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RESEARCH

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Effectiveness of a prenatal pilates program on ligamentous laxity and joint hypermobility in pregnant women: a dual-center randomized controlled trial

Merve Bulguroglu[1], Halil Ibrahim Bulguroglu[1*], Baran Degirmenci[2], Selcan Suicmez[1], Cansu Gevrek Aslan[1], Serenay Zorlu Develik[1] and Nevin Atalay Guzel[3]

Abstract

Background Pregnancy-related anatomical and hormonal changes, including increased relaxin levels, may cause ligamentous laxity and joint hypermobility, while also contributing to decreased overall body mobility, potentially affecting functional stability. Pilates, focusing on core strength and postural control, is recommended during pregnancy, but its effects on ligamentous laxity and joint hypermobility have not been tested in a randomized controlled trial. This study aimed to investigate the effectiveness of a prenatal Pilates program on ligamentous laxity and joint hypermobility in pregnant women.

Methods In this prospectively registered, dual-center randomized controlled trial (ClinicalTrials.gov: NCT06684002), 42 healthy primiparous women at 14–16 weeks' gestation were randomized to an 8-week structured prenatal Pilates program ($n=21$) or standard prenatal care without exercise ($n=21$). The intervention was delivered by the same certified physiotherapist at both centers to ensure consistency. Outcomes included anterior cruciate ligamentous laxity measured with the GNRB arthrometer, generalized joint hypermobility using the Beighton score, and activity limitations due to pelvic girdle pain assessed by the Pelvic Girdle Questionnaire, evaluated at baseline, 4 weeks, and 8 weeks.

Results Participants in the Pilates group showed no significant changes in ligamentous laxity and joint hypermobility and reported minimal activity limitations throughout the intervention ($p>0.05$). In contrast, the control group demonstrated significant deterioration across all outcomes ($p<0.05$). After 8 weeks, the Pilates group demonstrated significant improvements compared to the control group, with medium effect sizes for ligamentous laxity ($p<0.05$, $\eta p^2 \geq 0.06$), a small effect size for joint hypermobility ($p=0.017$, $\eta p^2=0.039$), and a large effect size for activity limitations due to pelvic girdle pain ($p=0.021$, $\eta p^2=0.317$).

Conclusions An 8-week structured prenatal Pilates program appears to effectively prevent the progression of ligamentous laxity and joint hypermobility while reducing activity limitations associated with pelvic girdle pain,

*Correspondence:
Halil Ibrahim Bulguroglu
fztibrahim@hotmail.com

Full list of author information is available at the end of the article

supporting its integration into routine prenatal care to enhance maternal musculoskeletal stability, functional capacity, and quality of life during pregnancy.

Trial registration: This study is registered on ClinicalTrials.gov with the identifier NCT06684002, registration date November 9, 2024.

Keywords Pregnancy, Prenatal pilates, Ligamentous laxity, Joint hypermobility, Pelvic girdle pain, Maternal musculoskeletal health, Quality of life, Randomized controlled trial

Introduction

Pregnancy induces profound anatomical, hormonal, and biomechanical adaptations essential for fetal development and maternal health. However, these physiological changes increase demands on the maternal musculoskeletal system, often leading to discomfort, decreased overall body mobility, and a heightened risk of musculoskeletal injuries, particularly in the later stages of pregnancy [1, 2].

Relaxin is one of the normal physiological adaptations of pregnancy, softening and loosening the pelvic ligaments to prepare for childbirth [3]. Rising during the first trimester, peaking at 12 weeks, and plateauing by 17 weeks, relaxin also contributes to cardiovascular changes such as vasodilation and increased blood volume [4]. In some women, however, its systemic effects on connective tissues may become excessive, leading to ligamentous laxity and joint hypermobility that can impair joint stability and neuromuscular control [5, 6]. Such changes may manifest as low back pain and knee instability [7, 8].

While pregnancy is a normal physiological state, some musculoskeletal adaptations can compromise maternal safety and functional capacity, increasing the risk of falls, limiting activity, and reducing quality of life [2]. Given the potential implications for reducing maternal morbidity associated with falls and functional decline, effective and low-risk interventions addressing ligamentous laxity and joint hypermobility are clinically significant. While external supports such as maternity belts provide temporary relief, current guidelines from the American College of Obstetricians and Gynecologists (ACOG) recommend regular, moderate-intensity exercise as a safe and effective strategy to improve maternal health and reduce musculoskeletal complaints during uncomplicated pregnancies [9]. Systematic reviews support exercise interventions in alleviating pregnancy-related pelvic girdle and low back pain while enhancing function and quality of life [10, 11].

