www.ijarp.com ISSN 2456-9992 Page: 01-14

International Journal Advanced Research Publications

Research Article

Volume: 02

Issue: 07

INDIVIDUAL VARIABILITY IN RESPONSE TO A 12-WEEK CORRECTIVE EXERCISE PROGRAMME AMONG UNIVERSITY BASKETBALL PLAYERS: PREDICTIVE ROLE OF BASELINE LUMBAR LORDOSIS

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Article Received: 18 June 2026, Article Revised: 08 July 2026, Published on: 28 July 2026

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Doi: https://doi-doi.org/101555/ijarp.2678

ABSTRACT

Background: Lumbar lordosis is an important marker of spinopelvic alignment in basketball players, yet individual responses to corrective exercise may vary substantially. Understanding whether baseline lumbar lordosis predicts treatment response may help refine personalized rehabilitation strategies in athletic populations.

Purpose: To investigate individual variability in response to a 12-week corrective exercise programme and to examine whether baseline lumbar lordosis predicts treatment response among university basketball players.

Methods: This secondary exploratory analysis included 17 university basketball players aged 18–25 years who completed a 12-week supervised corrective exercise programme consisting of pelvic tilts, glute bridges, bird-dog exercise, hip flexor stretch, hamstring stretch, wall sits, and cat-cow stretch. Baseline lumbar lordosis was treated as the predictor variable, and treatment response was defined as the pre-test to post-test reduction in lumbar lordosis angle. Percentage treatment response was also calculated. Data normality was assessed using the Shapiro–Wilk test. Pearson correlation and simple linear regression were used to examine the association between baseline lumbar lordosis and treatment response.

Results: The mean baseline lumbar lordosis was 49.71 ± 2.26°, and the mean treatment response was 5.00 ± 1.41°. The mean percentage treatment response was 9.99 ± 2.50%. Treatment response showed noticeable inter-individual variability, ranging from 3° to 8°. Baseline lumbar lordosis was strongly and positively correlated with treatment response (r =

0.744, p = 0.001). Simple linear regression showed that baseline lumbar lordosis significantly predicted treatment response (B = 0.466, β = 0.744, t = 4.312, p = 0.001), explaining 55.3% of the variance in treatment response ($R^2 = 0.553$; adjusted $R^2 = 0.524$).

Conclusion: Baseline lumbar lordosis was a significant predictor of treatment response following a 12-week corrective exercise programme in university basketball players. Players with greater initial lumbar lordosis demonstrated larger reductions after intervention, suggesting that pretreatment postural status may be useful for guiding individualized corrective exercise prescription.

KEYWORDS: *lumbar lordosis, basketball players, corrective exercise, treatment response, predictive rehabilitation, spinopelvic alignment*

1. INTRODUCTION

Lumbar lordosis is a key component of sagittal spinal alignment and plays an important role in the distribution of mechanical loads between the lumbar spine, pelvis, and lower extremities. In athletic populations, this alignment has particular relevance because repeated sport-specific loading can influence lumbopelvic posture over time. Basketball players are exposed to frequent jumping, landing, sprinting, deceleration, trunk rotation, and unilateral movement demands, all of which place substantial stress on the lumbopelvic region. Consistent with this biomechanical context, a recent systematic review and meta-analysis reported that basketball players commonly experience back pain, spinal injuries, and postural changes, including hyperlordosis and hyperkyphosis, indicating that spinal posture is a clinically meaningful issue in this sport (Borges et al., 2023).

The importance of lumbar lordosis in basketball is best understood within the broader framework of spinopelvic alignment. The lumbar spine functions in continuous interaction with pelvic tilt, hip mobility, trunk muscle activation, and lower-limb mechanics, and changes in one component can alter the others. In a sport such as basketball, where athletes repeatedly move through flexion, extension, rotation, and single-leg loading, even relatively small deviations in posture may accumulate through training exposure and repetitive loading. For this reason, lumbar lordosis should not be viewed merely as a static structural angle, but also as a marker of how the lumbopelvic system adapts to sport-specific mechanical demands (Borges et al., 2023).

