DOI: 10.7860/JCDR/2026/89921.24031

Original Article

Physiotherapy Section

Relationship between Core Muscle Endurance, Hamstring Flexibility and Pelvic Tilt with Low Back Pain-related Functional Limitation in Road Cyclists: A Cross-sectional Study

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ABSTRACT

Introduction: Low Back Pain (LBP) is one of the most common musculoskeletal injuries among both recreational and competitive cyclists, with reported prevalence rates ranging from 30% to 60%. Biomechanical factors such as insufficient trunk muscle endurance, limited hamstring extensibility, and abnormal pelvic positioning have been identified as potential contributors to cycling-related LBP; however, their combined impact on functional disability in this athletic population has not been thoroughly investigated.

Aim: To examine the relationships between core muscle endurance, hamstring flexibility, and pelvic tilt with LBP related functional disability in amateur road cyclists.

Materials and Methods: The present cross-sectional study was conducted at KLE Institute of Physiotherapy, Belagavi, Karnataka, India, between 10 January 2026 and 12 April 2026, included 41 (n=41) road cyclists with non specific LBP. McGill's trunk endurance test battery was used to assess core muscle endurance, the active knee extension test was used to measure hamstring extensibility, and the Artificial Intelligence (AI) Posture Evaluation and Correction System (APECS) smartphone application was used to quantify anterior pelvic tilt in both standing and on-cycle positions. The Oswestry Disability Index (ODI) was used to quantify functional limitation. Following confirmation of data normality via the Shapiro-Wilk test, bivariate associations were analysed using Pearson's correlation coefficient, followed by simple and multiple linear regression analyses.

Results: All trunk endurance parameters exhibited strong inverse correlations with ODI scores (r=-0.745 to -0.847). Hamstring restriction, indicated by increased Active Knee Extension angles, demonstrated significant direct correlations with disability (right r=0.823, left r=0.779). Pelvic tilt while standing (r=0.627) and while cycling (r=0.733) exhibited significant correlations with ODI scores. Multiple regression analysis revealed core endurance (β=-0.053) and pelvic tilt (β=0.243) as independent predictors of functional limitation, collectively explaining 82.6% of the variance in ODI scores.

Conclusion: Reduced core muscle endurance, limited hamstring extensibility, and increased anterior pelvic tilt in the cycling position correlated with greater functional disability. Core muscle endurance and pelvic tilt emerged as independent predictors of disability, underscoring their relevance in physiotherapy assessment and rehabilitation for this population.

Keywords: Hamstring muscles, Lumbar vertebrae, Musculoskeletal pain, Muscle endurance, Postural balance

INTRODUCTION

Cycling has grown into a widely practiced physical activity globally, valued for its cardiovascular and metabolic benefits and its comparatively low joint loading relative to other weight-bearing sports. Notwithstanding these advantages, musculoskeletal complaints are prevalent in this population, with LBP representing one of the most consistently reported problems across both recreational and competitive cohorts. Epidemiological investigations have recorded LBP occurrence rates of 30-60% among cyclists [1,2], and the condition is a well-recognised contributor to diminished training volume and functional decline in athletic populations [3,4].

The aerodynamic riding position characteristic of road cycling requires sustained trunk flexion, forward pelvic inclination, and uninterrupted mechanical loading of the lumbar spine. Protracted maintenance of this posture induces muscular fatigue, compressive loading on spinal structures, and stress accumulation in passive supporting elements, each of which may predispose to LBP [5,6]. Biomechanical investigations have highlighted the contributions of spinal kinematics, trunk muscle function, and rider positioning to cycling-associated LBP, yet the precise mechanisms through which specific physical characteristics translate into functional disability remain incompletely characterised [7].

Core muscle endurance is fundamental to lumbopelvic stability during prolonged, repetitive activities. The abdominal and paraspinal muscle groups serve as active stabilisers of the lumbar spine, neutralising the compressive and shear forces generated during cyclical movements such as pedalling. When this endurance capacity is exhausted, spinal support shifts progressively to passive structures including intervertebral discs, ligaments, and facet joint capsules thereby increasing the likelihood of tissue irritation and cumulative loading injury [8,9]. Cross-sectional studies across general and athletic populations have consistently documented lower trunk endurance values in individuals with LBP compared with asymptomatic counterparts, and this relationship has been confirmed in cyclists specifically [10-13].

Hamstring extensibility constitutes a secondary but mechanistically important determinant of lumbopelvic kinematics. Reduced hamstring flexibility constrains hip flexion range and disrupts the normal lumbopelvic rhythm during forward-trunk loading activities such as cycling, inducing compensatory lumbar flexion that amplifies disc loading and posterior ligamentous stress [14,15]. Numerous cross-sectional studies have identified diminished hamstring flexibility in individuals with LBP relative to asymptomatic controls, suggesting that muscular tightness creates a biomechanical milieu conducive to spinal discomfort [16,17].

