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ORIGINAL RESEARCH

A Comparison of the Instantaneous Effects of Spinal Manipulation and Mobilization Techniques Applied to L3 Level on Jumping, Agility and Sprint Speed in Male Volleyball Players

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Abstract
Objective: This study aims to investigate the effects of manipulation and mobilization treatments applied to the L3 segment on sportive performance to prevent performance anxiety and low performance resulting from competition stress in athletes.
Material-Method: Sixty male volleyball players aged 18 to 25 were enrolled in this randomized controlled trial. Participants were randomly assigned to one of three groups: a manipulation, a mobilization, and a control group. After completing the required warm-up program, participants underwent either manipulation or mobilization based on their assigned group. Hip range of motion, lumbar range of motion, T-Test time (seconds), 10-meter sprint time (seconds), vertical jump height (cm), and horizontal jump distance (cm) were evaluated immediately before and after the interventions.
Results: There were no significant differences between the groups regarding participants' age and height ($p>0.05$). The mobilization group had the highest mean body mass index and weight ($p=0.05$). In the intra-group analysis, statistically significant improvements were observed in the spinal manipulation group for hip external rotation, lumbar flexion, extension, T-test performance, and right lumbar flexion ($p<0.05$). In the mobilization group, significant changes were noticeable for right hip flexion, left hip abduction, hip external rotation, lumbar flexion, extension and lateral flexion, T-test performance, 10-meter sprint, and horizontal jump. Across all groups, all measures were statistically significant except for hip flexion, hip adduction, hip internal rotation, and lumbar lateral flexion ($p<0.05$).
Conclusion: Comparing the data between the groups revealed that the spinal manipulation group demonstrated superior outcomes in right hip extension, right hip external rotation, lumbar flexion, extension, T-test performance, and 10-meter sprint times compared to the spinal mobilization and control groups. We believe that pre-competition spinal manipulation interventions may offer the greatest benefit for volleyball players.
Keywords: Chiropractic, Spinal Manipulation, Spinal Mobilization, Sports Performance, Volleyball

INTRODUCTION

Volleyball is one of the world's most popular sports, played by two teams of six players and practiced by 200 million people worldwide. Jumping, landing, blocking, and spiking are specific movements of volleyball and require quick movements of the musculoskeletal system. Vertebral and biomechanical dysfunctions may impair neuroplasticity in the central nervous system (CNS), negatively impacting athletic performance. However, the application of spinal manipulative therapy (SMT) to these dysfunctional segments has been shown to enhance proprioception and motor response. A recent study has shown that a single session of spinal manipulation increases corticospinal excitability and electromyographic activity, which may lead to increased muscular strength. While some research has supported this hypothesis, others have found inconsistent results. Despite several neurophysiological hypotheses for the effects of SMT on athletes, no consensus has been established [1-3].

Many questions have been raised about whether chiropractic treatments can enhance athletic performance, but these questions have generally remained unresolved due to the lack of studies. Although some researchers have reported that chiropractic treatment enhances athletic performance, others have reported that chiropractic performance has no significant effect; these studies provide inadequate evidence. As a result, the role of chiropractic therapy in athletics still needs to be fully understood. Although the mechanism remains unclear, these techniques are hypothesized to increase the pain threshold and enhance motor neuron excitability by altering central perception. Despite the popularity of manipulative and mobilization techniques among athletes, this study was designed to evaluate their impact on performance, incorporating a control group and adhering to ethical considerations [4-6].

MATERIALS AND METHODS

Study design and participants

We used a randomized controlled clinical trial model with pre-and post-test evaluation methods. Healthy licensed volleyball players between the ages of 18 and 25 were included in this study at Bahçeşehir Okyanus College Sports Hall. After the players in the study were informed in detail about the manipulation and mobilization techniques, the height, weight, and body mass indexes of the volunteers who signed the consent form were evaluated and randomly divided into three groups. The groups were the control group (n=20), the L3 spinal manipulation group (n=20), and the L3 mobilization group (n=20). During the study, pre-application evaluations were performed, followed by the manipulation and mobilization techniques, and then the pre-application evaluations were repeated instantaneously. The evaluation times were T0 (before spinal manipulation/mobilization procedure), T1 (after spinal manipulation/mobilization procedure).

