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EFFECT OF AN EIGHT-WEEK INTERVENTION PROGRAM ON LUMBAR SPINE MOBILITY IN SEMI-PROFESSIONAL FEMALE BASKETBALL PLAYERS

VPLYV OSEMTÝŽDŇOVÉHO INTERVENČNÉHO PROGRAMU NA MOBILITU DRIEKOVEJ CHRBTICE U POLOPROFESIONÁLNYCH BASKETBALISTIEK

Andrea Izáková, Martina Barthová¹

Andrea Izáková pôsobí ako odborná asistentka na Fakulte telesnej výchovy, športu a zdravia, Univerzity Mateja Bela v Banskej Bystrici. Vo svojich výskumoch sa zameriava na problematiku vplyvu rôznych faktorov na pohybový výkon v basketbale, ale aj na problematiku vyučovania športových hier v školskom prostredí. Martina Barthová pôsobí ako interná doktorandka na Fakulte telesnej výchovy, športu a zdravia Univerzity Mateja Bela v Banskej Bystrici. Vo svojom dizertačnom výskume sa zameriava na problematiku únavy a jej vplyvu na pohybový výkon športovcov, so špecifickým dôrazom na parametre explozívnej sily dolných končatín.

Andrea Izáková works as an assistant professor at the Faculty of Physical Education, Sports and Health at Matej Bel University in Banská Bystrica. Her research focuses on the influence of various factors on motor performance in basketball, as well as on the teaching of sports games in the school environment. Martina Barthová is a full-time doctoral student at the Faculty of Sports Science and Health, Matej Bel University in Banská Bystrica. Her dissertation research focuses on the issue of fatigue and its impact on athletes' physical performance, with a specific emphasis on parameters of lower-limb explosive strength.

Abstract

Basketball places high demands on musculoskeletal system, in particular, on lumbar spine. During the regular season, repetitive high-intensity movements often lead to decreased mobility of spine and increased injury risk. Maintaining spinal-lumbar mobility is therefore important for optimal performance and injury prevention. The aim of study was to evaluate the influence of an 8-week intervention on standing bend tests, assessing mobility of lumbar spine in semi-professional female basketball players during the regular season. Fourteen semi-

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professional female players from BK ŠK UMB B. Bystrica (Niké Extraliga, Slovakia) participated and were randomly divided into an experimental group (N = 7, 50%) and a control group (N = 7, 50%). The experimental group performed a structured 8-week intervention (3x/ week/ 20 minutes) emphasizing dynamic mobility, spinal control, and lateral movement integration. Standing forward and side bend tests were conducted before and after the intervention. Non-parametric tests (Wilcoxon, Mann-Whitney U) assessed intra- and intergroup differences, with significance set at $p < 0.05$. Significant improvements ($p < 0.05$) were found in the experimental group across all tests; forward bend improved from -13.42 ± 3.04 cm to -4.14 ± 1.34 cm, and right/left side bends from 18.00 ± 0.81 cm and 18.00 ± 1.15 cm to 21.42 ± 0.78 cm ($r = 0.63 - 0.64$). No significant changes occurred in the control group. Post-test intergroup comparisons confirmed mobility in the experimental group ($p < 0.01$, $p < 0.05$). An 8-week in-season intervention effectively improved mobility of lumbar spine in semi-professional female basketball players without disrupting training loads.