Corrective exercise programmes are commonly prescribed to address altered lumbar lordosis through a combination of strengthening, stretching, and neuromuscular control strategies.

These programmes are typically designed to improve lumbopelvic stability, restore muscular balance around the trunk and pelvis, and reduce movement patterns that reinforce excessive curvature. Evidence supporting this approach has grown in recent years. A systematic review and meta-analysis by Dimitrijević et al. (2022) concluded that corrective exercise interventions have a significant positive effect on lumbar lordotic angle, with a moderate overall effect size. More recent evidence also suggests that strengthening-focused interventions may be more effective than stretching alone for improving spinal and lumbopelvic posture, especially when the aim is postural correction rather than symptom relief alone (Warneke et al., 2024).

Despite these findings, treatment response to corrective exercise is rarely uniform. In rehabilitation settings, athletes exposed to the same exercise programme often demonstrate markedly different magnitudes of improvement, even under comparable supervision and duration. Some show substantial structural change, whereas others exhibit more modest responses. This inter-individual variability is important because group mean effects may obscure clinically relevant differences in personal responsiveness. In postural rehabilitation, such variability may reflect baseline severity, flexibility restrictions, neuromuscular control, training load, tissue adaptability, or adherence to movement quality during the intervention (Dimitrijević et al., 2022).

This issue is closely related to the growing concept of predictive rehabilitation. Rather than assuming that all athletes respond similarly to the same treatment, predictive rehabilitation seeks to identify baseline factors that help estimate who is most likely to benefit from a given intervention. This approach is aligned with personalized exercise prescription, in which the intervention is tailored to the athlete's structural and functional presentation. In the context of lumbar lordosis, baseline posture is a plausible predictive factor because individuals with greater initial deviation may have more scope for measurable change following a corrective programme. If this assumption is correct, baseline lumbar lordosis may have practical value for prognosis and treatment planning.

At present, however, evidence on predictors of response to corrective exercise for lumbar lordosis remains limited, particularly in athletic populations. Most published studies have focused on whether exercise can improve lordotic angle at the group level, rather than whether pre-intervention posture can explain the magnitude of change achieved by individual participants. This gap is especially important in basketball players, given the meaningful prevalence of back pain, spinal injury, and postural alteration reported in this population (Borges et al., 2023). As a result, sports physiotherapists and rehabilitation professionals still have limited evidence to guide individualized prediction of treatment response in basketball-specific corrective programmes.

Accordingly, the present study was designed as a secondary exploratory analysis of data obtained from a pilot intervention study. The purpose was to investigate individual variability in treatment response following a 12-week corrective exercise programme and to determine whether baseline lumbar lordosis predicts treatment response among university basketball players. It was hypothesized that athletes with greater baseline lumbar lordosis would demonstrate greater improvement after completing the intervention.

2. MATERIALS AND METHODS

2.1 Study Design

This study was a secondary exploratory analysis of data obtained from a pilot intervention study designed to evaluate the effects of a 12-week corrective exercise programme on lumbar lordosis among university basketball players. The present analysis specifically investigated individual variability in treatment response and examined the predictive role of baseline lumbar lordosis following the intervention. The study adhered to the principles of transparent reporting for pilot studies.

2.2 PICO Framework

The study methodology was structured according to the PICO (Population, Intervention, Comparator, and Outcome) framework to clearly define the research question and analytical approach.

Population (P): The study included 17 university basketball players (male and female) aged 18–25 years who were selected from the experimental group of the parent intervention study. Participants demonstrated lumbar lordosis requiring corrective exercise intervention and completed the entire 12-week training programme. All participants underwent radiographic assessment of lumbar lordosis before and after the intervention.

