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EFFECTIVENESS OF INTEGRATED NEUROMUSCULAR TRAINING VERSUS JANDA-BASED CORRECTIVE EXERCISE ON ANTERIOR PELVIC TILT AND SPRINT PERFORMANCE AMONG YOUNG COLLEGIATE SPRINTERS: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT
Background: Anterior pelvic tilt (APT) is a common postural deviation among sprinters and may adversely affect sprint performance by altering lumbopelvic biomechanics. This study compared the effectiveness of Integrated Neuromuscular Training (INT) and Janda-Based Corrective Exercise (JBCE) on APT and sprint performance among collegiate sprinters.
Methods: A randomized controlled trial was conducted among 60 collegiate sprinters aged 18–25 years with APT greater than 12°. Participants were randomly assigned to either the INT group (n=30) or the JBCE group (n=30). Both groups underwent supervised exercise sessions for 45 minutes, three times weekly, for eight weeks. The primary outcome was anterior pelvic tilt angle, while secondary outcomes included 30-meter sprint time, core endurance, and hip flexor flexibility. Data were analyzed using paired and independent-samples t-tests.
Results: Both groups demonstrated significant improvements in all outcome measures after eight weeks ($p<0.001$). However, INT produced significantly greater reductions in APT (9.9±1.8° vs. 11.9±1.7°; $p<0.001$) and greater improvements in sprint time, core endurance, and hip flexor flexibility compared with JBCE. Moderate-to-large effect sizes favoured the INT intervention.
Conclusion: Both INT and JBCE were effective in improving pelvic alignment and performance outcomes. However, INT was superior in reducing anterior pelvic tilt and enhancing sprint performance, suggesting its potential as a comprehensive conditioning strategy for collegiate sprinters.

KEYWORDS: Anterior pelvic tilt, Integrated neuromuscular training, Janda-based corrective exercise, Sprint performance, Collegiate sprinters.

INTRODUCTION
Participation in organized sports and competitive athletics among young adults has increased substantially over recent decades. While sports participation offers numerous health benefits, it is also associated with an increased risk of musculoskeletal injuries, particularly in sprint-based activities. [1] Sprinting requires optimal lumbopelvic alignment for efficient force transmission and athletic performance. Excessive anterior pelvic tilt (APT) has been associated with altered biomechanics, lumbar hyper-lordosis, reduced sprint efficiency, and an increased risk of low back pain and lower-limb injuries. [2]

Anterior pelvic tilt commonly results from muscle imbalance characterized by tight hip flexors and lumbar extensors combined with weakness of the abdominal and gluteal musculature.[2] Low back pain remains one of the leading causes of disability worldwide, with increasing prevalence among young athletes due to repetitive biomechanical loading and inadequate neuromuscular control.[3–5] Therefore, interventions targeting lumbopelvic stability and movement efficiency are essential for improving athletic performance and preventing injury.

Exercise-based interventions remain the cornerstone for correcting postural dysfunction. Core stabilization exercises have been shown to improve neuromuscular control, spinal stability, balance, and sport-specific performance. [6–10] Integrated Neuromuscular Training (INT), which combines strength, balance, plyometric, agility, and core stabilization exercises, has demonstrated effectiveness in enhancing movement competency, athletic performance, and injury prevention among young athletes. [11,12]

The Janda-Based Corrective Exercise (JBCE) approach focuses on restoring muscle balance through stretching of facilitated muscles and strengthening of inhibited muscles based on Janda's muscle imbalance theory.[13–15] Previous studies have reported improvements in postural alignment and functional outcomes following Janda-based interventions.[15,16] More recently, Venkatesh et al. reported that 3D core stabilization was significantly more effective than the Janda protocol in reducing anterior pelvic tilt and improving sprint performance among young sprinters following an eight-week intervention.[17]
However, evidence directly comparing Integrated Neuromuscular Training with Janda-Based Corrective Exercise among collegiate sprinters remains limited. Therefore, the present randomized controlled trial was undertaken to compare the effectiveness of Integrated Neuromuscular Training and Janda-Based Corrective Exercise on anterior pelvic tilt and sprint performance among young collegiate sprinters.