Key words: basketball, in-season, female, spine, mobility

Abstrakt

Basketbal kladie vysoké nároky na pohybový aparát, najmä na oblasť driekovej chrbtice. Počas súťažného obdobia vedú opakované pohyby s vysokou intenzitou často k zníženiu mobility chrbtice a zvýšenému riziku zranení. Zachovanie mobility driekovej chrbtice je preto dôležité pre optimálny výkon a prevenciu zranení. Cieľom tejto štúdie bolo vyhodnotiť vplyv osemtyždňovej intervencie na testy ohybov postoja, ktoré hodnotia mobilitu driekovej chrbtice u poloprofesionálnych basketbalistiek počas súťažného obdobia. Štúdie sa zúčastnilo štrnásť hráčok z BK ŠK UMB Banská Bystrica (Niké Extraliga, Slovensko), ktoré boli náhodne rozdelené do experimentálnej skupiny (N = 7, 50 %) a kontrolnej skupiny (N = 7, 50 %). Experimentálna skupina absolvovala štruktúrovaný osemtyždňový intervenčný program (3x týždenne po 20 minút), ktorý sa zameriaval na dynamickú mobilitu, kontrolu chrbtice a integráciu laterálneho pohybu. Testy predklonu a úklonu v stoji boli realizované pred a po intervencii. Na vyhodnotenie rozdielov v rámci a medzi skupinami boli použité neparametrické testy (Wilcoxonov test, Mann-Whitneyho U test), pričom hladina významnosti bola stanovená na $p < 0,05$. V experimentálnej skupine došlo k štatisticky významnému zlepšeniu ($p < 0,05$) vo všetkých testoch – predklon sa zlepšil z $-13,42 \pm 3,04$ cm na $-4,14 \pm 1,34$ cm a úklony vpravo/vľavo z $18,00 \pm 0,81$ cm a $18,00 \pm 1,15$ cm na $21,42 \pm 0,78$ cm ($r = 0,63 - 0,64$). V kontrolnej skupine neboli zaznamenané žiadne významné zmeny. Porovnanie medzi skupinami po intervencii potvrdilo zlepšenú mobilitu v experimentálnej skupine ($p < 0,01$, $p < 0,05$). Osemtyždňová intervencia počas sezóny efektívne zlepšila mobilitu driekovej chrbtice u poloprofesionálnych basketbalistiek bez narušenia tréningovej záťaže.

Kľúčové slová: basketbal, súťažné obdobie, ženy, chrbtica, mobilita

Introduction

Basketball is an intensive team sport that places physical demands on the musculoskeletal system; in particular, during competitive periods when training volume and match exposure remain consistently high [12]. Semi-professional female basketball players often engage in

repetitive and asymmetrical movements, such as frequent jumping, sprinting, and rapid directional changes, which generate repetitive strain on the posterior kinetic chain [34]. Physical load, in time, can result in muscular tightness, postural imbalance, and reduced mobility; in particular, in lumbar regions, predisposing athletes to lower-limb injuries and restricted range of motion [39]. Within this biomechanical context, the standing bend tests (e.g., forward, side) serve as practical and standardized tools to assess spinal-lumbar mobility, providing valuable insight into the functional state of musculoskeletal system [10].

Female athletes, in particular, exhibit distinct neuromuscular characteristics that can influence (both) mobility and injury risk. Factors such as hormonal fluctuations, cumulative fatigue, and the demands of multi-directional (sport-specific) movements may contribute to increased muscular stiffness and reduced recovery capacity [9]. Maintaining optimal mobility of spine, in particular, in the lumbar region, is therefore important for preserving an adequate range of motion, promoting efficient load distribution, and preventing overuse injuries during the in-season (e.g., regular, play-off) [36].

Mobility of spine, encompassing (both) thoracic and lumbar mobility, is an important component of musculoskeletal health. The spine acts as biomechanical axis for force transmission between the upper and lower body, enabling stability and mobility during athletic movements [16]. Reduced mobility of spine, in particular, lumbar, can alter neuromuscular coordination and movement efficiency, leading to compensatory loading of the hip and knee joints and increasing the risk of injury [3]. Chronic reductions in mobility of lumbar spine are often accompanied by increased muscle stiffness in the paraspinal and hamstring regions, limiting athletes' ability to perform functional trunk movements such as forward bending, which assesses the flexion of trunk and the ability to reach toward the ground with extended knees. It provides simple yet valid measures of combined spinal-lumbar and posterior chain. This reflects not only hamstring extensibility but also the mobility of the lumbar spine and its supporting musculature [26].

In sports such as basketball, where athletes maintain flexing (semi-) postures during defensive plays and execute high-impact jumps, maintaining mobility of lumbar spine is critical for shock absorption and postural control [37]. Inadequate spinal-lumbar mobility can contribute to the development of muscle imbalances, lower back discomfort, and reduced trunk control, issues that are, in particular, common among female athletes because of differences in pelvic structure [38]. During the in-season, accumulated fatigue, high training frequency, and limited recovery time can exacerbate stiffness in the lower back and posterior chain muscles, affecting spinal alignment and mobility [35].

Scientific literature supports the effectiveness of short-term intervention programs, lasting four to eight weeks, in improving mobility of spine. Research in diverse athletic populations has shown that consistent mobility exercises targeting the spine and posterior musculature can significantly ($p < 0.01$, $p < 0.05$) enhance the dynamic function of trunk [24, 40].