A power analysis was conducted using the G*Power software (version 3.1.9.7) to determine the appropriate sample size for the study. The statistical power was represented as 1-β (with β being the probability of a Type II error). In a study by Thomas et al. (2022) that investigated the effects of manipulative treatment on lower extremity function in young professional football players, the mean and standard deviation of vertical jump data were used for comparison between the control group (34.0 ± 3.9) and the experimental group (39.3 ± 5.4) with a significance level of $\alpha = 0.05$. The power analysis, aiming for 95% power, calculated an effect size (d) of 0.5789. Based on these calculations, it was determined that a total of 51 participants would be required for this study, distributed across three groups.

In the study, the T-test was used to evaluate agility, the contact mat (SMART JUMP-AUS) was used to assess vertical jump, a photocell was used to measure a 10-meter straight sprint run, and goniometry was used to evaluate the range of motion. Horizontal jump was measured on the gym floor with the help of a tape measure.[8-12] Each evaluation was repeated three times and averaged.

Evaluation criteria

Inclusion criteria: Being male, having signed the voluntary consent form, being between the ages of 18 and 25, being a licensed volleyball player, not using performance-enhancing supplements, and not having any contraindications to chiropractic applications.

Exclusion criteria: Having a history of orthopedic injury in the last three months, being a volleyball player for less than one year, and practicing volleyball less than three days a week.

Exclusion from the study: Volunteers who sustained any injuries during the measurements and declined to continue the study.

Intervention

Spinal manipulation: Spinal manipulation is a specialized form of manual therapy for musculoskeletal injuries and disorders that is non-invasive and hands-on. The most common type of spinal manipulation used by practitioners is low-amplitude and high-velocity thrusts (HVLA; high-velocity low-amplitude). The patient is lying on the side, in a lateral decubitus position. The knee of the lower leg is extended, and the knee of the upper leg is flexed and placed in the popliteal fossa of the lower leg. The physiotherapist places their hand on the L3 segment and rolls the patient towards them, and when the joint is locked, performs the high intensity and low amplitude (HVLA) maneuver from posterior to anterior [13,14].

Spinal mobilization: It is a manual therapy method applied to a specific segment with low intensity and low speed, and generally, no ‘’popping’’ sound is heard after application. A rhythmic force with passive oscillations is applied to the affected segment. Vertebral mobilizations are also called "passive and oscillating movements within the range allowed by the vertebra"[15,16].

Posteroanterior mobilizations in the lumbar spine involve placing the patient's hands on their back, with the clinician's hands acting as springs. The patient lies prone with their hands either by their side or above their head, with their head turned to one side. The clinician's left hand is placed on the patient's back, with the clinician's shoulders over the contact point. The clinician's right hand is reinforced by

placing the carpus over the radial aspect of the left carpus at the base of the left index finger. Stability is maintained through grasping the clinician's palm and sustained wrist extension. The technique involves grade 1 and 2 joint oscillations for 30 seconds each, with 6 repetitions [17].
The control group did not receive any treatment.

Warm – Up Protocol
Sports scientists and trainers are constantly searching for new ways to maximize the performance of athletes. Although different exercise protocols are constantly applied in warm-ups before competition and training, the effect of these exercises (static-dynamic stretching, resistance exercises, jumping, jogging, etc.) on jumping performance, especially in volleyball players, is not fully known. In a study conducted on female volleyball players, the effects of static and dynamic stretching on vertical jump were compared, and the two types of exercises did not outperform each other even though they increased vertical jump. Another study compared the effect of various exercises on vertical jumping in young volleyball players and showed that vertical jumping exercises were superior to other groups. In young elite volleyball players, dynamic exercises were shown to positively affect the directional change performance of volleyball players [18,19,20].
It has been argued that pre-training warm-up programs, including static stretching exercises, reduce the risk of injury and improve athletic performance. Static stretching exercises were suggested to increase joint range of motion, reduce injury risk, and rehabilitate the muscle. However, recent studies have found that static stretching exercises decrease performance in sports involving explosive exercise. Therefore, their use in sports requiring high force output is questioned [21].
For the factors mentioned above, the volleyball players were given a warm-up program that included dynamic stretching and vertical jumps, prepared jointly with volleyball coaches.