Pelvic alignment during cycling has attracted less research attention than trunk muscle function, despite its mechanistic significance. Anterior pelvic tilt modifies lumbar lordosis, alters the lumbosacral angle, and redistributes loading across lumbar motion segments [18]. A clinically pertinent consideration is that pelvic posture in the on-bicycle position shaped by saddle height, handlebar reach, and rider flexibility may diverge substantially from posture during quiet standing, yet the majority of prior investigations have relied solely on static measurements, which limits their applicability to cycling-specific biomechanical demands [19-21]. Modified recruitment patterns in the erector spinae have been reported in cyclists with prior LBP episodes [22], further implicating trunk-pelvic interaction in the pathomechanics of cycling-related spinal pain.

Although the literature addressing individual contributors to cycling-related LBP continues to expand, no previous study has concurrently evaluated core muscle endurance, hamstring flexibility, and pelvic tilt assessed in both standing and cycling postures in relation to functional limitation in amateur cyclists. Elucidating the combined and independent contributions of these biomechanical variables to disability may enhance clinical assessment frameworks and guide more precisely targeted rehabilitation approaches. Accordingly, the present investigation sought to: i) characterise the associations between core endurance, hamstring flexibility, pelvic tilt (standing and on-cycle), and LBP-related functional limitation among amateur road cyclists; and ii) identify which of these variables independently predict disability level.

MATERIALS AND METHODS

The present cross-sectional study was conducted at KLE Institute of Physiotherapy, Belagavi, Karnataka, India, between 10 January 2026 and 12 April 2026, in accordance with the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) guidelines [23]. Ethics clearance was obtained from the Institutional Research and Ethics Committee of KLE Institute of Physiotherapy, Belagavi, Karnataka (Reference No: KIPT/876/23/11/2024), and the study protocol was prospectively registered with the Clinical Trials Registry of India (CTRI/2025/01/078932). Written informed consent was obtained from each participant prior to enrolment.

Inclusion criteria:

- Amateur road cyclists aged 18-50 years;
- Regular cycling participation for ≥1 year at a frequency of 3-5 sessions per week;
- Self-reported non specific LBP occurring during or after cycling activity.

Exclusion criteria:

- Prior spinal surgery;
- Neurological disorders affecting movement or sensation;
- Active lower-limb injury within the three months preceding enrolment;
- Diagnosed structural spinal pathology (e.g., disc prolapse, spondylolisthesis, vertebral fracture).

Sample size calculation: The required sample was estimated using the correlation-coefficient formula described by Bonett DG and Wright TA [24]. A correlation coefficient of r=0.596, derived from an initial subset of screened participants (between trunk extensor endurance and ODI scores), was used as the basis for calculation, with a two-sided alpha of 1% and a targeted power of 95% [25]. This procedure established a minimum enrolment of 36 participants; the study was continued until 41 eligible cyclists were enrolled to account for dropouts.

Study Procedure

Participants were identified through convenience sampling across local cycling clubs, social media networks, and community cycling events; approximately 237 cyclists were screened, of whom 41 met all eligibility criteria and were enrolled. The principal investigator attended cycling club sessions and local events, where on-site screening camps were organised. Because the on-bicycle pelvic tilt assessment required participants to adopt their habitual riding posture on their own bicycles, all assessments were conducted at the cycling venues.

Outcome measures: A single trained physiotherapist administered all outcome assessments to ensure consistency. Each measurement was conducted on two separate occasions, and the highest value of the two trials was retained for analysis.

1. **Core muscle endurance (McGill trunk endurance test battery) [8].** This validated battery {Intraclass Correlation Coefficient (ICC)=0.87} encompasses four component tests: i) trunk flexor endurance, requiring participants to maintain a 50° trunk incline against gravitational resistance; ii) trunk extensor endurance conducted in the Biering-Sørensen position; and iii) bilateral side bridge endurance. The endurance duration (seconds) was recorded for each test. Longer hold times indicate greater trunk endurance capacity; lower values reflect impaired lumbopelvic stabilisation ability.
2. **Hamstring flexibility (Active Knee Extension test):** Participants completed the Active Knee Extension (AKE) test (ICC=0.78-0.99) [26] in the supine position with the test limb held at 90° of hip flexion. Each participant extended the knee to the maximum achievable range without altering hip angle, and the residual knee flexion angle was recorded using a universal goniometer. A numerically higher AKE angle reflects greater hamstring restriction.
3. **Pelvic tilt (APECS application).** Anterior pelvic tilt was measured using the APECS smartphone application (ICC=0.987) [27]. Measurements were obtained in two conditions: i) Standing: the participant stood at ease in minimal clothing while a standardised lateral image was captured; and (ii) On-cycle: the participant adopted their habitual riding posture on their own bicycle and a lateral photograph was taken at a fixed distance. The application automatically detected anatomical landmarks and computed the anterior pelvic tilt angle (degrees) in each position. A higher pelvic tilt angle (in degrees) indicates greater anterior rotation of the pelvis.
4. **Functional limitation {Oswestry Disability Index (ODI), version 2.1a}.** The ODI (ICC=0.87) is a validated, disease-specific 10-item questionnaire measuring LBP-related disability across a range of daily activities [28]. Each item is scored 0-5, and the total is expressed as a percentage (0-100%). Higher scores indicate greater functional limitation.
5. **Composite variable derivation:** For the parsimonious three-predictor regression model, composite scores were computed as follows: (i) the core endurance composite was the arithmetic mean of the four McGill test component durations (trunk flexor endurance, trunk extensor endurance, right-side bridge, and left-side bridge), all expressed in seconds; (ii) the hamstring flexibility composite was the mean of the right and left Active Knee Extension angles (degrees); and (iii) the pelvic tilt composite was the mean of the standing and on-cycle pelvic tilt angles (degrees). This approach reduced dimensionality while preserving the directional contribution of each domain to the regression model.