Standing bend tests (e.g., forward, side) are practical and commonly used tools for assessing mobility of spine and hamstring in sports and clinical environments. Its results are influenced by the extensibility of posterior chain and mobility of lumbar spine, making it an important diagnostic and monitoring tool [26]. Improvements in standing bend tests following

mobility interventions are documented across various populations, demonstrating the tests' sensitivity to changes in functions of spine (muscle) [30]. In-season interventions focusing on mobility of spine and trunk not only support injury prevention but also help maintain athletes' readiness for training and competition. Given the continuous physical demands experienced by semi-professional basketball players, mobility interventions that can be integrated into regular training schedules are of high practical value [23, 39].

Despite growing evidence on benefits of mobility interventions (training), limited research has focused on mobility of lumbar spine among semi-professional female basketball players during the regular season. Available literature emphasizes pre-season conditioning and/or general mobility evaluations without addressing in-season adaptations in mobility of spine; however, maintaining spinal-lumbar mobility during competitive periods is important for mitigating postural fatigue, preventing muscle overuse, and ensuring consistent functional performance [39]. Because of dynamic demands of basketball, athletes must maintain (both) mobility and stability of trunk to manage repetitive loading and rotational stresses [33]; therefore, structured interventions targeting the lumbar spine may represent an important strategy for maintaining musculoskeletal health and functional movement effectiveness across the in-season.

In view of considerations, the present study aimed to evaluate the influence of an 8-week intervention on standing bend tests (lumbar spine) in semi-professional female basketball players during the regular season.

Materials and Methods

In terms of study aim, the sample (i.e., target population) consisted of 14 (100%) semi-professional female basketball players, representing BK ŠK UMB B. Bystrica, competing in the Niké Extraliga, the highest women's basketball league in Slovakia. Participants met the inclusion criteria of continuous engagement in basketball training and regular participation in competitive matches during the in-season. Participants were assigned to either an experimental group (N = 7; 50%) or control group (N = 7; 50%) using balanced allocation according to playing position and training load to ensure comparable group composition. To reduce the potential influence of somatic parameters (e.g., body height, body weight) on intervention outcomes, the allocation process also considered these anthropometric variables. Players were stratified into subgroups with similar physical characteristics before randomization to maintain group homogeneity. Baseline comparisons confirmed no statistically significant differences ($p > 0.05$) in age, height, or weight, supporting the validity of the selection method. Inclusion criteria required minimum of 10 years of basketball experience, and the absence of any acute or chronic musculoskeletal injury.

Characteristics (Table 1) were comparable between groups. The experimental group (N = 7, 50%) had means age of 22.00 ± 1.34 years, weight of 66.20 ± 6.20 kg, and height of 172.80 ± 4.28 cm. The control group (N = 7, 50) had means age of 21.50 ± 1.28 years, weight of 68.80 ± 4.82 kg, and height of 175.40 ± 3.41 cm. Position distribution was identical across both groups, with 57.14% (N = 4) of guards, 28.57% (N = 2) of forwards, and 14.29% (N = 1) of centers. Participants in the experimental group had an average length of basketball career of 15.00 ± 1.41 years, compared to 14.60 ± 1.43 years in the control group, while daily

practice averaged 1.38 ± 0.40 hours and 1.48 ± 0.26 hours. At baseline, there was no significant ($p > 0.05$) difference between groups in age ($t(12) = 0.87$, $p = 0.40$), height ($t(12) = 1.46$, $p = 0.17$), weight ($t(12) = -0.86$, $p = 0.40$), practice/ day ($t(12) = 0.74$, $p = 0.47$), and practice/ career ($t(12) = 0.53$, $p = 0.60$), confirming group homogeneity and allowing valid between-group comparisons.

All participants provided written informed consent prior to the commencement of study. Participation was voluntary and in accordance with the ethical principles of the Declaration of Helsinki (Harriss et al., 2020).

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	Experimental group	Control group
Anthropometric		
Age (years; $M \pm SD$)	22.00 ± 1.34	21.50 ± 1.28
Body weight (kg; $M \pm SD$)	66.20 ± 6.20	68.80 ± 4.82
Body height (cm; $M \pm SD$)	172.80 ± 4.28	175.40 ± 3.41
Position		
Guard (N ; %)	4; 57.14%	4; 57.14%
Forward (N ; %)	2; 28.57%	2; 28.57%
Center (N ; %)	1; 14.29%	1; 14.29%
Practice		
Day (hours; $M \pm SD$)	1.38 ± 0.40	1.48 ± 0.26
Career (years; $M \pm SD$)	15.00 ± 1.41	14.60 ± 1.43
Occupation		
Student (N ; %)	6; 85.71%	6; 85.71%
Employed (N ; %)	1; 14.29%	1; 14.29%

^M Mean, ^{SD} Standard deviation, ^{kg} Kilogram, ^{cm} Centimeter, ^N Number of participants, [%] Percentage.