Intervention (I): Participants completed a 12-week supervised corrective exercise programme specifically designed to improve lumbopelvic alignment, spinal stability, flexibility, and postural control. The intervention was performed three sessions per week and consisted of:

1. Pelvic Tilts
2. Glute Bridges

3. Bird-Dog Exercise
4. Hip Flexor Stretch
5. Hamstring Stretch
6. Wall Sits
7. Cat-Cow Stretch

The exercise programme progressed according to standardized exercise prescriptions and was supervised throughout the intervention period.

Comparator (C): As this investigation represents a secondary analysis of the intervention group only, no between-group comparison was performed. Instead, each participant's baseline lumbar lordosis (pre-test) served as the reference value for evaluating individual treatment response following the intervention.

Outcome (O): The primary outcome was treatment response, defined as the absolute reduction in lumbar lordosis angle following the intervention and calculated as:

$$\textit{Treatment Response } (^\circ) = \textit{Pre-test Lumbar Lordosis} - \textit{Post-test Lumbar Lordosis}$$

A secondary outcome, percentage treatment response, was calculated using the following equation:

$$\textit{Percentage Treatment Response } (\%) = \frac{\textit{Pre-test} - \textit{Post-test}}{\textit{Pre-test}} \times 100$$

Baseline lumbar lordosis was considered the predictor variable in the regression analysis, whereas treatment response served as the dependent variable.

2.3 Participants

Seventeen university basketball players who completed the corrective exercise programme were included in this secondary analysis. Participants were between 18 and 25 years of age and represented both sexes. Inclusion in the present study required completion of the entire intervention programme and availability of both pre-intervention and post-intervention lumbar lordosis measurements.

2.4 Measurement of Lumbar Lordosis

Lumbar lordosis was assessed using radiographic (X-ray) evaluation, and the lumbar lordosis angle (degrees) was obtained from radiological reports prepared by qualified medical professionals. Measurements were recorded before the commencement of the corrective exercise programme and immediately after completion of the 12-week intervention. These measurements served as the basis for calculating individual treatment response.

2.5 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics. Descriptive statistics, including mean, standard deviation, median, minimum, maximum, and range, were calculated for baseline lumbar lordosis, treatment response, and percentage treatment response. Data normality was assessed using the Shapiro–Wilk test.

The relationship between baseline lumbar lordosis and treatment response was examined using Pearson's product-moment correlation coefficient. Subsequently, simple linear regression analysis was performed to determine whether baseline lumbar lordosis significantly predicted treatment response following the corrective exercise programme. Statistical significance was established at $p < 0.05$.

3. RESULTS

3.1 Descriptive Characteristics of Baseline Lumbar Lordosis and Treatment Response

A total of **17 university basketball players** who completed the 12-week corrective exercise programme were included in the secondary analysis. The mean baseline lumbar lordosis angle was **49.71 ± 2.26°** (range: 46–54°). Following the intervention, the mean treatment response, calculated as the difference between pre-test and post-test lumbar lordosis angles, was **5.00 ± 1.41°**, with individual responses ranging from **3° to 8°**. The mean percentage treatment response was **9.99 ± 2.50%**, ranging from **6.25% to 15.09%**. The distribution of treatment responses demonstrated noticeable inter-individual variability among participants. Descriptive statistics are presented in **Table 1**.

Table 1. Descriptive Statistics of Baseline Lumbar Lordosis and Treatment Response. (n = 17)

Variable	Mean ± SD	Median	Minimum	Maximum	Range
Baseline Lumbar Lordosis (°)	49.71 ± 2.26	50.00	46.00	54.00	8.00
Treatment Response (°)	5.00 ± 1.41	5.00	3.00	8.00	5.00
Percentage Treatment Response (%)	9.99 ± 2.50	10.00	6.25	15.09	8.84

3.2 Assessment of Data Normality

The normality of baseline lumbar lordosis, treatment response, and percentage treatment response was assessed using the Shapiro–Wilk test. All variables demonstrated nonsignificant results ($p > 0.05$), indicating that the data were normally distributed. Therefore, parametric statistical analyses, including Pearson correlation and simple linear regression, were considered appropriate for subsequent analyses (**Table 2**).