STATISTICAL ANALYSIS

Statistical Package for the Social Sciences (SPSS) version 26.0 was used for all calculations. The Shapiro-Wilk test confirmed the normality of each variable. Pearson's correlation coefficient (r) quantified bivariate relationships between each predictor and ODI scores, and simple linear regression was performed for every statistically significant correlate. Correlation magnitude was classified using the scheme proposed by Mukaka M [29]: r≥0.90=very strong; 0.70-0.89 = strong; 0.50-0.69 = moderate; 0.30-0.49 = weak. A multiple linear regression model (enter method) was constructed to identify variables with independent predictive value for ODI%; model adequacy was appraised via R^2, adjusted R^2, the F-statistic, and the standard error of the estimate; p<0.05 was used for statistical significance.

RESULTS

Participant characteristics: A total of 41 road cyclists (25 male and 16 female) with non specific LBP were analysed. The mean participant age was 34.51±10.13 years (range 18-50), mean Body Mass Index (BMI) was 23.93±3.95 kg/m², and cycling experience ranged from one to eight years [Table/Fig-1].

Variables	Minimum	Maximum	Range	Mean	Median	SD
Age (year)	18.00	50.00	32.00	34.51	35.00	10.13
Height (cm)	145.00	180.00	35.00	165.37	166.00	8.01
Weight (kg)	46.00	84.00	38.00	65.29	65.00	11.17
BMI (kg/m²)	16.50	31.20	14.70	23.93	23.20	3.95
Experience (years)	1.00	8.00	7.00	4.20	3.00	2.52

[Table/Fig-1]: Participant characteristics (N=41).

Descriptive statistics by gender: Male cyclists recorded greater average core endurance across all test components compared with their female counterparts. The mean pelvic tilt angle in the on-bicycle position (17.79±3.08°) substantially exceeded that measured during standing (12.98±2.70°) across the entire sample, a difference attributable to the anterior pelvic shift imposed by the cycling posture. The cohort's overall mean ODI score was 24.29±7.70% [Table/Fig-2].

Parameters	Total Mean±SD	Male Mean±SD	Female Mean±SD
Trunk flexor endurance (s)	61.71±17.67	67.00±16.28	53.44±16.99
Trunk extensor endurance (s)	109.02±25.80	117.00±22.09	96.56±26.88
Right-side bridge (s)	59.17±14.24	62.16±13.77	54.50±14.12
Left-side bridge (s)	58.66±13.99	61.16±14.01	54.75±13.47
Flexor: Extensor ratio	0.57±0.09	0.58±0.10	0.55±0.08
Right: Left bridge ratio	1.01±0.05	1.02±0.05	0.99±0.04
Bridge: extensor ratio	0.54±0.06	0.53±0.06	0.57±0.05
Right AKE (°)	28.46±5.66	27.58±5.83	29.83±5.26
Left AKE (°)	28.68±5.68	27.94±6.09	29.84±4.94
Pelvic tilt- standing (°)	12.98±2.70	12.88±2.94	13.14±2.37
Pelvic Tilt- On-cycle (°)	17.79±3.08	17.60±3.21	18.08±2.94
ODI (%)	24.29±7.70	23.12±7.42	26.13±8.02

[Table/Fig-2]: Descriptive statistics of outcome variables stratified by gender.

Assessment of normality: The Shapiro-Wilk test indicated that all 12 study variables exhibited normal distribution (p-values: 0.059-0.886), satisfying the necessary conditions for parametric analysis [Table/Fig-3].

Parameters	Shapiro-Wilk	Df	p-value	Distribution
Trunk flexor endurance (s)	0.978	41	0.589	Normal
Trunk extensor endurance (s)	0.951	41	0.076	Normal
Right-side bridge endurance (s)	0.978	41	0.615	Normal
Left-side bridge endurance (s)	0.980	41	0.671	Normal
Flexor: extensor ratio	0.961	41	0.166	Normal
Right: left-side bridge ratio	0.965	41	0.059	Normal
Side bridge : extensor ratio	0.954	41	0.069	Normal
Right AKE (°)	0.975	41	0.501	Normal
Left AKE (°)	0.972	41	0.388	Normal
Pelvic Tilt - Standing (°)	0.978	41	0.610	Normal
Pelvic Tilt - On-cycle (°)	0.986	41	0.886	Normal
ODI (%)	0.980	41	0.660	Normal

[Table/Fig-3]: Shapiro-Wilk normality test results for all study variables.