Table 1 - Characteristics of participants ($N = 14$, 100%)

Source: Own

This study employed true experimental designs with randomized assignment into two parallel groups: an experimental group (N = 7; 50%) that received an 8-week intervention (program) targeting spinal-lumbar mobility, and a control group (N = 7; 50%) that maintained their standard training regimen without additional intervention. The design conformed to established methodological standards for controlled trials in physical education and sports science research [29].

The study was conducted over eight consecutive weeks (September 22 - November 16, 2025) during the in-season of Niké Extraliga, the highest women's basketball league in Slovakia. During the period, participants trained 5x/ week (Monday to Friday) and played 8 official league matches; 2 at home and 6 away. The intervention was performed at the end of regular team trainings to ensure integration within the in-season training and minimize interference with competitive performance.

The 8-week intervention was designed to improve the mobility of lumbar spine in semi-professional female basketball players. The intervention was implemented 3x/ week (Monday, Wednesday, and Friday), with each session lasting approximately 20 minutes. Each session was conducted in structured group settings under the direct supervision of authors and synchronized with the team's training load to prevent excessive fatigue:

Warm-up (\pm 3 minutes)

An activation of exercises focused on dynamic mobilization of trunk, hips, and hamstrings (e.g., torso rotations, hip circles, dynamic lunges, cat-camel movements).

Main block (\pm 14 minutes)

Each session emphasized progressive mobility of spine focused on trunk flexion, lateral flexion, and controlled dynamic movement. Each exercise was organized into four progressive stages across 2-week cycles (Table 2).

Cool-down (\pm 3 minutes)

Passive stretching and diaphragmatic breathing to promote relaxation, restore muscle length, and reduce post-session stiffness.

Week	Focus	Exercise
1 - 2	Activation & Awareness	<ul style="list-style-type: none"> - Cat-camel (8 - 10 reps) - Dynamic flexion (8 reps) - Lateral side bends (8 reps/ side) - Shoulder rolls + thoracic extension (10 reps) - Hip circles + spine elongation (10 reps/ direction) - Standing hamstring sweeps (10 reps) - Supine pelvic tilts (10 reps)
3 - 4	Control & Stability	<ul style="list-style-type: none"> - Seated forward fold (3x/ 20 s) - Kneeling rotation (8 reps/ side) - Bird-dog with alternating arm/ leg extension (8 reps/ side) - Resistance-band rotation (8 -10 reps/ side) - Half-kneeling side bend stretch (3x/ 20/ side) - Supine hamstring stretch with resistance band (3x 20 s/ leg)

5 - 6	Strengthening & Reeducation	<ul style="list-style-type: none"> - Prone shoulder lift (“Y-T-W” sequence, 6 reps) - Dynamic hamstring stretches (10 reps/ leg) - Active flexion of spine and extension (10 reps) - Side flexion with resistance (8 reps/ side) - Reverse lunge with spinal twist (8 reps/ side) - Prone swimmer (10 reps) - Standing good morning (10 reps)
7 - 8	Control & Integration	<ul style="list-style-type: none"> - Wall-assisted thoracic extension (10 reps) - Combined forward–lateral bend flow (6 - 8 reps) - Standing trunk rotation (8 reps/ side) - Side plank with rotation (6 - 8 reps/ side) - Forward fold to overhead reach (8 reps) - Controlled windmill stretch (8 reps/ side) - Stability ball trunk rollouts (8 reps) - Deep breathing with spinal decompression (3x/ 30 s)

Table 2 - Overview of 8-week intervention

Source: Own

The intensity of exercises increased every 2 weeks while maintaining controlled tempo and movement quality. All participants in the experimental group followed the same protocol under consistent supervision to ensure proper technique and adherence. Attendance and compliance exceeded 95%, and no musculoskeletal complaints or adverse events were reported [20]. The program was designed to complement regular basketball training without interfering with technical or tactical practice sessions. The group setting was chosen as the method of delivery because of its cost-effectiveness, the benefits of peer support, and increased engagement [2].