Pilates, a low-impact exercise modality emphasizing core strength, postural alignment, controlled breathing, flexibility, and body awareness, has emerged as a popular option during pregnancy [12]. Evidence from non-pregnant populations indicates that Pilates can improve neuromuscular control, postural stability, and balance [13]. Preliminary studies in pregnant populations have linked Pilates to enhanced physical function and psychological well-being [12, 14]. From a mechanistic perspective, Pilates may help counteract pregnancy-related increases in ligamentous laxity not by directly altering collagen structure, but by improving dynamic joint stability through enhanced neuromuscular control, proprioception, and balanced muscle activation around the joints [12]. Strengthening periarticular muscles can reduce excessive strain on lax ligaments, thereby maintaining functional stability despite hormonal influences such as elevated relaxin [5]. However, to date, no randomized controlled trial has specifically investigated the effects of prenatal Pilates program on ligamentous laxity and joint hypermobility—two critical factors influencing maternal function, stability, and delivery outcomes.

Therefore, we conducted a randomized controlled trial to evaluate the effects of a structured prenatal Pilates program on ligamentous laxity, joint hypermobility, and activity limitation related to pelvic girdle pain in pregnant women. We hypothesized that regular participation in prenatal Pilates program would prevent the progression of ligamentous laxity and joint hypermobility while mitigating activity limitations during pregnancy.

Methods

Study design

This dual-center, parallel-group randomized controlled trial was conducted at the Department of Physical Therapy and Rehabilitation, Faculty of Health Sciences, Ankara Medipol University, and a private physiotherapy clinic in Ankara, Turkey. The study adhered to the CONSORT guidelines and is reported according to its checklist. Ethical approval was obtained from the Ankara Medipol University Non-Interventional Clinical Research Ethics Committee (Approval No: 128, dated 07.10.2024). All procedures were performed under this approval and by the principles outlined in the Declaration of Helsinki. All participants provided written informed consent prior to participation.

Participants

Healthy primiparous women aged 20 to 35 years with singleton pregnancies between 14- and 16-weeks' gestation were recruited at both centers between November 15, 2024, and January 15, 2025. Exclusion criteria included cardiovascular or pulmonary diseases, contraindications to exercise during pregnancy, and prior participation in structured physical activity programs [9].

Sample size calculation

Sample size calculation was based on means and standard deviations for generalized joint laxity measured by the Beighton score reported by Long et al. [15], using an estimated effect size of $d = 0.5$, corresponding to a moderate, clinically relevant between-group difference in Beighton score. To achieve 90% statistical power at an alpha level of 0.05, 18 participants were required per group (36 in total). Allowing for a 20% dropout rate, 22 participants per group (44 in total) were planned to be enrolled.

Randomization and blinding

After two withdrawals, 42 participants were randomly allocated (1:1) to the Pilates group (PG; $n = 21$) or the control group (CG; $n = 21$) using a computer-generated randomization sequence, with recruitment at both Ankara Medipol University ($n = 24$) and a private physiotherapy clinic in Ankara ($n = 18$). Due to the nature of the intervention, participants and therapists were not blinded; however, outcome assessors and data analysts were blinded to group allocation. All baseline and post-intervention evaluations were performed by an experienced physiotherapist (SS), who was blinded to group allocation.

Before the interventions commenced, all participants received standardized care education covering prenatal care and ergonomic advice. This session was delivered once, prior to the intervention, by a physiotherapist (HIB) who was not involved in conducting the Pilates sessions.

Intervention

Participants in the Pilates group attended supervised 60-minute sessions twice weekly for eight weeks, led by a certified physiotherapist trained by the Australian Institute of Pilates and Physiotherapy (MB). The same physiotherapist delivered all Pilates sessions at both centers to ensure consistency in intervention delivery and adherence to the standardized protocol. The intervention adhered to the American College of Obstetricians and Gynecologists (ACOG) prenatal exercise guidelines [9], emphasizing breathing control, centering, alignment, and stabilization. Exercise intensity was monitored using the Talk Test [16] and was maintained at a level where participants could speak comfortably but not sing during the activity. The Pilates program consisted of 15 exercises: arm scissors, windmills, pillow squeeze, abdominal prep, gluteal stretch, buttock squeeze, bend and stretch with theraband, lift and lower with theraband, clam variations, cat stretch, thread the needle, row, triceps in standing, ball push-up at the wall, and mermaid. During the first four weeks, each exercise was performed for 2 sets of 6–8 repetitions. In the following four weeks, the repetition range was increased to 8–12 per set, with the total number of exercises remaining the same. Each session included a warm-up, core exercises with progressive resistance using TheraBands, and a cool-down that involved postural education and stretching.

Adherence

Adherence to the Pilates program was assessed by recording the number of attended sessions out of the total 16 scheduled sessions for each participant. Attendance was documented by the instructor at every session.

Outcome measures

Ligamentous laxity

Anterior cruciate ligament (ACL) laxity was selected as a representative measure of generalized ligamentous laxity due to its sensitivity to hormonal influences, particularly relaxin, which is markedly elevated during pregnancy [17]. The ACL predominantly consists of type I collagen fibers, rendering it susceptible to biomechanical changes under hormonal modulation. Previous studies have indicated that elevated relaxin levels may reduce collagen integrity and increase ligament extensibility, particularly in the knee joint [18]. The GNRB arthrometer was used due to its high sensitivity, reproducibility, and ability to apply standardized anterior translational forces, allowing precise quantification of subtle laxity that is difficult to detect with manual testing [17]. Although a few studies have investigated ACL laxity in pregnant populations, Chu et al. demonstrated the feasibility and utility of instrumented assessment in this context [7]. Thus, ACL laxity serves as a practical biomechanical proxy for systemic connective tissue adaptation during pregnancy, particularly in individuals with generalized hypermobility.