Table 2. Shapiro–Wilk Test for Normality.

Variable	**W**	**p-value**	**Interpretation**
Baseline Lumbar Lordosis	0.972	0.849	Normally distributed
Treatment Response	0.938	0.297	Normally distributed
Percentage Treatment Response	0.960	0.640	Normally distributed

3.3 Relationship between Baseline Lumbar Lordosis and Treatment Response

Pearson's correlation analysis demonstrated a **strong positive relationship** between baseline lumbar lordosis and treatment response ($r = 0.744$, $p = 0.001$). Participants presenting with greater baseline lumbar lordosis tended to exhibit larger reductions in lumbar lordosis following the corrective exercise programme. The correlation coefficient indicated that higher initial lumbar lordosis was associated with a greater magnitude of treatment response (**Table 3**).

Table 3. Pearson Correlation between Baseline Lumbar Lordosis and Treatment Response

Variables	**Pearson's *r***	***p***
Baseline Lumbar Lordosis vs. Treatment Response	0.744	0.001

3.4 Predictive Role of Baseline Lumbar Lordosis

A simple linear regression analysis was performed to determine whether baseline lumbar lordosis significantly predicted treatment response following the corrective exercise programme. The regression model was statistically significant ($F(1,15) = 18.593$, $p = 0.001$), explaining **55.3%** of the variance in treatment response ($R^2 = 0.553$; Adjusted $R^2 = 0.524$). Baseline lumbar lordosis emerged as a significant positive predictor of treatment response (B = 0.466, $\beta = 0.744$, $t = 4.312$, $p = 0.001$). The regression coefficient indicates that for every **1° increase** in baseline lumbar lordosis, the expected treatment response increased by approximately **0.47°** (**Table 4**).

Table 4. Simple Linear Regression Predicting Treatment Response from Baseline Lumbar Lordosis.

Predictor	**B**	**SE**	**β**	***t***	***p***
Baseline Lumbar Lordosis	0.466	0.108	0.744	4.312	0.001

Model statistics: $R = 0.744$, $R^2 = 0.553$, Adjusted $R^2 = 0.524$, $F(1,15) = 18.593$, $p = 0.001$.