Standardized measures for evaluating the standing bend tests (e.g., forward, side) [19] were carried out before the intervention (week 1, September 22, 2025) and after its completion (week 8, November 14, 2025):

Standing Forward Bend Test

Norm: Fingertips touch the ground (floor).

Deviation: Fingertips do not touch the ground (floor).

Standing Side Bend Test

Norm: Distance of 20 - 22 cm.

Deviation: Extension \geq than the norm.

Analysis of data (available) was performed using IBM SPSS Statistics, version 24.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables (relevant), including means (M) and standard deviations (SD), to summarize participant characteristics and study results [7].

To evaluate the distribution of data, the Shapiro-Wilk Test was used [13]. Results indicated violations of normality for several variables, prompting the use of non-parametric procedures for inferential analysis; however, age, height, and weight conformed to normal distribution assumptions; therefore, independent-samples t-tests were employed to assess

group differences at baseline [18]. Because of small sample size and non-normal data distributions, non-parametric tests were employed. Differences within groups (pre- vs. post-) were evaluated using the Wilcoxon Tests, while between-group comparisons (experimental vs. control) at both pre- and post- stages were performed using the Mann-Whitney U-Test [22, 28]. The level of statistical significance was set at $p < 0.05$. Because of significant results, effect size (r) was calculated using the formula $r = Z / \sqrt{N}$, where N is the total number of observations. Effect sizes were interpreted using Cohen's [6] classification: small ($r \leq 0.10$), medium ($r \leq 0.30$), and large ($r \geq 0.50$). All results are reported with corresponding test statistics, p -values, and effect sizes, ensuring adherence to established guidelines in sports and health sciences research.

Results

Within the experimental group ($N = 7$, 50%), the Wilcoxon test demonstrated statistically significant improvements ($p < 0.05$) in all tests. Results of standing forward bend tests improved from -13.42 ± 3.04 cm before the intervention to -4.14 ± 1.34 cm after the intervention ($Z = 2.37$, $p < 0.05$, $r = 0.63$), indicating large effect sizes. Results in the standing side bend test significantly increased for (both) the right and left. The right-side flexion improved from 18.00 ± 0.81 cm to 21.42 ± 0.78 cm ($Z = 2.38$, $p < 0.05$, $r = 0.63$), while the left-side flexion significantly increased from 18.00 ± 1.15 cm to 21.42 ± 0.78 cm ($Z = 2.41$, $p < 0.05$, $r = 0.64$) (Table 3). The results confirm that the 8-week intervention effectively enhanced forward and lateral spinal mobility, with large effect sizes indicating substantial practical significance.

Within the control group, no statistically significant change ($p > 0.05$) was observed across any of measured tests over the same period. Standing forward bend tests remained constant (-7.42 ± 3.50 cm pre-test vs. -7.28 ± 3.86 cm post-test; $Z = 0.27$, $p > 0.05$, $r = 0.07$), as did the right-side (19.00 ± 0.57 cm vs. 19.14 ± 0.69 cm; $Z = 0.57$, $p > 0.05$, $r = 0.15$) and left-side (18.71 ± 1.11 cm vs. 18.57 ± 1.61 cm; $Z = 0.57$, $p > 0.05$, $r = 0.15$). The results suggest that maintaining regular basketball training, without additional intervention, did not produce measurable improvements in lumbar spine during the in-season.

Experimental group			
Standing bend tests ($M \pm SD$)	Pre- (week 1)	Post- (week 8)	Wilcoxon Test (p)
Forward	-13.42 ± 3.04	-4.14 ± 1.34	$Z = 2.37$, $p < 0.05$, $r = 0.63^*$
Side (Right)	18.00 ± 0.81	21.42 ± 0.78	$Z = 2.38$, $p < 0.05$, $r = 0.63^*$
Side (Left)	18.00 ± 1.15	21.42 ± 0.78	$Z = 2.41$, $p < 0.05$, $r = 0.64^*$
Control group			
Standing bend tests ($M \pm SD$)	Pre- (week 1)	Post- (week 8)	Wilcoxon Test (p)
Forward	-7.42 ± 3.50	-7.28 ± 3.86	$Z = 0.27$, $p > 0.05$, $r = 0.07$
Side (Right)	19.00 ± 0.57	19.14 ± 0.69	$Z = 0.57$, $p > 0.05$, $r = 0.15$
Side (Left)	18.71 ± 1.11	18.57 ± 1.61	$Z = 0.57$, $p > 0.05$, $r = 0.15$