Measurements were performed with participants in the supine position, knees flexed at 20° on a 30° inclined table (Lachman position). The tibial tuberosity and inferior patellar margin were identified and marked on the dominant leg and maintained in neutral rotational alignment throughout the procedure. A displacement sensor was affixed to the tibial tuberosity, and anterior forces of 134 N and 200 N were applied in three trials. The mean of these trials was calculated and recorded for analysis [19].

Generalized joint hypermobility

Generalized joint hypermobility (GJH) was assessed using the Beighton scoring system, which consists of five bilateral and unilateral maneuvers. Each positive test scored one point, with a maximum score of 9. A score of ≥ 5 indicated GJH [20]. The Beighton score complemented ACL laxity measurements by providing a standardized, non-invasive assessment of widespread hypermobility [21]. Given that hormonal changes during pregnancy—particularly elevated relaxin—affect systemic ligamentous properties, this measure allowed for the assessment of individual variability in ligamentous laxity beyond the knee joint [8]. Previous research has supported the utility of the Beighton score in identifying musculoskeletal risk profiles and guiding preventive exercise interventions during pregnancy [22, 23]. All measurements using the GNRB arthrometer and Beighton scoring were performed by an experienced physiotherapist who was blinded to group allocation to reduce measurement bias.

Activity limitation due to pelvic girdle pain

Activity limitation related to pelvic girdle pain was assessed using the Turkish version of the Pelvic Girdle Questionnaire (PGQ), a 25-item instrument comprising activity (20 items) and symptom (5 items) subscales [24, 25]. Items were rated on a 4-point scale from 0 (“no problem at all”) to 3 (“a great deal of problems”). Total scores were converted to percentages, with higher scores indicating greater symptom severity and activity limitation.

Physical activity level

Participants’ physical activity was monitored using the Omron HJ-321-E pedometer (Omron Healthcare, Japan), which detects vertical oscillations and stores up to seven days of data. Participants wore the device during waking hours for at least five consecutive days, including both weekdays and at least one weekend day to ensure activity pattern balance, excluding water activities. Weekly average step counts were calculated to assess activity levels. The validity of the pedometer in pregnant populations has been established [26].

Statistical analysis

Data was analyzed using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA). Normality was assessed via histograms, Q–Q plots, skewness, kurtosis, and the Shapiro–Wilk and Kolmogorov–Smirnov tests. Baseline group differences were examined using independent samples t-tests. Within-group changes over time were evaluated using one-way repeated measures ANOVA, while group-by-time interactions were analyzed using two-way mixed-model repeated measures ANOVA. Post hoc comparisons were performed using the Least Significant Difference (LSD) test where appropriate. Effect sizes were calculated using partial eta squared (ηp^2) and interpreted as small (≥ 0.01), medium (≥ 0.06), or large (≥ 0.14) [27]. A p-value < 0.05 was considered statistically significant. All analyses were conducted following an intention-to-treat principle. Due to the minimal missing data, complete case analysis was performed without imputation.

Results

Forty-two participants completed the study: 21 in the Pilates group (PG) and 21 in the control group (CG). The recruitment, randomization, and follow-up process are summarized in the CONSORT flow diagram (Fig. 1). No adverse events or exercise-related complications were reported in either group during the intervention period. Adherence to the Pilates program was high, with participants attending on average 14.56 out of 16 sessions (91%).

Baseline demographic and obstetric characteristics were similar between groups, with no significant differences observed ($p > 0.05$; Table 1). Mean weekly step counts measured by pedometer were comparable between groups at 4 weeks ($p > 0.05$), whereas a significant difference favoring the Pilates group emerged at 8 weeks ($p = 0.041$; Table 1).

In the Pilates group, ligamentous laxity measured at 134 N and 200 N anterior forces did not change significantly across baseline, week 4, and week 8 ($p > 0.05$; Table 2). In contrast, the control group exhibited significant increases in ligamentous laxity at both time points compared to baseline ($p < 0.05$, $\eta p^2 \geq 0.14$; Table 2). Although ligamentous laxity was similar between groups at baseline, significant group differences appeared at weeks 4 and 8 ($p < 0.05$; Table 2). Over the 8 weeks, changes in ligamentous laxity showed a medium effect size favoring the Pilates group ($p < 0.05$, $\eta p^2 \geq 0.06$; Table 2).

Beighton scores did not change significantly within the Pilates group across baseline, week 4, and week 8 ($p > 0.05$; Table 3). Meanwhile, the control group showed significant increases over this period ($p = 0.34$, $\eta p^2 = 0.048$; Table 3). No significant differences were observed between weeks 4 and 8 in either group ($p > 0.05$; Table 3). Although baseline Beighton scores were similar between groups, significant differences emerged at weeks 4 and 8 ($p < 0.05$; Table 3). The between-group comparison over 8 weeks revealed a small but significant effect size favoring the Pilates group ($p = 0.017$, $\eta p^2 = 0.039$; Table 3).