Core Muscle Endurance and Functional Limitation

All four trunk endurance measures exhibited statistically significant inverse correlations with ODI scores (all p<0.001) [Table/Fig-4]. Trunk flexor endurance yielded the strongest bivariate relationship (r=-0.847), indicating that cyclists with lower flexor holding capacity had markedly higher disability scores. Left-side bridge endurance (r=-0.819) and right-side bridge endurance (r=-0.810) were of comparable magnitude, while trunk extensor endurance produced the weakest inverse association within this group (r=-0.745). These findings collectively affirm that diminished capacity in all trunk endurance components is consistently associated with increased functional limitation. Scatter plots are presented in [Table/Fig-5].

Core Endurance Ratios and Functional Limitation

Among the three ratio variables assessed [Table/Fig-6], only the Flexor: Extensor ratio demonstrated a statistically significant inverse relationship with ODI scores (r=-0.453, p=0.003), indicating that a relative predominance of extensor over flexor endurance capacity is associated with greater disability. The Right: left-side bridge ratio (r=0.000, p=0.999) and the side bridge: extensor ratio (r=-0.135, p=0.402) showed no meaningful correlation with functional limitation. Scatter diagrams for ratio variables are presented in [Table/Fig-7].

Hamstring Flexibility, Pelvic Tilt, and Functional Limitation

Active knee extension angles representing the magnitude of hamstring restriction were positively and substantially correlated with ODI scores on both sides (right r=0.823, p<0.001; left r=0.779, p<0.001) [Table/Fig-8], confirming that greater hamstring tightness corresponds to higher disability in this cohort. Both pelvic tilt measurements were significantly and directly associated with ODI scores. The on-cycle pelvic tilt produced the stronger relationship (r=0.733, p<0.001), with each additional degree of anterior inclination during riding corresponding to a 1.831-percentage-point increment in ODI. Standing pelvic tilt also reached significance (r=0.627, p<0.001), with a regression coefficient of 1.786 per degree. These findings indicate that greater anterior pelvic inclination especially in the actual riding posture, was significantly associated with higher functional disability. Scatter diagrams are presented in [Table/Fig-9].