^N Number, % Percentage, ^M Mean, ^{SD} Standard deviation, ^p Value; ^z Value; ^r Effect size; * Significance (p) < 0.05

Table 3 - Intragroup (within) comparisons of participants ($N = 14$, 100%)

Source: Own

Between-group (intergroup) comparisons using the Mann-Whitney U-Tests provided further confirmation of intervention's effectiveness. At baseline, significant difference was found between the groups in the standing forward bend tests ($Z = -2.69, p < 0.01, r = -0.72$) and the standing right side bend test ($Z = -2.21, p < 0.05, r = -0.59$), with the control group showing greater mobility before the intervention. No significant difference was observed in the standing left side bend test ($Z = -1.06, p > 0.05, r = -0.28$); however, after the 8-week intervention, the experimental group demonstrated significantly better performance across all tests compared with the control group. Post-intervention results showed significant differences in the standing forward bend test ($Z = -1.94, p < 0.05, r = -0.52$), standing right side bend ($Z = -3.08, p < 0.01, r = -0.82$), and standing left side bend test ($Z = -3.00, p < 0.01, r = -0.80$), with large effect sizes confirming the meaningful impact of intervention.

Pre- (week 1)			
Standing bend tests ($M \pm SD$)	Experimental group	Control group	Mann-Whitney U-Test (p)
Forward	-13.42 ± 3.04	-7.42 ± 3.50	$Z = -2.69, p < 0.01, r = -0.72^{**}$
Side (Right)	18.00 ± 0.81	19.00 ± 0.57	$Z = -2.21, p < 0.05, r = -0.59^*$
Side (Left)	18.00 ± 1.15	18.71 ± 1.11	$Z = -1.06, p > 0.05, r = -0.28$
Post- (week 8)			
Standing bend tests ($M \pm SD$)	Experimental group	Control group	Mann-Whitney U-Test (p)
Forward	-4.14 ± 1.34	-7.28 ± 3.86	$Z = -1.94, p < 0.05, r = -0.52^*$
Side (Right)	21.42 ± 0.78	19.14 ± 0.69	$Z = -3.08, p < 0.01, r = -0.82^{**}$
Side (Left)	21.42 ± 0.78	18.57 ± 1.61	$Z = -3.00, p < 0.01, r = -0.80^{**}$

^N Number, [%] Percentage, ^M Mean, ^{SD} Standard deviation, ^p Value; ^z Value; ^r Effect size; ^{**} Significance (p) < 0.01; ^{*} Significance (p) < 0.05

Table 4 - Intergroup (between) comparisons of participants (N = 14, 100%)

Source: Own

Discussion

The present study examined the influence of 8-week intervention on standing bend tests (lumbar spine) in semi-professional female basketball players during the regular season. The results showed statistically significant improvements in all standing bend tests in the experimental group (N = 7, 50%) ($p < .05$) with large effect sizes ($r = 0.63 - 0.64$), while the control group (N = 7, 50%) showed no meaningful changes ($p > 0.05$). Participants improved their standing forward bend by over 9 cm and their lateral side bends by ± 3.4 cm.

The improvements in mobility of lumbar spine are consistent with findings from previous interventions in both athletic and general populations. Repetitive instrument-assisted manual therapy sessions improved mobility of hamstrings and lumbar range of motion in female soccer players [32]. 4-week core stabilization program significantly enhanced mobility of lumbar spine and trunk muscle activity in participants with spinal stiffness [24]. The current results parallel these findings, supporting the assumption that short-term, structured interventions can meaningfully increase lumbar mobility.

Comparing the current results with data from other sports, the magnitude of improvement observed here is comparable to those found in proprioceptive or flexibility-based interventions in volleyball and soccer athletes. 8-week proprioceptive training program significantly improved spinal range of motion among professional basketball players [11].

The size of change in the current study is thus within the expected range for sport-specific interventions aiming to enhance spinal function.

The intervention's progressive structure, transitioning from activation and awareness to control, strengthening, and integration phases, likely underpinned the significant improvements observed. This design aligns with recommendations that mobility of lumbar spine programs should gradually increase complexity while maintaining control over spinal alignment and breathing patterns [25]. Improved spinal control in flexion and lateral movement may reflect neural adaptations, such as enhanced proprioceptive feedback and reduced co-contraction of antagonistic muscles [5].