Pelvic Girdle Questionnaire (PGQ) scores remained stable within the Pilates group at all time points ($p > 0.05$; Table 3). In contrast, the control group experienced significant worsening at weeks 4 and 8 compared to baseline ($p < 0.05$; Table 3). Although baseline PGQ scores did not differ between groups, significant differences emerged at weeks 4 and 8 ($p < 0.05$; Table 3). Comparison of PGQ score changes over 8 weeks revealed a large and significant effect size favoring the Pilates group ($p = 0.021$, $\eta p^2 = 0.317$; Table 3).

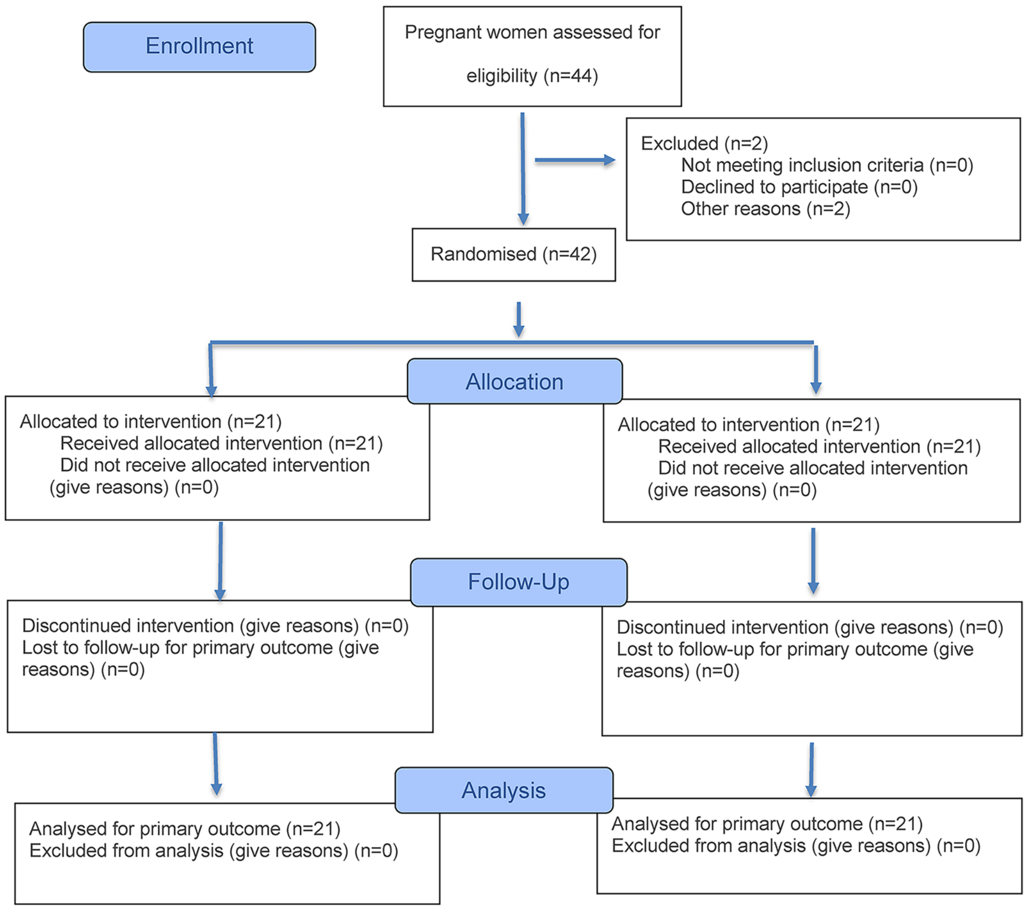

Fig. 1 CONSORT flow diagram

Table 1 Demographic characteristics and weekly step counts of the groups

	PG ($n=21$) X ± SD	CG ($n=21$) X ± SD	p
Age (years)	29.71 ± 4.13	29.11 ± 3.57	0.121
Gestational age at study start (weeks)	12.86 ± 4.19	13.09 ± 3.89	0.428
BMI-1 (kg/m^2)	23.32 ± 2.98	23.11 ± 3.12	0.458
BMI-2 (kg/m^2)	24.87 ± 2.93	25.01 ± 2.81	0.635
Weekly steps in week four	40150.13 ± 2013.11	38917.14 ± 1679.19	0.312
Weekly steps in week eight	36191.07 ± 1239.71	32688.36 ± 1733.59	**0.041***

Independent t-test, *$p<0.05$. **PG**: Pilates group; **CG**: Control group; **cm**: Centimeter, **m**: Meter; **kg**: Kilogram; **BMI-1**: Baseline body mass index; **BMI-2**: Latest body mass index; **X**: Mean; **SD**: Standard deviation; **n**: Sample size

Discussion

In this study, ligamentous laxity measurements under both anterior forces remained stable among pregnant women who participated in the Pilates intervention, despite the physiological changes associated with pregnancy progression. In contrast, ligamentous laxity increased significantly in the control group over the same period. Previous research has demonstrated that relaxin, a hormone secreted during pregnancy, contributes to increased ligamentous laxity throughout the body, particularly in the pelvic region, thereby facilitating childbirth [5]. However, excessive laxity may predispose pregnant women to musculoskeletal injuries and pregnancy-related complications [2, 14].