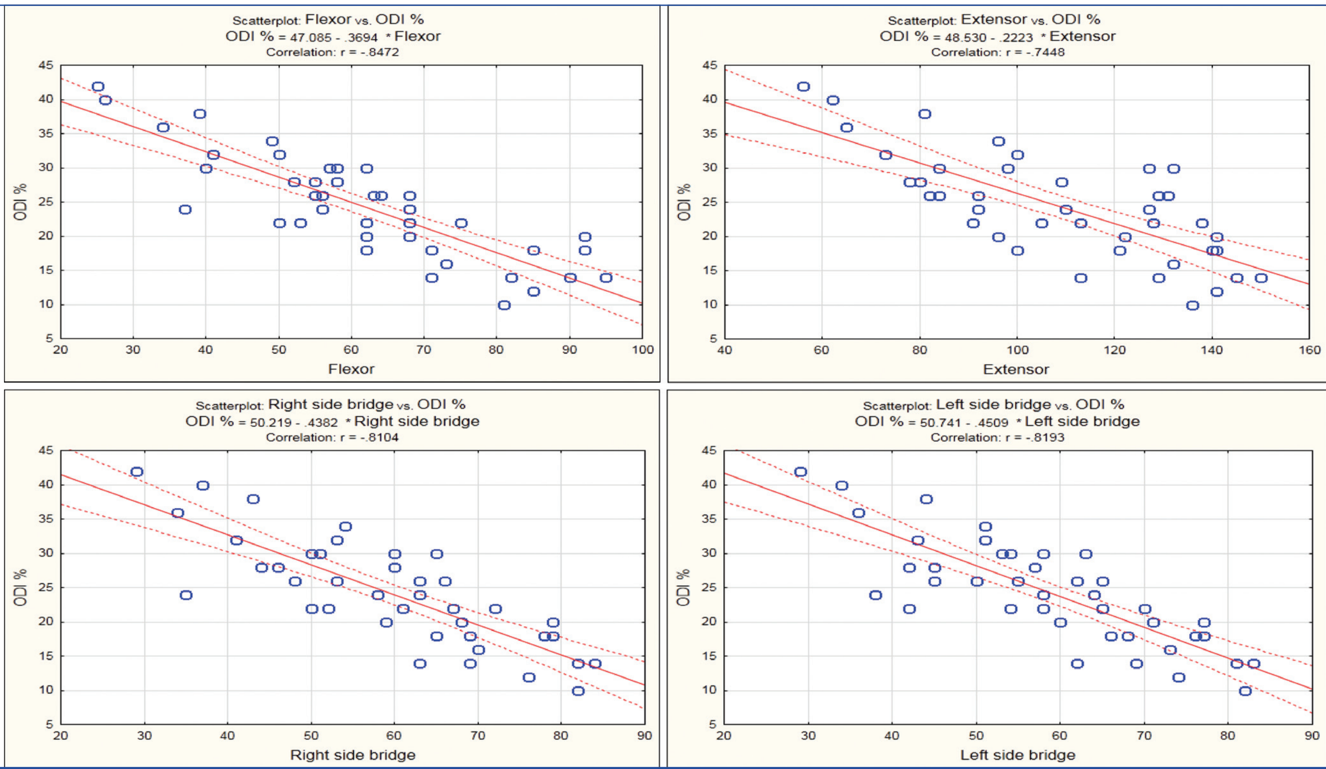
Multiple Linear Regression Analysis

The full multiple regression model [Table/Fig-10,11] incorporating all individual predictors of ODI% achieved an excellent overall fit (R^2=0.914, Adjusted R^2=0.881, F(11,29)=28.000, p<0.001). After correcting for multicollinearity among predictors, only on-cycle pelvic tilt (β=5.345, p=0.001) and standing pelvic tilt (β=-4.702, p=0.008) retained independent statistical significance. The opposing directions of these coefficients reflect their differential contributions to disability: anterior pelvic tilt during cycling predicts greater functional limitation, while the negative coefficient for standing pelvic tilt reflects its attenuation once on-cycle posture is accounted for.

The parsimonious three-predictor model [Table/Fig-12] incorporating composite scores for core endurance, hamstring flexibility, and pelvic tilt yielded an equivalently robust fit (R^2=0.826, Adjusted R^2=0.812, F(3,37)=58.535, p<0.001). Within this reduced model, core endurance (β=-0.053, p<0.001) and pelvic tilt (β=0.243, p<0.001) emerged as significant independent predictors of ODI%, while hamstring flexibility did not independently account for disability variance once the other two variables were held constant (β=-2.887, p=0.469). Core endurance and pelvic tilt jointly explained 82.6% of the variability in functional limitation [Table/Fig-13].

Variables	r	T	p-value	Constant (a)	Reg. Coeff. (b)	Interpretation
Trunk flexor endurance	-0.847	-9.959	<0.001*	47.08	-0.369	Strong negative
Trunk extensor endurance	-0.745	-6.971	<0.001*	48.53	-0.222	Strong negative
Right-side Bridge	-0.810	-8.638	<0.001*	50.22	-0.438	Strong negative
Left-side Bridge	-0.819	-8.923	<0.001*	50.74	-0.451	Strong negative

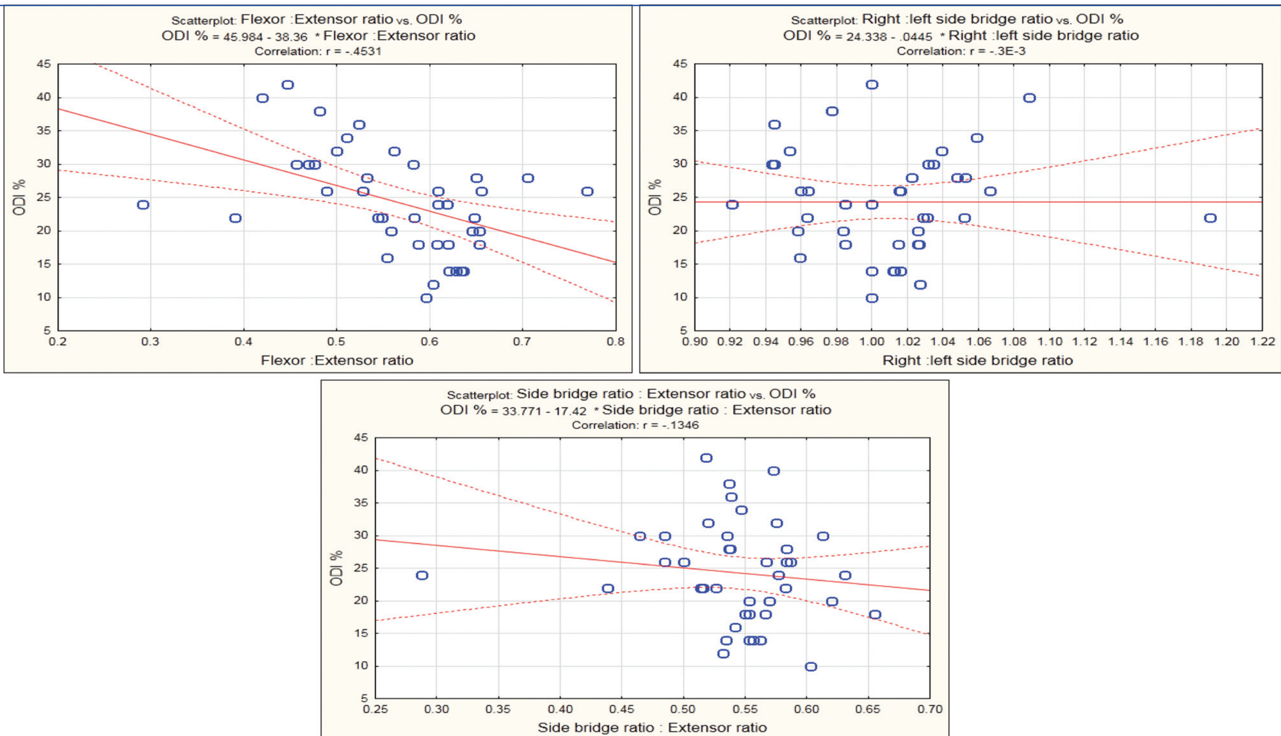
[Table/Fig-4]: Pearson's correlation and simple linear regression- Core endurance vs ODI%.
*p<0.05; AKE: Active knee extension; ODI: Oswestry disability index; Reg. Coeff.: regression coefficient



