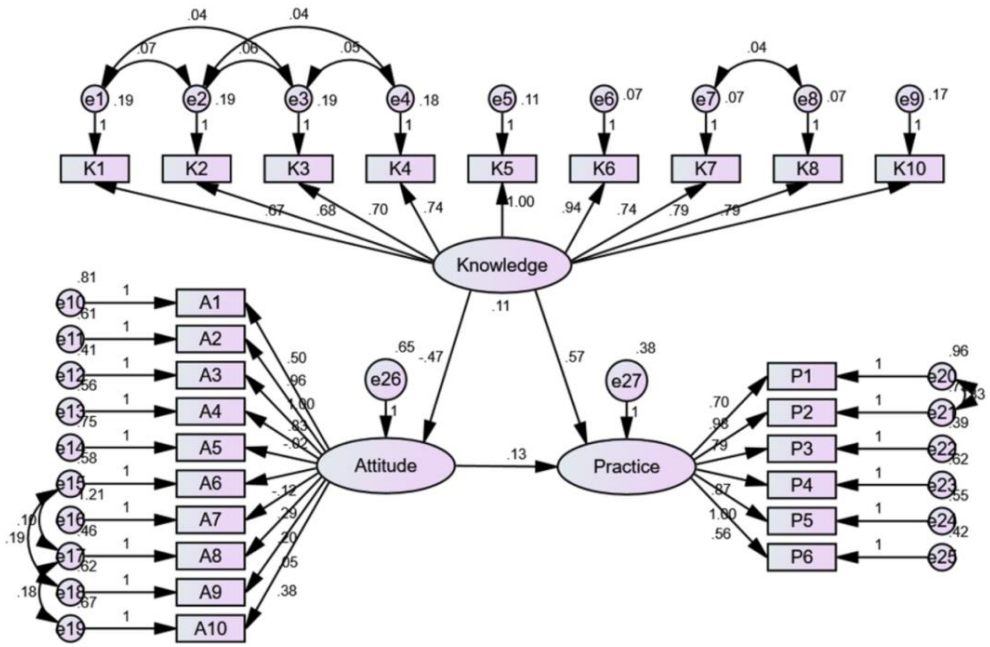

Figure 1. SEM diagram.

Table 8. The SEM results.

			β	***P***
Attitude	←	Knowledge	−0.472	< 0.001
Practice	←	Attitude	0.126	0.004
Practice	←	Knowledge	0.566	< 0.001
K1	←	Knowledge	0.670	< 0.001
K2	←	Knowledge	0.680	< 0.001
K3	←	Knowledge	0.702	< 0.001
K4	←	Knowledge	0.741	< 0.001
K5	←	Knowledge	1.000	
K6	←	Knowledge	0.941	< 0.001
K7	←	Knowledge	0.739	< 0.001
K8	←	Knowledge	0.790	< 0.001
K10	←	Knowledge	0.795	< 0.001
K11	←	Knowledge	0.801	< 0.001
A11	←	Attitude	0.031	0.223
A10	←	Attitude	0.377	< 0.001
A9	←	Attitude	0.051	0.255
A8	←	Attitude	0.198	< 0.001
A7	←	Attitude	0.293	<0.001
A6	←	Attitude	−0.115	0.009
A5	←	Attitude	−0.021	0.675
A4	←	Attitude	0.832	< 0.001
A3	←	Attitude	1.000	
A2	←	Attitude	0.957	< 0.001
A1	←	Attitude	0.504	< 0.001
P1	←	Practice	0.704	< 0.001
P2	←	Practice	0.982	< 0.001
P3	←	Practice	0.790	< 0.001
P4	←	Practice	0.866	< 0.001
P5	←	Practice	1.000	
P6	←	Practice	0.556	< 0.001
P7	←	Practice	0.747	< 0.001

Table 9. SEM fitting.

Indicator	**Reference standard**	**Actual results**
CMIN/DF	1–3 excellent, 3–5 good	3.082
RMSEA	< 0.08 good	0.061
IFI	> 0.8 good	0.860
TLI	> 0.8 good	0.838
CFI	> 0.8 good	0.859

4. Conclusion and discussion

4.1. Findings and analysis

4.1.1. Summary of key findings

This study suggests that pregnant women in Nanchong had a moderate KAP toward prenatal anxiety. Higher knowledge scores and attitude scores were independently associated with higher and lower occurrences of anxiety. The present study may contribute to the design of educational programs and tools in the perspective of considering biomechanical influences in order to increase awareness of prenatal anxiety among pregnant women.