Although the specific effects of Pilates on ligament flexibility during pregnancy have not been extensively explored, existing literature highlights the positive impact of Pilates on overall body stabilization, neuromuscular control, and balance across various populations [28, 29]. From a mechanistic standpoint, the observed prevention of ligamentous laxity progression in the Pilates group is unlikely due to direct modification of collagen or ligament ultrastructure. Instead, Pilates may enhance periarticular muscle strength, proprioception, and coordinated muscle activation patterns around the joints, thereby improving dynamic joint stability and reducing mechanical load on already lax ligaments. This neuromuscular adaptation could counterbalance the ligament-loosening effects of pregnancy-related hormonal changes such as elevated relaxin, ultimately helping to

Table 2 Comparison of ligament laxity measurements of pilates and control groups

Assessment		Group	T0 X±SD	T1 X±SD	T2 X±SD	p^a	ηp^2_a	p^b	ηp^2_b
ACL Laxity	**Displacement (mm) @ 134N**	**Pilates**	4.87±0.91	5.19±1.13	5.16±0.84	0.643	0.085	**0.037***	0.062
		Control	4.53±0.55	6.21±0.20	6.56±0.55	**0.021***	0.998		
		p^c	0.250	**0.028***	**0.017***				
	Displacement (mm) @ 200N	**Pilates**	4.82±1.39	5.08±0.77	5.10±0.76	0.142	0.324	**0.018***	0.081
		Control	4.32±0.58	6.12±0.46	6.40±0.45	**0.012***	0.999		
		p^c	0.426	**0.021***	**0.012***				

*p<0.05, **T0:** Initial evaluation; **T1:** Intermediate evaluation; **T2:** Final evaluation; **mm:** milimeter; **ηp^2:** Partial eta squared; X: Mean; **SD:** Standard deviation; **n:** Sample size; **a**: One-way repeated measures ANOVA; **b**: 2-by-3, mixed-model repeated measures ANOVA (group-by-time interaction); **c**: Independent samples t test

Table 3 Comparison of joint hypermobility and pelvic girdle pain measurements of the pilates and control groups

Assessment	Group	T0 X ± SD	T1 X ± SD	T2 X ± SD	p^a	ηp^2_a	p^b	ηp^2_b
Beighton Score (0–9)	**Pilates**	4.81 ± 0.52	5.03 ± 0.29	5.09 ± 0.41	0.062	0.016	**0.017***	0.039
	Control	4.77 ± 0.34	6.28 ± 0.31	6.57 ± 0.42	**0.034***	0.048		
	p^c	0.246	**0.024***	**0.011***				
PGQ (0-100)	**Pilates**	12.26 ± 4.18	13.87 ± 3.91	12.64 ± 4.57	0.328	0.072	**0.021***	0.317
	Control	13.73 ± 3.82	23.91 ± 4.82	29.62 ± 5.21	**0.004***	0.521		
	p^c	0.426	**0.009***	**0.002***				

*p < 0.05. **PGQ**: Pelvic girdle questionnaire, **T0:** Initial evaluation; **T1:** Intermediate evaluation; **T2:** Final evaluation; **ηp^2:** Partial eta squared; X: Mean; **SD**: Standard deviation; **n**: Sample size; **a**: One-way repeated measures ANOVA; **b**:2-by-3, mixed-model repeated measures ANOVA (group-by-time interaction); **c**: Independent samples t test

preserve functional stability despite ongoing physiological remodeling [5, 11]. Stabilization of weight-bearing joints such as the knees and elbows is critical for injury prevention and maintaining functional performance [30]. We propose that Pilates-induced stabilization of the knee joint may enhance pregnant women's confidence and neuromuscular control during daily activities, such as sitting and walking, thereby supporting the maintenance of physical activity throughout pregnancy. This hypothesis is supported by our observation that participants in the Pilates group maintained walking activity levels during the 8-week intervention.

Conversely, ligamentous laxity increased significantly in the control group. The moderate effect sizes observed may be explained by the high baseline ligamentous laxity measurements in both groups. Consistent with prior findings, the results of this randomized controlled study indicate that Pilates-based stabilization helps maintain anterior cruciate ligamentous laxity near baseline levels despite pregnancy-related physiological changes. Pilates, as a comprehensive exercise modality, engages the entire body and promotes well-being through controlled movements and core stabilization [31]. Although knee ligamentous laxity remained stable, the Pilates group showed no statistically significant change in Beighton scores, a measure of generalized joint hypermobility. In contrast, the control group demonstrated a moderate, statistically significant increase over the 8 weeks. We interpret the slight increase in the Pilates group as a consequence of hormonal effects on connective tissue during pregnancy. At the same time, Pilates exercises may have limited influence on hypermobility in joints that are less engaged during training, such as the fingers. Pilates primarily strengthens the lumbopelvic region and core musculature, facilitating adaptation to biomechanical and balance changes during pregnancy rather than directly modulating peripheral joint hypermobility [11].