[Table/Fig-5]: Scatter diagram of correlation between ODI % scores with flexor, extensor, right-side bridge and left-side bridge scores.

Ratio Variable	r	t	p-value	Constant (a)	Reg. Coeff. (b)
Flexor: Extensor ratio	-0.453	-3.175	0.003*	45.98	-38.36
Right: Left-side bridge ratio	0.000	-0.002	0.999	24.34	-0.04
Side bridge: extensor ratio	-0.135	-0.848	0.402	33.77	-17.42

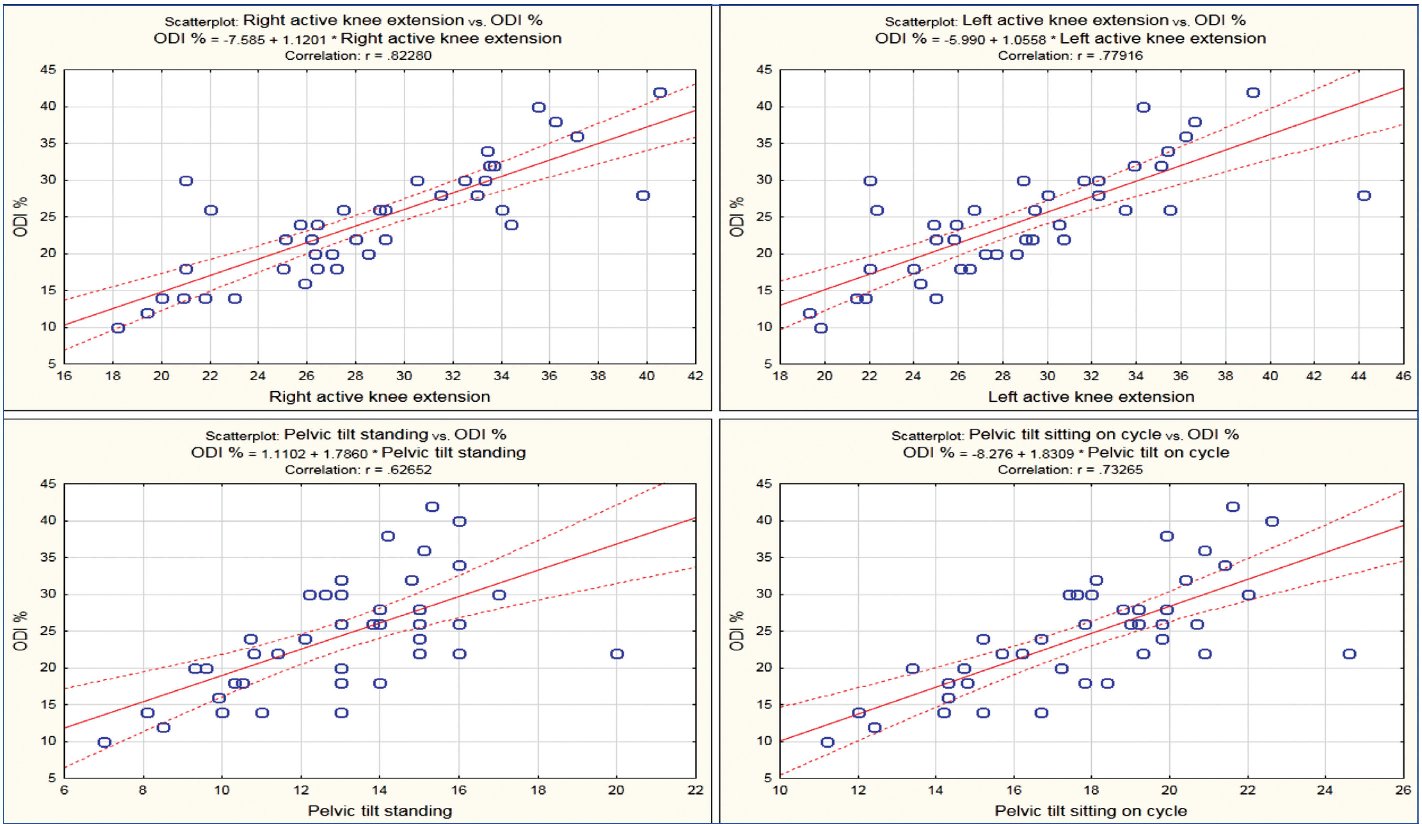
[Table/Fig-6]: Pearson's correlation and simple linear regression- Core endurance ratios vs ODI%.
*p<0.05; ODI: Oswestry disability index