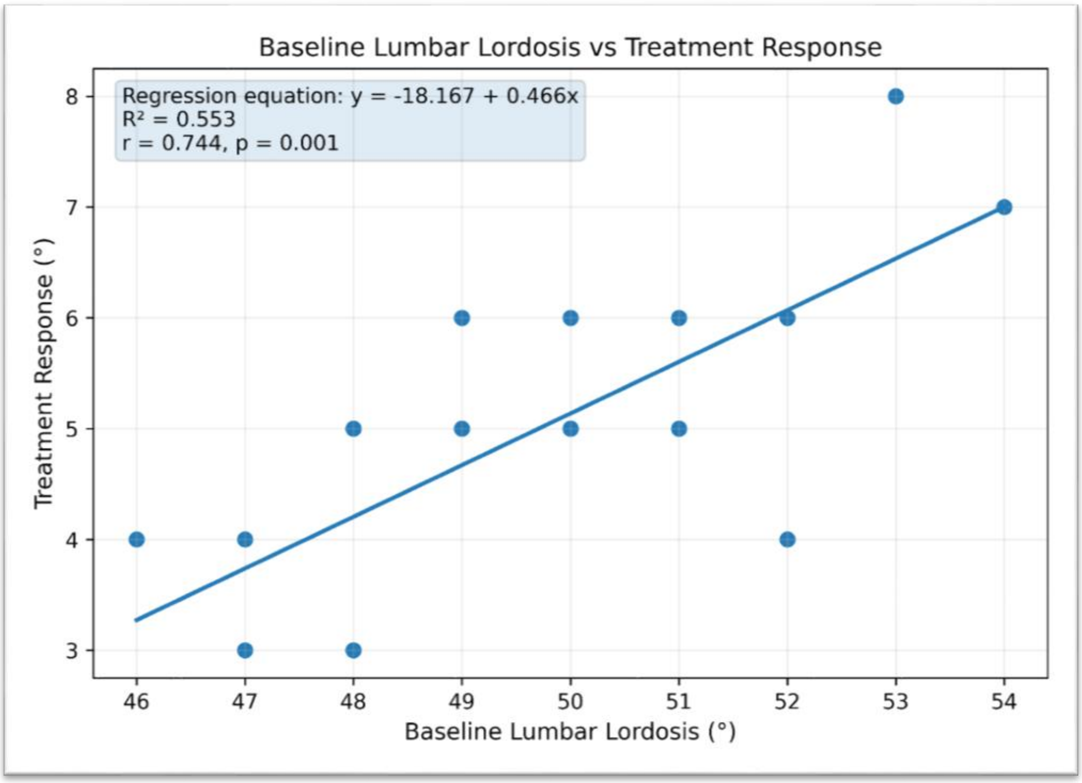

Figure 1. Relationship between baseline lumbar lordosis and treatment response following the 12-week corrective exercise programme among university basketball players. Each point represents an individual participant (n = 17). The solid line represents the fitted linear regression model, demonstrating a significant positive association between baseline lumbar lordosis and treatment response (r = 0.744, p = 0.001; R² = 0.553).

4. DISCUSSION

This secondary exploratory analysis was undertaken to examine individual variability in response to a 12-week corrective exercise programme and to determine whether baseline lumbar lordosis predicted treatment response among university basketball players. The main finding was that athletes with greater baseline lumbar lordosis demonstrated larger reductions in lumbar curvature following the intervention. In addition, the results showed clear inter-individual variability, with treatment response ranging from 3° to 8° despite all participants completing the same supervised programme. Taken together, these findings suggest that baseline postural status may be an important determinant of how strongly an athlete responds to corrective exercise and that average group change alone may not fully capture clinically meaningful differences between individuals.

The presence of inter-individual variability is itself an important finding. Rehabilitation and exercise studies often report mean changes at the group level, but those means can conceal substantial differences in responsiveness between participants. In the present study, the mean treatment response was 5.00°, yet the range of responses indicates that some athletes improved much more than others. From a clinical perspective, this is consistent with everyday rehabilitation practice, where athletes exposed to the same exercise protocol often do not adapt in the same way because of differences in structural alignment, neuromuscular control, flexibility, training load, and movement strategy. The current analysis therefore adds value by showing that corrective exercise response in basketball players is not uniform and warrants closer consideration at the individual level.

The most important statistical finding was the strong positive association between baseline lumbar lordosis and treatment response. Participants with greater initial lordotic angles tended to show larger post-intervention reductions, and baseline lordosis explained 55.3% of the variance in response. This suggests that initial sagittal alignment was not merely associated with change but also carried meaningful predictive information within this sample. A possible explanation is that players with greater pre-intervention lordosis had more scope for measurable correction, whereas those with smaller deviations had less structural room for change over the same intervention period. In rehabilitation terms, this pattern is compatible with the idea that baseline severity can influence response magnitude when the treatment is specifically targeted to the underlying biomechanical problem.

The observed relationship is also biomechanically plausible. Excessive lumbar lordosis is often associated with altered lumbopelvic control, anterior pelvic tilt, hip flexor tightness, and relative weakness or under-recruitment of abdominal and gluteal musculature. The exercise programme used in this study included pelvic tilts, glute bridges, bird-dog exercise, hip flexor and hamstring stretching, wall sits, and cat-cow movements, which collectively targeted many of these mechanisms. When baseline lordosis is greater, the combined effect of improving trunk stability, pelvic awareness, posterior-chain activation, and lower-limb flexibility may produce a larger observable reduction in curvature. This interpretation is consistent with the broader corrective exercise literature, which supports combined strengthening and stretching approaches for improving lumbar lordotic posture (Dimitrijević et al., 2022).