While increased joint mobility is physiologically necessary during pregnancy, it must be regulated to mitigate potential adverse outcomes. We propose that Pilates provides a controlled means of managing this physiological increase in joint mobility while maintaining functional stability and preventing musculoskeletal complications.

This randomized study results also showed that participants in the Pilates group experienced no activity limitations due to pelvic girdle pain, while those in the control group reported progressive worsening of symptoms. Existing evidence supports the role of exercise, including Pilates, in managing pelvic girdle pain during pregnancy [32]. Pilates aids pain management by activating deep stabilizing muscles and accommodating pregnancy-related physiological changes. Furthermore, its focus on breathing, concentration, and mind-body awareness addresses the multifactorial nature of pain [33]. Additionally, the small-group Pilates sessions employed in this study may have positively influenced the psychological and social dimensions related to pain, which can affect pain perception and coping.

Another important finding was the difference in weekly step counts after eight weeks. Although step counts declined in both groups with advancing pregnancy, participants in the Pilates group maintained higher activity levels, likely due to the preservation of joint stability and reduced pain-related limitations. Pilates not only confers physical benefits but also supports mental well-being, enabling pregnant women to maintain normal daily functioning and quality of life during pregnancy [34].

Although between-group differences in ligamentous laxity measured by the GNRB® knee arthrometer were statistically significant, the absolute changes provide important context. Over the 8-week period, the control group exhibited an average increase of approximately 2.0 mm at both 134 N and 200 N anterior forces, whereas the Pilates group showed minimal changes (< 0.3 mm). The device is sensitive enough to detect changes as small as 0.1 mm [35]; however, the minimal clinically important difference (MCID) for ACL laxity in pregnant populations has not been established. While a difference of ~ 2 mm may be considered clinically relevant in some ACL injury contexts, no consensus exists on its applicability during pregnancy. Therefore, the clinical implications of these statistically significant differences should be interpreted with caution.

This study has several strengths. It was a randomized controlled trial with standardized delivery of the intervention by a certified physiotherapist, and it incorporated objective outcome measures such as the GNRB® knee arthrometer and pedometer-based activity monitoring, as well as a standardized clinical assessment of joint hypermobility using the Beighton score. The study also addresses a relatively underexplored area by evaluating the effects of Pilates during pregnancy on gait parameters and ligamentous laxity.

Limitations

This study has several limitations. First, ligamentous laxity was assessed solely at the knee joint without multi-joint evaluation, and no objective hormonal measurements (e.g., relaxin levels) were obtained, limiting insight into the relationship between hormonal changes and ligamentous laxity. Second, while physical activity was objectively monitored using a pedometer, non–step-based activities (e.g., swimming, stationary cycling) were not recorded and could not be controlled. Third, although the GNRB® knee arthrometer protocol followed Vauhnik et al. [19] with reported acceptable inter-rater reliability, variations in applied force or testing conditions may still have influenced measurements. Future research with larger cohorts, comprehensive multi-joint and hormonal assessments, and long-term follow-up, including postpartum evaluations, is needed to clarify the role of Pilates during and after pregnancy.

Conclusion

Pilates exercises may serve as a safe and effective intervention for maintaining ligament flexibility and regulating joint hypermobility during pregnancy, potentially reducing activity limitations related to pelvic girdle pain. Rather than directly altering ligament collagen structure, Pilates may help preserve joint stability by strengthening periarticular muscles, enhancing proprioception, and optimizing neuromuscular control, thereby offsetting the laxity-inducing effects of pregnancy-related hormonal changes such as elevated relaxin. This randomized controlled study's findings suggest that Pilates can moderate pregnancy-induced increases in ligamentous laxity and joint hypermobility while mitigating associated risks of pain and injury through improved biomechanical stabilization and neuromuscular control.

Integrating structured prenatal Pilates programs into routine antenatal care may enhance maternal musculoskeletal health and quality of life, ultimately contributing to safer and more comfortable pregnancies. Future research should explore the effects of Pilates on postpartum recovery and compare it with other exercise modalities to optimize maternal musculoskeletal outcomes. These findings could encourage healthcare providers to integrate Pilates into antenatal care to support maternal physical and psychological well-being. Large-scale, multicenter trials across diverse populations are essential to strengthen the evidence base for integrating Pilates into routine antenatal care.

Abbreviations

ACOG	American College of Obstetricians and Gynecologists
ACL	Anterior cruciate ligament
CG	Control group
GJH	Generalized joint hypermobility
PG	Pilates group
PGQ	Pelvic Girdle Questionnaire

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Author contributions
MB was involved in conceptualization, methodology, project administration, and the main writing original draft. HIB was in conceptualization, methodology, project administration, resources, and the main writing original draft. BD contributed to organizing the study method and guidance throughout the project. SS was involved in conceptualization, methodology and investigation. CGA conducted data analysis. SZD was involved in conceptualization. NAG was involved in resources and contributed to organizing the study method and providing supervision. All authors contributed to reviewing and editing the manuscript and approved the final manuscript.