4.1.2. Comparison with previous research

In this study, the prevalence of prenatal anxiety was 23.30%, higher than the 10% observed in developed countries but similar to the 25% found in developing countries [4,5]. As China is a developing country, these results are concordant. Still, the prevalence of prenatal anxiety can vary among regions because China is a vast country with significant socioeconomic differences among provinces. Indeed, the gross domestic product per capita is 86,885 yuan in Chongqing, compared with 64,357 yuan in Sichuan (where the present study was performed) [32]. Topographic biomechanical features may exacerbate this discrepancy: the mountainous terrain of Sichuan allows pregnant women to have 1.3 times the average daily number of gait slope changes as in Chongqing, leading to alternating fatigue of the lower limb muscle groups [33], and this mechanical load affects anxiety levels through the HPA axis. A study in Chongqing (China) revealed a prevalence of 15% of prenatal anxiety, but it was performed before the COVID-19 pandemic, and the stress and anxiety induced by COVID-19 might influence the results [29]. COVID-19 induced anxiety in almost all individuals due to the fear of becoming sick, sanitary procedures, loss of income, lockdowns, fear of seeing other people, etc. [34,35]. Home isolation during the COVID-19 pandemic resulted in 32% longer sedentary time and a 15% reduction in multifidus muscle cross-sectional area (measured by ultrasound) [36], weakening spinal dynamic stability and affecting vestibular-emotion regulation pathways. Furthermore, pregnancy leads to a protective comportment driven by maternal instinct [37], which probably acted synergistically or at least additively with COVID-19 to induce a pro-anxiety state in many pregnant women due to the possible adverse outcomes of COVID-19 on maternal health and the uncertainty of how it could affect the fetuses [24,25]. A study in Shenyang reported 11.2% of prenatal anxiety [28], but it used a different anxiety screening tool than in the present study. Of course, different tools will have different sensitivity and specificity [38], leading to differences among studies. A meta-analysis reported a pooled rate of prenatal anxiety of 17.4% in China but also highlighted a significant heterogeneity due to the use of different self-reported tools [39].

4.1.3. Biomechanical effects of anxiety in pregnancy

Anxiety is a serious issue in pregnant women. In fact, prenatal anxiety has been associated with fear of labor, higher rates of cesarean section, eating disorders, ineffective coping strategies, and suicidal ideation [1,2], as well as with fear of other

major illnesses, such as cancer [40,41]. Exercise biomechanics studies have shown a 25% increase in pelvic tilt angle variability in anxious pregnant women, which may affect the kinetics of fetal head descent during labor [42]. Prenatal anxiety has also been associated with intrauterine growth restriction, premature labor, and low birth weight [43,44]. Furthermore, children born from mothers with prenatal anxiety have higher risks of depression, impulsivity, attention deficit/hyperactivity disorder, and cognitive impairment [45]. The first generation of children born after the alleviation of the one-child policy in China has reached the childbearing age and are experiencing their first pregnancy [46]. In addition, women during their first pregnancy are more susceptible to anxiety [47]. Furthermore, cultural aspects (e.g., gender preference for male children) are associated with prenatal anxiety in Chinese women [48,49]. The present study revealed that the symptoms, manifestations, and impacts of prenatal anxiety were poorly known among pregnant women. Improving health literacy regarding prenatal anxiety might help improve maternal and offspring outcomes. Biomechanical education interventions can be combined with postural retraining, and modified "cat's hump" exercises have been shown to increase the homogeneity of stress distribution in the sacroiliac joints of anxious pregnant women and to decrease SAS scores.

In the present study, the lowest KAP scores were mostly observed among young women, women at their first pregnancy, non-urban residents, women with freelancer jobs, those with lower education, and those without medical insurance. Still, the frequency of anxiety was not different between women at their first or subsequent pregnancies. Hence, despite the experience of a first pregnancy, pregnancy remains a stressful period filled with uncertainties and worries [1,6]. Prenatal anxiety is known to be associated with lower socioeconomic status [50], as well as with younger age and a first pregnancy [46,47]. Women meeting one of these characteristics should be targeted to improve health literacy.

In this study, high knowledge and attitude scores were positively and negatively associated with anxiety, respectively. In the biomechanical perspective, higher knowledge scores are associated with anxiety because from biomechanical knowledge, one can be more aware of changes and hazards in the body, which can increase anxiety, and women can be more aware of signs and symptoms that need attention, focusing on them and increasing anxiety [12]. It is also supported by the SEM analysis, which showed that knowledge had a negative influence on attitudes toward prenatal anxiety. This finding suggests that as knowledge increases, attitudes become less favorable. One interpretation is that while higher knowledge levels raise awareness of risk factors, they may also contribute to a more pessimistic or fatalistic outlook regarding the manageability of prenatal anxiety. In other words, increased knowledge might not translate into a positive or proactive attitude if it predominantly emphasizes potential dangers without offering balanced, reassuring strategies for coping. This relationship underscores the importance of designing educational interventions that do not merely impart information but also foster constructive attitudes and self-efficacy, thereby transforming potentially anxiety-provoking knowledge into positive behavioral outcomes.