The present findings fit reasonably well with the existing evidence base, while also extending it in a clinically relevant direction. Dimitrijević et al. (2022) reported in a systematic review and meta-analysis that corrective exercise interventions have a significant positive effect on lumbar lordotic angle, although the pooled effect was moderate. More recent evidence has also suggested that strengthening-oriented interventions may be more effective than stretching alone for improving posture, although results in the lumbar and lumbopelvic region remain variable across studies (Warneke et al., 2024). The current study does not contradict those findings; rather, it suggests that one source of variability may be the degree of baseline postural deviation. If participants begin with different levels of lordotic alteration, then treatment effects observed at the group level may partly reflect differences in starting posture rather than programme content alone.

The basketball-specific context is also important when interpreting these findings. Basketball players are exposed to repeated jumping, landing, trunk rotation, and rapid changes of direction, all of which challenge lumbopelvic stability and may contribute to accumulated spinal loading. A recent systematic review and meta-analysis found a substantial prevalence of back pain, low back pain, spinal injury, and postural changes in basketball players, emphasizing that spinal posture is a meaningful clinical issue in this sport (Borges et al., 2023). The current results extend this understanding by suggesting that lumbar lordosis is not only relevant as a descriptive postural measure, but may also serve as a practical prognostic marker when clinicians are planning corrective interventions for basketball players.

From a rehabilitation perspective, the findings support the emerging emphasis on predictive rehabilitation and personalized exercise prescription. In sports physiotherapy and strength and conditioning practice, interventions are often more effective when they are tailored to the athlete's specific presentation rather than applied uniformly across all players. The present regression results suggest that baseline lumbar lordosis may help clinicians estimate expected structural response to a corrective programme. Athletes with greater baseline lordosis may be more likely to demonstrate a larger measurable reduction, whereas those with milder deviation may require different outcome expectations or a greater focus on functional performance, movement quality, or symptom-related targets. In this sense, baseline lordosis assessment may have value not only for diagnosis but also for goal setting, programme planning, and communication with athletes.

The clinical significance of these findings should, however, be interpreted cautiously. Although the model explained a substantial proportion of variance in treatment response, nearly half of the variance remained unexplained. This indicates that factors other than baseline lumbar lordosis are also likely to influence how strongly an athlete responds to corrective exercise. Variables such as pelvic tilt, hip mobility, trunk endurance, sex, training volume, pain status, exercise adherence, and movement mechanics may all contribute to treatment responsiveness and should be examined in future work. Baseline lumbar lordosis may therefore be a useful predictor, but it is unlikely to be sufficient as a standalone basis for personalized prescription.

Several limitations need to be acknowledged. First, this was a secondary exploratory analysis based on a small pilot sample of 17 participants, which limits statistical precision and generalizability. Regression estimates derived from small samples can be unstable, and the predictive model should therefore be considered preliminary rather than definitive. Second, the analysis was restricted to the intervention group, so the predictive relationship was examined only within the context of one specific corrective exercise programme. Third, the study focused on one structural predictor and one structural outcome, without incorporating additional biomechanical or clinical variables that may influence responsiveness. Finally, the study did not assess whether the observed postural changes were maintained over time or whether they were associated with changes in pain, function, or basketball performance.

Future research should build on these findings by testing predictive models in larger and more diverse basketball samples. Prospective studies should include additional candidate predictors such as pelvic tilt, hip flexibility, trunk muscle endurance, movement control, pain characteristics, and training exposure. It would also be valuable to examine whether baseline posture interacts with exercise dose, progression strategy, or supervision level. More broadly, rehabilitation research in athletic populations would benefit from moving beyond average treatment effects and toward identifying which athletes respond, why they respond, and how interventions can be refined to optimize individual outcomes.