[Table/Fig-7]: Scatter diagram of correlation between ODI% scores with flexor: Extensor ratio, right: left-side bridge ratio and side bridge ratio: extensor ratio scores.

Variables	r	t	p-value	Constant (a)	Reg. Coeff. (b)	Interpretation
Right AKE (°)	0.823	9.041	<0.001*	-7.59	1.120	Strong positive
Left AKE (°)	0.779	7.763	<0.001*	-5.99	1.056	Strong positive
Pelvic tilt - standing (°)	0.627	5.020	<0.001*	1.11	1.786	Moderate positive
Pelvic tilt - on-cycle (°)	0.733	6.723	<0.001*	-8.28	1.831	Strong positive

[Table/Fig-8]: Pearson's correlation and simple linear regression- AKE and pelvic tilt vs ODI%.
*p<0.05; AKE: Active knee extension; ODI: Oswestry disability index



[Table/Fig-9]: Scatter diagram of correlation between ODI% scores with right active knee extension, left active knee extension, pelvic tilt standing and pelvic tilt on-cycle scores.

Independent variable	β Coefficient	SE	T	p-value
Intercept	80.507	60.971	1.320	0.197
Trunk flexor endurance	0.091	0.240	0.377	0.709
Trunk extensor endurance	-0.114	0.305	-0.375	0.711
Right-side bridge	1.543	1.042	1.481	0.150
Left-side bridge	-1.610	1.059	-1.520	0.139
Flexor: extensor ratio	-19.323	24.989	-0.773	0.446
R:L side bridge ratio	-79.362	46.694	-1.700	0.100
Bridge: extensor ratio	10.846	67.297	0.161	0.873
Right AKE	-0.013	0.390	-0.032	0.975
Left AKE	0.180	0.321	0.561	0.579
Pelvic tilt- standing	-4.702	1.645	-2.858	0.008*
Pelvic tilt - on-cycle	5.345	1.509	3.541	0.001*

[Table/Fig-10]: Full multiple linear regression model - all predictors of ODI%.
*p<0.05: statistically significant; AKE: Active knee extension; ODI: Oswestry disability index

Model fit statistic	Value
Multiple R	0.956
R^2	0.914
Adjusted R^2	0.881
F (11, 29)	28.000
p-value	<0.001
SE of estimate (%)	2.653

[Table/Fig-11]: Fit statistics- full regression model.
SE: standard error; *p<0.05: statistically significant

Independent variable	β Coefficient	SE	t	p-value
Intercept	24.403	12.182	2.003	0.053
Core Endurance (composite score)	-0.053	0.011	-4.838	<0.001*
Hamstring flexibility (AKE)	-2.887	3.945	-0.732	0.469
Pelvic tilt (composite)	0.243	0.052	4.721	<0.001*

[Table/Fig-12]: Parsimonious multiple linear regression model - composite predictors of ODI%.
*p<0.05: statistically significant; AKE: Active knee extension; ODI: Oswestry disability index

Model fit statistic	Value
Multiple R	0.909
R^2	0.826
Adjusted R^2	0.812
F (3, 37)	58.535
p-value	<0.001
SE of estimate (%)	3.341

[Table/Fig-13]: Fit statistics - parsimonious regression model.
*p<0.05: statistically significant; SE: standard error

DISCUSSION

In a sample of 41 amateur road cyclists with functional limitations due to low back discomfort, the present study examined the associations between core muscle endurance, hamstring flexibility, and pelvic tilt assessed at two distinct postural positions. There were three primary findings. First, there was a strong inverse relationship between functional limitation and all aspects of trunk endurance, with trunk flexor endurance producing the strongest single-variable connection. Second, elevated ODI scores were significantly associated with hamstring limitation and increased anterior pelvic inclination in both standing and on-cycle postures, with the on-cycle pelvic measurement showing a larger association than its standing counterpart. Third, a multiple regression analysis revealed that pelvic tilt and core endurance were the only independent predictors of functional restriction, collectively explaining over 82% of the variation in ODI scores.