This effect is observed in many diseases, including COVID-19-related anxiety [51,52] and inflammatory bowel diseases [53]. On the other hand, a favorable attitude

toward prenatal anxiety was associated with a lower occurrence of anxiety [52], also supported by the SEM, which showed that attitude was positively associated with practice; knowledge was also positively associated with practice, suggesting that improving knowledge should also improve practice despite the fact that the attitude can decrease. Nevertheless, the results imply that determining how to transform good knowledge into a positive attitude should be the focus of future programs for preventing prenatal anxiety. The correlation results showed that the knowledge scores were not correlated with the attitude scores, which might be because the knowledge dimension and attitude dimension in this study focused on different aspects of prenatal anxiety. Finally, the results showed that the practice scores were not associated with prenatal anxiety. This may be due to the fact that anxiety is a psychological state that primarily affects hormonal changes in the body and requires complex interventions and sometimes medication to treat it [15,16].

4.1.4. Limitations and future research directions

This study had limitations. The generalizability of the results was limited since the study was designed by local investigators and only enrolled pregnant women from the Nanchong area. Considering the large number of pregnant women, the sample size was relatively small. In addition, the level of education was higher than in the general population, indicating a possible selection bias. KAP surveys are snapshots of a specific population at a precise time point [22,23]. In addition, a major limitation of the KAP survey is the social acceptability bias, in which some participants might be tempted to answer what would be expected instead of what they really think/do [22,23]. Future studies will incorporate wearable devices to monitor body mechanics data and incorporate objective biomechanical metrics (e.g., center of pressure trajectory analysis), which will enhance assessment validity.

In conclusion, pregnant women in Nanchong had a moderate KAP toward prenatal anxiety. Good knowledge should translate into active practice to prevent prenatal anxiety. Future learning activities should focus on the symptoms and consequences of prenatal anxiety, as well as the methods to prevent and manage it. Combining biomechanical training (e.g., DNS neurodevelopmental postural reconstruction) with traditional educational programs is recommended, and joint interventions can lead to knowledge-practice translation rates.

4.2. Exercise interventions to alleviate prenatal depression from the biomechanical perspective

4.2.1. Conventional biomechanical interventions

From a biomechanical perspective, exercise interventions offer an effective and multifaceted approach to alleviating prenatal depression. First, during pregnancy, increases in body weight, an anterior shift in the center of gravity, and changes in hormone levels often lead to a series of adaptive modifications in the musculoskeletal system. These include realignment of the spinal and pelvic structures, imbalances in muscle tension, and alterations in joint load distribution [17–19]. Such physiological changes may provoke or exacerbate physical discomfort and pain, thereby triggering negative emotions and depressive symptoms. Moderate exercise regimens—such as prenatal yoga, aerobic workouts, and strength training—can improve body posture and

movement patterns, enhance core and lower limb muscle strength, and consequently stabilize the pelvic and spinal structures, reducing discomfort associated with postural imbalances.

Secondly, exercise plays a vital role in enhancing blood circulation, regulating metabolism, and lowering systemic inflammation [54]. Research indicates a close link between inflammatory responses and the development of depressive disorders [55]. Appropriate exercise can promote the release of anti-inflammatory factors, improve neuroendocrine function, and stimulate the secretion of neurotransmitters like endorphins and dopamine, thereby improving mood and mitigating the symptoms of prenatal depression.

Furthermore, from an exercise biomechanics standpoint, training can also improve balance and motor coordination in pregnant women, thereby increasing self-efficacy and bodily control. This enhancement in self-confidence not only contributes to better physical performance but also serves as positive psychological reinforcement, encouraging the adoption of a healthier lifestyle and further reducing the risk of depression [56].

4.2.2. Customized biomechanical interventions based on KAP data

Interventions may be tailored according to the overall KAP profile. The observed disparities in KAP scores among various demographic groups suggest that a one-size-fits-all approach may not be optimal for prenatal care. For example, pregnant women with lower levels of education, younger age, or from non-urban areas—who tend to exhibit lower KAP scores—could particularly benefit from customized interventions. Based on the KAP data, targeted biomechanical interventions, such as postural retraining, modified "cat's hump" exercises, and balance training, can be developed to address specific deficiencies in both knowledge and physical function. These interventions are designed not only to improve physical stability but also to alleviate anxiety by reducing discomfort and pain associated with postural imbalances.

4.2.3. Integration of psychological and biomechanical assessments

Moreover, the findings of this study provide empirical support for integrating psychological assessments (e.g., KAP surveys) with biomechanical evaluations (e.g., gait analysis, center-of-pressure trajectory analysis) into prenatal care protocols. Such an integrated assessment approach would enable healthcare providers to more accurately identify high-risk individuals and deliver comprehensive interventions that address the cognitive, emotional, and physical dimensions of prenatal anxiety. Future research could leverage wearable devices to monitor objective biomechanical parameters, thereby refining intervention strategies and enabling real-time evaluation of their efficacy.

In summary, exercise interventions grounded in biomechanical principles provide a robust theoretical and practical framework for alleviating prenatal depression by improving bodily structure, regulating physiological functions, and enhancing psychological resilience. Future research may further explore personalized exercise prescription designs to offer more precise interventions for the prevention and treatment of prenatal depression.

Ethical approval: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of the Medical Ethics Committee of the Affiliated Hospital of North Sichuan Medical College (protocol code 2022ER323-1).

Conflict of interest: The authors declare no conflict of interest.

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