5. CONCLUSION

This exploratory analysis indicates that baseline lumbar lordosis may be an important predictor of response to a 12-week corrective exercise programme in university basketball players. Players who presented with greater initial lumbar lordosis tended to show larger reductions after the intervention, suggesting that pretreatment postural status may help identify athletes who are more likely to benefit from corrective exercise. The findings support a more individualized approach to sports rehabilitation and justify further prospective research in larger basketball samples.

PRACTICAL IMPLICATIONS

The present findings suggest that baseline lumbar lordosis may have practical value in the planning of corrective exercise programmes for university basketball players. Players with greater pre-intervention lumbar lordosis tended to demonstrate larger structural improvement after the 12-week programme, indicating that baseline postural assessment may help clinicians estimate which athletes are more likely to show a stronger response. This is consistent with the broader rehabilitation literature, which increasingly emphasizes the clinical value of prognostic models for supporting individualized treatment planning when they are interpreted cautiously and used alongside clinical judgment (Naye et al., 2023).

For sports physiotherapists, these findings support incorporating lumbar lordosis assessment into routine screening when sagittal-plane dysfunction is suspected. For strength and conditioning professionals, the results suggest that athletes with more pronounced lordotic deviation may be appropriate candidates for targeted lumbopelvic corrective exercise, whereas those with milder deviation may require different priorities, such as movement quality, trunk endurance, or symptom-related goals. In this way, the study supports a more personalized exercise prescription model rather than a uniform corrective programme for all players. Evidence from exercise research in low back pain also supports the broader principle that treatment effects can vary according to participant characteristics, reinforcing the need to identify effect modifiers and tailor interventions more precisely (Hayden et al., 2020).

LIMITATIONS

Several limitations should be acknowledged when interpreting the findings of this study. First, the analysis was based on a small pilot sample of 17 participants, which limits statistical power and reduces the stability and generalizability of the regression model. In exercise therapy research, inadequate sample size and limited follow-up are among the most commonly reported limitations and can restrict confidence in the broader applicability of study findings (Sundstrup et al., 2024).

Second, this was a secondary exploratory analysis rather than a study originally designed and powered to develop a prognostic model. Although the association between baseline lumbar lordosis and treatment response was statistically significant, the model was based on a single predictor and did not account for other potentially important variables such as pelvic tilt, hip flexibility, trunk endurance, pain status, training load, sex, or exercise adherence. Prognostic model research in rehabilitation consistently shows that model performance and transportability depend on broader evaluation and validation procedures than can be achieved in a small exploratory dataset (Collins et al., 2024; Naye et al., 2023).

Third, the regression equation was derived and tested within the same sample, and no external validation was performed. External validation is essential before a prediction model can be considered sufficiently robust for routine clinical use because models often perform less well when applied to new samples or settings (Collins et al., 2024; Wingbermühle et al., 2023). Finally, the study focused on structural response in a specific population of university basketball players and did not evaluate long-term retention, pain outcomes, functional outcomes, or sport performance. As a result, the clinical significance of the observed postural changes should be interpreted with caution.

FUTURE RESEARCH

Future research should examine these findings in larger and more diverse basketball cohorts using prospectively designed prognostic studies. Additional candidate predictors such as pelvic alignment, hip mobility, core endurance, movement control, pain status, and training exposure should be incorporated into multivariable models to provide a more complete understanding of treatment responsiveness. Broader and more rigorous evaluation of predictive performance, including calibration and external validation, will be necessary before such models can be confidently applied in clinical practice (Collins et al., 2024; Naye et al., 2023).

It would also be valuable for future studies to move beyond postural change alone and examine whether baseline lumbar lordosis predicts clinically meaningful outcomes such as pain reduction, functional improvement, or sport-specific performance. Exercise research has already shown that some baseline characteristics can modify treatment effect in low back pain populations, although the available evidence remains incomplete and inconsistent across settings (Hayden et al., 2020). Applying this type of effect-modifier and prognostic research more directly to athletic populations may help refine rehabilitation strategies and improve the precision of corrective exercise prescription.