MATERIALS AND METHODS

Study design and participants

A parallel-group randomized controlled trial was conducted from January 2026 to June 2026 at the Sports Physiotherapy Unit, Vinayaka Mission Medical College and Hospital, Puducherry. The study was reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines. Collegiate sprinters aged 18–25 years with anterior pelvic tilt greater than 12°, measured using a digital inclinometer, were screened for eligibility.
Participants with a minimum of one year of sprint training experience who provided written informed consent were included in the study. Athletes with current musculoskeletal injuries, a history of spinal or lower-limb surgery, neurological disorders affecting movement, structural spinal deformities, or participation in any structured corrective exercise program during the preceding three months were excluded.

Sample size

The sample size was calculated using the formula:
$n = 2(Z\alpha/2 + Z\beta)^2\sigma^2/d^2$
Assuming a 95% confidence level, 80% power, a standard deviation of 2.5°, and an expected mean difference of 2° in anterior pelvic tilt between the groups, the minimum required sample size was 26 participants per group. After accounting for a 15% attrition rate, the final sample size was increased to 30 participants per group, resulting in a total sample of 60 participants.

Randomization and blinding

Eligible participants were randomly allocated in a 1:1 ratio to either the Integrated Neuromuscular Training (INT) group or the Janda-Based Corrective Exercise (JBCE) group using a computer-generated random sequence. Allocation concealment was ensured through sequentially numbered opaque sealed envelopes prepared by an investigator not involved in recruitment or outcome assessment. Outcome assessment was performed by an assessor blinded to group allocation.

Intervention

Participants in the INT group underwent a structured integrated neuromuscular training program comprising dynamic warm-up exercises, core stabilization exercises, balance and proprioceptive training, plyometric drills, agility exercises, and sprint-specific movement training. Participants in the JBCE group received a structured Janda-based corrective exercise program consisting of hip flexor and lumbar extensor stretching, abdominal and gluteal strengthening exercises, sensorimotor training, and postural correction exercises. Both interventions were delivered under supervision for 45 minutes per session, three times per week, for eight weeks. Exercise intensity was progressively increased according to participant tolerance and performance.

Outcome measures

All outcome measures were assessed at baseline and at the end of the eight-week intervention period. The primary outcome was anterior pelvic tilt angle measured in degrees using a calibrated digital inclinometer positioned over the anterior superior iliac spine and posterior superior iliac spine. Secondary outcomes included sprint performance assessed using a 30-meter sprint test with electronic timing gates, core muscle endurance measured using the plank hold test, and hip flexor flexibility assessed using the Modified Thomas Test.

Statistical analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 30.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation. Normality was assessed using the Shapiro–Wilk test. Within-group comparisons were performed using paired t-tests, while between-group comparisons were conducted using independent-samples t-tests. Effect sizes were calculated using Cohen's d. A p-value of less than 0.05 was considered statistically significant.

ETHICAL CONSIDERATIONS

The Study Protocol Was Approved By The Institutional Ethics Committee Of Vinayaka Mission Medical College And Hospital, Puducherry (Iec/Vmmc/2025/October/018). Written Informed Consent Was Obtained From All Participants Before Enrolment. Confidentiality Of Participant Information Was Maintained Throughout The Study.

RESults
A total of 72 collegiate sprinters were screened for eligibility. Of these, 60 participants met the inclusion criteria and were randomly allocated to either the Integrated Neuromuscular Training (INT) group (n=30) or the Janda-Based Corrective Exercise (JBCE) group (n=30). All participants completed the 8-week intervention period, and no adverse events were reported.

Baseline characteristics
The mean age of participants in the INT group was 20.4 ± 1.8 years, while that of the JBCE group was 20.7 ± 1.9 years. Baseline anterior pelvic tilt angle, sprint performance, core endurance, and hip flexor flexibility were comparable between the two groups, with no statistically significant differences ($p>0.05$) [Table 1].

Table 1. Baseline characteristics of participants

Variable	INT Group (n=30) Mean ± SD	JBCE Group (n=30) Mean ± SD	p-value
Age (years)	20.4 ± 1.8	20.7 ± 1.9	0.53
Anterior Pelvic Tilt (°)	15.7 ± 2.3	15.5 ± 2.1	0.72
30-m Sprint Time (s)	4.78 ± 0.31	4.75 ± 0.28	0.68
Core Endurance (s)	74.5 ± 18.2	72.8 ± 17.9	0.71
Hip Flexor Flexibility (°)	12.1 ± 3.5	11.8 ± 3.2	0.75

Independent-samples t-test.

Within-group comparison
Following the 8-week intervention, both groups demonstrated significant improvements in anterior pelvic tilt angle, sprint performance, core endurance, and hip flexor flexibility ($p<0.001$) [Table 2].