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Data availability
The datasets used and analyzed during the study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Institutional approval was obtained from the Ankara Medipol University Non-Interventional Clinical Research Ethics Committee (Approval No: 128). Informed consent, both written and verbal, was obtained from participants before the research commenced. The study followed the principles of the Declaration of Helsinki.

Consent for publication
Written and verbal informed consent was obtained from all individual participants included in the study.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Ankara Medipol University, Ankara, Turkey
[2]Department of Family Medicine, Mugla Training and Research Hospital, Mugla, Turkey
[3]Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Gazi University, Ankara, Turkey

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References
1. Sánchez-Polán M, Nagpal TS, Zhang D, Silva-Jose C, Montejo R, Barakat R. The influence of physical activity during pregnancy on maternal pain and discomfort: a meta-analysis. J Pers Med. 2023;14(1): 44. https://doi.org/10.3390/jpm14010044.
2. Fiat F, Merghes PE, Scurtu AD, Guta BA, Dehelean CA, et al. The main changes in pregnancy-therapeutic approach to musculoskeletal pain. Medicina (B Aires). 2022;58(8): 1115. https://doi.org/10.3390/medicina58081115.
3. Thorell E, Goldsmith L, Weiss G, Kristiansson P. Physical fitness, serum relaxin and duration of gestation. BMC Pregnancy Childbirth. 2015;15:168. https://doi.org/10.1186/s12884-015-0607-z.
4. Conrad KP. Emerging role of relaxin in the maternal adaptations to normal pregnancy: implications for preeclampsia. Semin Nephrol. 2011;31(1):15–32. https://doi.org/10.1016/j.semnephrol.2010.10.003.
5. Dehghan F, Haerian BS, Muniandy S, Yusof A, Dragoo JL, Salleh N. The effect of relaxin on the musculoskeletal system. Scand J Med Sci Sports. 2014;24(4):e220–9. https://doi.org/10.1111/sms.12149.
6. Conder R, Zamani R, Akrami M. The biomechanics of pregnancy: a systematic review. J Funct Morphol Kinesiol. 2019;4(4): 72. https://doi.org/10.3390/jfmk4040072.
7. Chu SR, Boyer EH, Beynnon B, Segal NA. Pregnancy results in lasting changes in knee joint laxity. PM R. 2019;11(2):117–24. https://doi.org/10.1016/j.pmrj.2018.06.012.
8. Ahlqvist K, Bjelland EK, Pingel R, Schlager A, Peterson M, Olsson CB, et al. Generalized joint hypermobility and the risk of pregnancy-related pelvic girdle pain: is body mass index of importance?-a prospective cohort study. Acta Obstet Gynecol Scand. 2023;102(10):1259–68. https://doi.org/10.1111/aogs.14664.
9. Physical Activity and Exercise During Pregnancy and the Postpartum Period. ACOG committee opinion, number 804. Obstet Gynecol. 2020;135(4):e178–88. https://doi.org/10.1097/AOG.0000000000003772.
10. Liddle SD, Pennick V. Interventions for preventing and treating low-back and pelvic pain during pregnancy. Cochrane Database Syst Rev. 2015;2015(9): CD001139. https://doi.org/10.1002/14651858.CD001139.pub4.
11. Davenport MH, Marchand AA, Mottola MF, Poitras VJ, Gray CE, Garcia AJ, et al. Exercise for the prevention and treatment of low back, pelvic girdle and lumbopelvic pain during pregnancy: a systematic review and meta-analysis. Br J Sports Med. 2019;53(2):90–8. https://doi.org/10.1136/bjsports-2018-099400.
12. Turan Alagoz A, Gercek H, Unuvar BS, Findik FY, Ozgul S. The effects of pilates method in pregnant women: scoping review. BMC Pregnancy Childbirth. 2025;25(1):485. https://doi.org/10.1186/s12884-025-07622-z.
13. de Campos Júnior JF, de Oliveira LC, Dos Reis AL, de Almeida LIM, Branco LV, de Oliveira RG. Effects of pilates exercises on postural balance and reduced risk of falls in older adults: a systematic review and meta-analysis. Complement Ther Clin Pract. 2024;57: 101888. https://doi.org/10.1016/j.ctcp.2024.101888.
14. Song BH, Kim J. Effects of pilates on pain, physical function, sleep quality, and psychological factors in young women with dysmenorrhea: a preliminary randomized controlled study. Healthcare. 2023;11(14): 2076. https://doi.org/10.3390/healthcare11142076.
15. Long G, Yaoyao Z, Na Y, Ping Y, Mingsheng T. Generalized joint laxity as a predictor of recovering from low back pain during pregnancy - A prospective study. J Orthop Sci. 2022;27(2):342–7. https://doi.org/10.1016/j.jos.2021.01.010.