Previous research in non-athletic LBP groups is strengthened by the negative associations between trunk endurance and ODI scores (r=-0.745 to -0.847) [9-11], demonstrating that this association is not only present but also noticeably strong among cyclists. When muscle endurance is reduced or fatigued, mechanical support shifts to passive structures, such as intervertebral discs and posterior spinal ligaments, increasing the risk of tissue strain and discomfort. Road cycling necessitates constant, coordinated activation of trunk flexors and extensors to maintain lumbar stability during each pedalling revolution [8,30,31]. The finding that the Flexor: Extensor endurance ratio showed a moderately inverse correlation with disability (r=-0.453, p=0.003) presents a clinical nuance that was not previously discussed in previous research: disability cannot be fully explained by absolute endurance capacity alone; the relative equilibrium between anterior and posterior trunk musculature is also important. According to electromyographic study, symptomatic cyclists may have insufficient anterior trunk recruitment, which could be indicated by disproportionate extensor dominance [22].

Increased hamstring tightness was positively correlated with ODI scores (left r=0.779; right r=0.823), supporting the mechanistic theory that restricted hamstring extensibility limits hip flexion, causes compensatory lumbar motion during cycling, and ultimately raises spinal loading [14-16]. The relationships that were found (higher AKE angle = increased limitation = greater disability) are in line with cross-sectional results that have already been published [11]. Hamstring flexibility stopped being an independent predictor of ODI scores when core endurance and pelvic tilt were added as covariates, according to a clinically relevant finding from the regression analysis. This trend suggests that rather than acting through a direct, independent mechanism, hamstring tightness may have an indirect effect on functional limitation by influencing pelvic alignment and trunk kinematics. Nevertheless, hamstring assessment should remain part of routine clinical screening methods for cyclists.

The considerable correlation between on-cycle pelvic tilt and functional restriction (r=0.733, p<0.001) was the most clinically important finding; this correlation was stronger than that between standing pelvic tilt and functional limitation (r=0.627, p<0.001). Because the pelvis tilts forward more when riding than when standing stationary, this discrepancy is biologically plausible (mean difference of roughly 4.8° in this sample). This is because maintaining proper posture is made more difficult by the forward reach to saddle and handlebars and saddle configuration. Throughout the recurrent pedalling motion, increased anterior tilt during cycling improves lumbar lordosis and transfers compressive stresses to the posterior annulus and facet joints [5,18,32]. This study is among the first to quantify pelvic tilt in the cycling posture and link it to functional disability in this cohort, whereas static pelvic tilt has been investigated as a correlate of LBP in general populations. The significance of position-specific postural measurement in the evaluation of cyclists is highlighted by the independent predictive value of on-cycle pelvic tilt in the full regression model (β=5.345, p=0.001).

These results support treatment approaches that concurrently address deficiencies in trunk endurance and on-cycle postural alignment from a rehabilitation standpoint. In both athletic and clinical populations, structured progressive core stabilisation regimens that emphasise trunk flexor and extensor endurance have demonstrated notable reductions in LBP and improvements in functional capacity [28,30,33]. Position-specific interventions, including saddle height optimisation, handlebar adjustment, and saddle tilt modification, can considerably reduce anterior pelvic inclination while riding and may serve as useful adjuncts to exercise-based rehabilitation [32]. Further support for the inclusion of trunk endurance training in the comprehensive care of cyclists comes from the recognition of core stability inadequacies as an independent predictor of lower-extremity injury risk in athletes.

Limitation(s)

Several methodological limitations must be taken into account when assessing the current data. The cross-sectional design precludes establishing causal directionality; for instance, it is still unclear whether decreased endurance leads to increased functional limitation or whether disability limits activity and causes endurance loss. Convenience sampling may restrict the generalisability of the results to diverse cycling populations, despite the sample being sized prospectively and attaining the requisite statistical power.

Furthermore, it is essential to conduct longitudinal studies that incorporate dynamic biomechanical testing and evaluate the outcomes of targeted rehabilitation programs to enhance the existing cross-sectional data.

CONCLUSION(S)

Core muscle endurance, hamstring flexibility, and anterior pelvic tilt, evaluated in both standing and cycling positions, exhibited significant correlations with functional limitations. A multiple regression analysis revealed that core endurance and pelvic tilt were independent predictors of disability, explaining 82.6% of the variance in ODI scores. The on-cycle position of pelvic tilt exhibited a more robust correlation with functional limitation compared to the standing pelvic position. These findings highlight the importance of conducting position-specific postural assessments within this demographic.

Physiotherapy interventions that concurrently target trunk endurance deficits and on-cycle pelvic alignment are likely to provide the most significant functional advantage for cyclists experiencing LBP.

Acknowledgement

The research team expresses profound gratitude for the time and effort contributed by all cyclists who participated in the present study.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 23, 2026
- Manual Googling: Jun 08, 2026
- iThenticate Software: Jun 10, 2026 (2%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Apr 21, 2026**
Date of Peer Review: **May 20, 2026**
Date of Acceptance: **Jun 12, 2026**
Date of Publishing: **Aug 01, 2026**