Table 2. Within-group comparison of outcome measures

Outcome	Group	Baseline Mean ± SD	Post-test Mean ± SD	Mean Difference	p-value
Anterior Pelvic Tilt (°)	INT	15.7 ± 2.3	9.9 ± 1.8	5.8	<0.001
	JBCE	15.5 ± 2.1	11.9 ± 1.7	3.6	<0.001
30-m Sprint Time (s)	INT	4.78 ± 0.31	4.44 ± 0.25	0.34	<0.001
	JBCE	4.75 ± 0.28	4.57 ± 0.24	0.18	<0.001
Core Endurance (s)	INT	74.5 ± 18.2	126.6 ± 22.5	52.1	<0.001
	JBCE	72.8 ± 17.9	104.4 ± 19.6	31.6	<0.001
Hip Flexor Flexibility (°)	INT	12.1 ± 3.5	21.5 ± 3.2	9.4	<0.001
	JBCE	11.8 ± 3.2	17.5 ± 3.0	5.7	<0.001

Paired t-test.

Between-group comparison
Post-intervention comparison revealed significantly greater improvements in the INT group than in the JBCE group. Participants receiving INT demonstrated significantly lower anterior pelvic tilt angles, faster sprint times, greater core endurance, and improved hip flexor flexibility compared with those receiving JBCE ($p<0.05$) [Table 3].

Table 3. Between-group comparison of post-intervention outcomes

Outcome	INT Group Mean ± SD	JBCE Group Mean ± SD	Mean Difference	p-value
Anterior Pelvic Tilt (°)	9.9 ± 1.8	11.9 ± 1.7	2.0	<0.001
30-m Sprint Time (s)	4.44 ± 0.25	4.57 ± 0.24	0.13	0.03
Core Endurance (s)	126.6 ± 22.5	104.4 ± 19.6	22.2	<0.001
Hip Flexor Flexibility (°)	21.5 ± 3.2	17.5 ± 3.0	4.0	<0.001

Independent-samples t-test.
Effect size analysis demonstrated moderate-to-large effects favouring the INT group for anterior pelvic tilt correction (Cohen's d = 0.88), core endurance (Cohen's d = 0.94), and hip flexor flexibility (Cohen's d = 0.81). No intervention-related adverse events were reported during the study period.

DISCUSSION
The present randomized controlled trial compared the effectiveness of Integrated Neuromuscular Training (INT) and Janda-Based Corrective Exercise (JBCE) on anterior pelvic tilt and sprint performance among collegiate sprinters. Both interventions resulted in significant improvements in anterior pelvic tilt angle, sprint performance, core endurance, and hip flexor flexibility. However, participants who received INT demonstrated significantly greater improvements across all outcome measures than those who received JBCE.