16. Evenson KR, Hesketh KR. Monitoring physical activity intensity during pregnancy. Am J Lifestyle Med. 2021;17(1):18–31. https://doi.org/10.1177/15598276211052277.
17. Konopka JA, DeBaun MR, Chang W, Dragoo JL. The intracellular effect of relaxin on female anterior cruciate ligament cells. Am J Sports Med. 2016;44(9):2384–92. https://doi.org/10.1177/0363546516646374.
18. Smith K, Miller N, Laslovich S. The reliability of the GNRB® knee arthrometer in measuring ACL stiffness and laxity: implications for clinical use and clinical trial design. Int J Sports Phys Ther. 2022;17(6):1016–25. https://doi.org/10.26603/001c.38252.
19. Vauhnik R, Morrissey MC, Perme MP, Sevsek F, Rugelj D. Inter-rater reliability of the GNRB® knee arthrometer. Knee. 2014;21(2):541–3. https://doi.org/10.1016/j.knee.2013.10.004.
20. Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. Ann Rheum Dis. 1973;32(5):413–8. https://doi.org/10.1136/ard.32.5.413.
21. Malek S, Reinhold EJ, Pearce GS. The beighton score as a measure of generalised joint hypermobility. Rheumatol Int. 2021;41(10):1707–16. https://doi.org/10.1007/s00296-021-04832-4.
22. Stendal Robinson H, Lindgren A, Bjelland EK. Generalized joint hypermobility and risk of pelvic girdle pain in pregnancy: does body mass index matter? Physiother Theory Pract. 2022;38(12):2222–9. https://doi.org/10.1080/09593985.2021.1913774.
23. Cherni Y, Desseauve D, Decatoire A, et al. Evaluation of ligament laxity during pregnancy. J Gynecol Obstet Hum Reprod. 2019;48(5):351–7. https://doi.org/10.1016/j.jogoh.2019.02.009.
24. Stuge B, Garratt A, Krogstad Jenssen H, Grotle M. The pelvic girdle questionnaire: a condition-specific instrument for assessing activity limitations and symptoms in people with pelvic girdle pain. Phys Ther. 2011;91(7):1096–108. https://doi.org/10.2522/ptj.20100357.
25. Yilmaz Yelvar GD, Çırak Y, Parlak Demir Y, Turkyılmaz ES. Cultural adaptation, reliability and validity of the pelvic girdle questionnaire in pregnant women. Ankara Med J. 2019;19(3):513–23. https://doi.org/10.17098/amj.624417.
26. Lindseth G, Vari P. Measuring physical activity during pregnancy. West J Nurs Res. 2005;27(6):722–34. https://doi.org/10.1177/0193945905276523.
27. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Lawrence Erlbaum Associates; 1988.
28. Pereira MJ, Mendes R, Mendes RS, Martins F, Gomes R, Gama J, et al. Benefits of pilates in the elderly population: a systematic review and meta-analysis. Eur J Investig Health Psychol Educ. 2022;12(3):236–68. https://doi.org/10.3390/ejihpe12030018.
29. Adıguzel H, Elbasan B. Effects of modified pilates on trunk, postural control, gait and balance in children with cerebral palsy: a single-blinded randomized controlled study. Acta Neurol Belg. 2022;122(4):903–14. https://doi.org/10.1007/s13760-021-01845-5.
30. Vincent HK, Brownstein M, Vincent KR, Injury Prevention. Safe training techniques, rehabilitation, and return to sport in trail runners. Arthrosc Sports Med Rehabil. 2022;4(1):e151–62. https://doi.org/10.1016/j.asmr.2021.09.032.
31. Tarnas M, Marszałek A, Kufel-Grabowska J, Marszałek S, Wieliński D, Zieliński J. Effects of pilates training on cardiorespiratory functions in medical conditions - comprehensive approach: a narrative review. Aging Dis. 2024;15(4):1771–83. https://doi.org/10.14336/AD.2023.0929.
32. Malhotra D, Khan AR, Nigam A, Khan A, Jaleel G. Effectiveness of pilates in pregnancy: a review. Sport Sci Health. 2025. https://doi.org/10.1007/s11332-025-01373-2.
33. Vera-Saura P, Agudo-Pavón J, Velázquez-Torres DM, Martin-Aleman M, Leon Morillas F, et al. The importance of Mind-Body in pilates method in patients with chronic Non-Specific low back Pain-A randomized controlled trial. J Clin Med. 2024;13(16):4731. https://doi.org/10.3390/jcm13164731

34. Li Y, Lu H, Zhang L, Ren Y, Dai X, Lin L. Pilates exercise in pregnancy: a systematic review and meta-analysis. BMC Sports Sci Med Rehabil. 2025;17(1):20. https://doi.org/10.1186/s13102-025-01067-9.
35. Magdič M, Dahmane RG, Vauhnik R. Intra-rater reliability of the knee arthrometer GNRB® for measuring knee anterior laxity in healthy, active subjects. J Orthop. 2023;39:7–10. https://doi.org/10.1016/j.jor.2023.03.016.

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