Randomization
Each subject was assigned a number between 1 and 60 by random lottery. Using the simple random sampling method, a number sequence was generated using the Microsoft Excel program. Groups were formed by utilizing the data in the number array.

Permission
For the study to be planned and conducted following the Principles of the Declaration of Helsinki, ethics committee approval was obtained from the Gümüşhane University Scientific Research and Publication Ethics Committee dated 29.09.2021 and numbered 2021/6.

Statistical analysis
After the data were organized in an Excel program, they were analyzed with SPSS 29.0 IBM. Categorical variables were presented with frequency and percentage values, and numerical data were presented with mean, standard deviation and median values. Since the amount of data in each group was less than 30, the data were analyzed using nonparametric tests. The Kruskal-Wallis-H Test was used to analyze the data between 3 groups, and Wilcoxon Sign Test statistics were used to analyze two separate measurements for each group. Intergroup comparisons were made with Kruskal-Wallis-H by taking the differences between the measurement times. Significance level $p<0.05$ was considered for all tests.

RESULTS
Demographic data of the groups are given in Table 1. There is no statistically significant difference between the groups regarding age (p=0.368) and height (p=0.412). However, weight (p=0.05) and BMI (p=0.019) were statistically significant. The mobilization group had the highest mean weight and BMI (Table 1).

Table 1. Demographic Characteristics of the Groups

		Age (Years)	Height (cm)	Weight (kg)	BMI (Kg / m^2)
Manipulation Group	**Mean ± St. Dev.**	20,30±1,45	189,20±6,35	82,80±9,33	23,10±1,99
	Median	20	188	80,5	23,5
Mobilization Group	**Mean ± St. Dev.**	21,35±2,41	187,10±7,76	86,00±12,09	24,50±2,61
	Median	21,0	187	83,5	24,4
Control Group	**Mean ± St. Dev.**	21,05±2,19	186,50±6,42	77,75±10,68	22,30±2,39
	Median	20	187,5	75,0	21,8
Kruskal-Wallis Test Value		2,00	1,755	5,993	7,883
	p value	0,368	0,412	**0,05**	**0,019**

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Table 2. Intragroup Comparision