Anterior pelvic tilt is a common postural deviation among athletes and has been associated with altered lumbopelvic biomechanics, reduced movement efficiency, and increased susceptibility to low back pain and lower-limb injuries. [2] Excessive anterior pelvic tilt may impair hip extension and force transmission during sprinting, thereby negatively affecting athletic performance. Effective correction of lumbopelvic dysfunction is therefore essential not only for performance enhancement but also for injury prevention. [1,2]
The greater reduction in anterior pelvic tilt observed in the INT group may be attributed to improvements in neuromuscular control and dynamic stabilization of the lumbopelvic region. Integrated neuromuscular training incorporates multiple exercise components, including balance training, plyometric exercises, agility drills, and core stabilization, which collectively enhance movement quality and motor control.[10,11] Previous studies have demonstrated that neuromuscular training improves postural stability, biomechanical efficiency, and functional performance among young athletes.[11,12] These findings support the present results, where participants undergoing INT exhibited superior correction of pelvic alignment compared with those receiving JBCE.
The observed improvement in sprint performance among participants receiving INT may be explained by enhanced force transmission and trunk stability during running. Hodges and Richardson reported that deep stabilizing muscles, particularly the transversus abdominis and multifidus, play a critical role in maintaining spinal stability during dynamic movement.[6] Similarly, Akuthota and Nadler emphasized that core stabilization improves neuromuscular efficiency and functional performance by optimizing load transfer through the kinetic chain.[7] Kibler et al. further suggested that proximal stability is fundamental for efficient distal mobility and athletic performance.[8] The significant reduction in sprint time observed in the present study is consistent with these biomechanical principles.
The findings also align with the results of Dong et al., whose meta-analysis demonstrated that structured core training significantly improves sport-specific performance outcomes in athletes. [9] The improvement in core endurance observed among INT participants further supports the role of comprehensive neuromuscular conditioning in enhancing athletic performance. Enhanced core endurance may improve trunk control during sprinting, thereby facilitating more efficient movement patterns and reducing energy loss during force generation.
Janda-Based Corrective Exercise also produced significant improvements in all measured outcomes. These findings are consistent with Janda's muscle imbalance theory, which proposes that restoration of balance between tonic and phasic muscle groups can improve posture and movement efficiency.[13,14] Previous studies have reported beneficial effects of Janda-based interventions on postural stability, flexibility, and pain reduction among individuals with musculoskeletal disorders.[15,16] In the present study, stretching of shortened hip flexors and strengthening of weakened abdominal and gluteal muscles likely contributed to improvements in pelvic alignment and flexibility. However, the relatively smaller improvements observed in the JBCE group suggest that correction of isolated muscle imbalance alone may not fully address the complex neuromuscular demands of sprint performance.
A notable finding of the present study is its consistency with the recent randomized controlled trial conducted by Venkatesh et al., who compared 3D core stabilization with the Janda protocol among young sprinters. The authors reported significantly greater reductions in anterior pelvic tilt and superior improvements in sprint performance in the core stabilization group compared with the Janda group. [17] The present findings extend this evidence by demonstrating that a broader Integrated Neuromuscular Training approach, incorporating balance, agility, proprioceptive, and plyometric components in addition to core stabilization, may provide even greater benefits for sprint athletes.
From a public health perspective, sports-related musculoskeletal injuries contribute substantially to healthcare utilization and disability among young adults. [1,3] Early identification and correction of biomechanical dysfunctions may reduce injury risk and improve long-term musculoskeletal health. Incorporation of integrated neuromuscular training into collegiate athletic conditioning programs may therefore represent a practical and cost-effective strategy for improving performance while reducing injury burden.
The study has certain limitations. First, the study was conducted at a single center, which may limit the generalizability of the findings. Second, the intervention period was limited to eight weeks, and long-term follow-up was not performed. Third, advanced biomechanical assessment techniques such as three-dimensional motion analysis were not used to evaluate dynamic pelvic kinematics during sprinting. Future multicentred studies with larger sample sizes and longer follow-up periods are recommended to confirm the sustainability of the observed benefits.
Overall, the findings suggest that although both interventions are effective, Integrated Neuromuscular Training provides superior improvements in pelvic alignment, sprint performance, core endurance, and flexibility compared with Janda-Based Corrective Exercise among collegiate sprinters.

CONCLUSION

Both Integrated Neuromuscular Training and Janda-Based Corrective Exercise significantly improved anterior pelvic tilt, sprint performance, core endurance, and hip flexor flexibility among collegiate sprinters following eight weeks of intervention. However, Integrated Neuromuscular Training demonstrated significantly greater improvements across all outcome measures compared with Janda-Based Corrective Exercise. The findings suggest that a comprehensive neuromuscular training approach incorporating core stabilization, balance, proprioceptive, plyometric, and agility exercises is more effective in correcting lumbopelvic dysfunction and enhancing sprint performance. Incorporation of Integrated Neuromuscular Training into collegiate athletic conditioning programs may improve athletic performance and contribute to the prevention of sports-related musculoskeletal injuries. Further multicentre studies with larger sample sizes and long-term follow-up are warranted to confirm these findings.

Strengths and Limitations

The strengths of this study include its randomized controlled design, assessor blinding, and the use of validated outcome measures to assess pelvic alignment and sprint performance. The study also evaluated multiple performance-related outcomes, providing a comprehensive assessment of intervention effectiveness.

However, certain limitations should be acknowledged. The study was conducted at a single center with a relatively modest sample size, which may limit the generalizability of the findings. The intervention period was restricted to eight weeks, and long-term follow-up was not performed. Additionally, advanced biomechanical assessment tools such as three-dimensional motion analysis were not utilized to evaluate dynamic lumbopelvic kinematics during sprinting.

Acknowledgements

The authors acknowledge all collegiate athletes who participated in the study and the staff of the Sports Physiotherapy Unit, Vinayaka Mission Medical College and Hospital, Puducherry, for their support during data collection and intervention delivery.

Financial Support and Sponsorship

Nil.

Conflicts of Interest

There are no conflicts of interest.

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