REFERENCES

1. Borges, S. C. de C., Mendonça, C. R., Silva, R. M. F., De Vitta, A., & Noll, M. (2023). Prevalence and risk factors of musculoskeletal disorders in basketball players: Systematic review and meta-analysis. Healthcare, 11(8), 1190.
2. Chung, N. S., Jeon, C. H., Lee, H. D., & Won, S. H. (2017). Measurement of Spinopelvic Parameters on Standing Lateral Lumbar Radiographs: Validity and Reliability. *Clinical spine surgery*, *30*(2), E119–E123. https://doi.org/10.1097/BSD.0000000000000448
3. Collins, G. S., Dhiman, P., Ma, J., Schlussel, M. M., Archer, L., Van Calster, B., Harrell, F. E., Jr, Martin, G. P., Moons, K. G. M., van Smeden, M., Sperrin, M., Bullock, G. S., &

Riley, R. D. (2024). Evaluation of clinical prediction models (part 1): from development to external validation. *BMJ (Clinical research ed.)*, *384*, e074819. https://doi.org/10.1136/bmj-2023-074819

4. Dimitrijević, V., Šćepanović, T., Milankov, V., Milankov, M., & Drid, P. (2022). Effects of corrective exercises on lumbar lordotic angle correction: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health, 19*(8), 4906.
5. Harrison, D. E., Harrison, D. D., Cailliet, R., Janik, T. J., & Holland, B. (1996). Measurement of lumbar lordosis: Evaluation of lumbar lordosis measures as part of sagittal plane analysis of the spine. Spine, 21(11), 1332–1342.
6. Hayden, J. A., Ellis, J., Ogilvie, R., Malmivaara, A., & van Tulder, M. W. (2020). Exercise treatment effect modifiers in persistent low back pain: An individual participant data meta-analysis of 3,514 participants from 27 randomised controlled trials. *British Journal of Sports Medicine, 54*(21), 1277–1278.
7. Lee, J. S., Goh, T. S., Son, S. M., Kim, D. S., & Lee, C. S. (2013). Radiographic measurement reliability of lumbar lordosis in ankylosing spondylitis. European Spine Journal, 22(4), 813–818.
8. Naye, F., Décary, S., Houle, C., LeBlanc, A., Cook, C., Dugas, M., Skidmore, B., & Tousignant-Laflamme, Y. (2023). Six Externally Validated Prognostic Models Have Potential Clinical Value to Predict Patient Health Outcomes in the Rehabilitation of Musculoskeletal Conditions: A Systematic Review. *Physical therapy*, *103*(5), pzad021. https://doi.org/10.1093/ptj/pzad021
9. Siviter, L. M., Morretta, M., Petosky, T., Klopper, M., Rhon, D. I., & Young, J. L. (2024). Self-acknowledged limitations in exercise therapy trials for low back pain. *Journal of evaluation in clinical practice*, *30*(7), 1251–1260. https://doi.org/10.1111/jep.14033
10. Warneke, K., Lohmann, L. H., & Wilke, J. (2024). Effects of Stretching or Strengthening Exercise on Spinal and Lumbopelvic Posture: A Systematic Review with Meta-Analysis. *Sports medicine - open*, *10*(1), 65. https://doi.org/10.1186/s40798-024-00733-5
11. Wingbermühle, R. W., Chiarotto, A., van Trijffel, E., Stenneberg, M. S., Kan, R., Koes, B. W., & Heymans, M. W. (2023). External validation and updating of prognostic models for predicting recovery of disability in people with (sub)acute neck pain was successful: broad external validation in a new prospective cohort. *Journal of physiotherapy*, *69*(2), 100–107. https://doi.org/10.1016/j.jphys.2023.02.002