Single session of instrument-assisted manual therapy improved mobility and tissue compliance in the lumbar fascia of female soccer players [31]. In both studies, short-term interventions targeting myofascial continuity and neuromuscular reeducation yielded measurable changes in mobility results. The improvements in lateral flexion observed here also mirror findings reporting increased side-bending mobility following lumbar manipulation protocols among baseball players [27].

An exclusive focus on female athletes provides valuable insights into populations often underrepresented in mobility research. Female athletes exhibit greater lumbar and pelvic mobility than their male counterparts, which may contribute to higher baseline mobility values [21]; however, the present study shows that even with potentially higher baseline mobility, additional improvements can still be achieved through targeted training. Similar observations have been made in female soccer players, who achieved significant flexibility gains despite already possessing adequate mobility of spine [32].

Results (our) corroborate findings from research on age- and sex-related mobility of spine differences, which show that younger adults tend to exhibit higher spinal range of motion compared to older populations, in particular, in forward flexion [8]. Given that participants in this study were young adults (mean age 22 years), their capacity to respond to mobility training is expectedly high.

The use of standing bend tests as primary assessment tools is supported by validation research showing that they are simple and reproducible measures of mobility of spine and hamstrings [1]; however, some authors caution that these tests may not isolate lumbar motion from hip contributions [4], their reliability for tracking within-subject changes over time remains high under controlled conditions. The large effect sizes reported here confirm that the intervention-induced differences exceed typical measurement error.

The results also align with findings from elite sport contexts. Greater mobility of lumbar and thoracic spine has been observed in elite table tennis players than in non-athletes, attributed to sport-specific mobility training [15]. In our basketball players, the improvement in spinal range of motion likely reflects the additive effect of targeted intervention beyond routine sports participation.

Large effect sizes ($r = 0.63 - 0.64$) observed in this study indicate that the intervention not only produced statistically significant ($p < 0.05$) but also practically meaningful changes. Comparable magnitudes of effect have been found in research employing manual therapy or mobility-focused interventions of similar duration [31-32]. These consistent results reinforce

that even short-term, well-structured mobility interventions can yield measurable mobility improvements.

Future investigations should integrate objective biomechanical and imaging-based assessments, to better understand structural and functional changes resulting from mobility interventions. It would also be valuable to monitor whether improvements in mobility of spine translate to changes in athletic performance metrics such as agility, balance, or vertical jump efficiency, as suggested previously [17].

Expanding the participant pool across different competitive levels and age categories could provide insight into how training history and physical maturity influence adaptability of lumbar spine. Comparative research involving male basketball players or athletes from other team sports could help identify sex-specific or discipline-specific patterns of mobility adaptation.

This study's limitations primarily concern sample size, assessment methods, and time frame. The small number of participants ($N = 14$, 100%) limits generalizability, although the strong within-group effects support internal validity. The use of standing bend tests, while practical, does not allow precise separation of spinal from hip motion, and future research should employ segmental motion analysis for more detailed assessment. The short duration of intervention and lack of follow-up limit understanding of the long-term retention of mobility gains. Because this research was conducted during the regular season, variations in match load, fatigue, and hormonal fluctuations among female athletes may have introduced uncontrolled variability.

Conclusions

The results of this research align with prior research showing that structured mobility and spinal control programs can improve range of motion within short time frame. The observed magnitude of change is comparable to previously reported improvements in mobility interventions across different athletic populations. The progressive nature of intervention, moving from activation and awareness to control, strengthening, and integration, appears to be an effective methodological approach for achieving optimal neuromuscular adaptation and flexibility enhancement during the in-season.

From practical standpoints, the findings suggest that implementing short, 20-minute, 3x/ week mobility protocol can effectively improve lumbar function in female basketball players without disrupting regular training loads. This has direct implications for coaches and conditioning specialists seeking to maintain athletes' mobility and movement efficiency during the demanding competitive period.

Despite the small sample size, the consistency and magnitude of statistical improvements demonstrate that the program produced robust effects. The high attendance and adherence rate (> 95%) further support the acceptability of intervention in real-world team sport environments.

The results indicate that even under high physical and competitive demands, structured mobility interventions can yield large and practically meaningful gains in spinal-lumbar function. Future research should aim to validate these findings in larger and more diverse

athletic cohorts, explore the long-term retention of flexibility adaptations, and assess whether improvements in mobility of spine contribute to broader functional performance outcomes.

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