		Manipulation Group				**Mobilization Group**				**Control Group**			
		T0	**T1**	**Wilcoxon**	**p**	**T0**	**T1**	**Wilcoxon**	**p**	**T0**	**T1**	**Wilcoxon**	**p**
Hip Flexion	**Right**	107,85±6,79(110)	109,2±7,14(110)	-1,245	0,213	104,70±6,05(103)	106,50±6,13(105)	-2,790	**0,005**	106,70±5,43(105,5)	106,95±5,56(105,5)	-1,169	0,242
	Left	106,95±4,41(108,5)	107,35±6,3(105)	-0,119	0,905	105,65±5,86(105)	107,00±5,80(106,5)	-2,157	0,031	106,75±4,49(106,5)	106,90±4,59(106,5)	-0,317	0,751
Hip Extension	**Right**	19,2±2,72(19)	19,8±2,37(20)	-1,086	0,278	22,05±2,82(21,5)	22,60±3,28(22)	-1,374	0,170	23,70±3,06(23)	23,95±2,44(24)	-0,714	0,475
	Left	20,1±3,22(19)	21,35±2,7(21,5)	-2,001	0,045	21,30±3,48(20,5)	22,25±3,70(22)	-1,985	0,047	24,70±4,49(25)	24,20±3,97(24,5)	-0,956	0,339
Hip Abduction	**Right**	43,40±2,19(44)	42,65±2,76(42)	-0,988	0,323	45,55±5,07(44)	47,05±4,67(45)	-2,695	0,007	43,65±3,56(44)	43,95±3,10(44)	-1,015	0,310
	Left	43,65±3,17(44)	44,55±3,07(44,5)	-1,286	0,119	44,95±4,17(44,5)	46,20±4,23(45)	-2,800	**0,005**	44,00±3,03(44)	44,10±3,23(45)	-0,446	0,656
Hip Adduction	**Right**	32,90±2,67(38)	38,05±2,52(38,5)	-0,599	0,550	38,25±2,36(38)	39,10±1,92(39)	-2,170	0,030	37,10±2,45(37)	36,90±2,31(37)	-0,036	0,972
	Left	37,90±2,49(38,5)	38,05±2,72(39)	-0,518	0,604	36,90±2,31(36,5)	37,65±1,93(38)	-1,516	0,129	37,60±1,93(38)	37,25±2,31(37)	-0,694	0,488
Hip External Rotation	**Right**	47,85±4,51(48,5)	50,10±5,14(50)	-3,057	**0,002**	49,15±3,84(50)	51,20±4,11(51,5)	-3,620	**<0,001**	47,50±2,89(47,5)	47,95±2,70(48)	-0,936	0,349
	Left	47,40±5,64(48)	49,35±6,40(49)	-2,917	**0,004**	49,55±3,33(49)	51,60±3,19(51,5)	-3,570	**<0,001**	47,55±4,63(49)	47,95±2,98(48)	-0,070	0,944
Hip Internal Rotation	**Right**	36,55±2,78(36,5)	37,40±4,31(37)	-1,517	0,129	34,80±3,87(35)	35,70±4,21(36)	-1,867	0,062	35,45±4,06(35)	35,25±2,00(35,5)	-0,634	0,526
	Left	37,15±4,12(36)	38,10±4,59(37,5	-2,175	0,030	34,45±3,97(35)	35,25±4,17(35,5	-1,978	0,048	35,00±2,15(35)	34,70±2,15(35)	-0,914	0,361
Lumbar Flexion		56,25±3,39	60,45±4,59	-3,439	**<0,001**	71,70±5,05(71)	73,70±4,82(75)	-2,803	**0,005**	68,90±4,67(70)	69,05±4,77(69,5)	-0,310	0,757
Lumbar Extension		39,80±4,05	42,90±3,19	-3,619	**<0,001**	24,35±3,45(24)	27,40±4,38(27)	-3,853	**<0,001**	25,65±3,91(24,5)	26,00±3,16(25)	-1,059	0,289
Lumbar Lateral Flexion	**Right**	32,45±2,96	34,60±2,37	-3,223	**<0,001**	29,55±3,65(30)	30,95±3,76(32)	-3,646	**<0,001**	24,15±2,13(24)	24,95±2,52(25)	-2,527	0,011
	Left	33,25±2,36	34,85±3,36	-2,128	0,033	30,30±3,93(32)	31,95±4,05(32,5)	-3,410	**<0,001**	25,05±2,33(25)	26,10±2,69(25)	-2,747	0,006
T - Test (Seconds)		9,66±0,43	9,25±0,53	-3,884	**<0,001**	9,09±0,59(9)	9,33±0,58(9,2)	-3,773	**<0,001**	9,00±0,81(8,7)	9,06±0,85(9)	-1,270	0,204
10 Meter Sprint (Seconds)		2,04±0,15	1,92±0,14	-3,684	**<0,001**	1,92±0,13(1,9)	2,07±0,12(2,1)	-3,885	**<0,001**	1,99±0,10(2)	2,00±0,11(2)	-0,205	0,837
Vertical Jump (cm)		57,40±6,99	54,85±5,69	-1,419	0,156	36,35±7,36(37)	37,65±7,88(37,5)	-2,252	0,024	40,70±5,59(40)	42,20±5,68(42)	-3,168	0,002
Horizontal Jump (cm)		199,80±15,59	204,65±16,90	-2,223	0,026	206,35±19,04(202,5)	215,80±19,05(212)	-3,929	**<0,001**	206,22±6,83(204,5)	209,60±6,93(210,5)	-2,771	0,006

Table 3. Comparison of Differences Between Groups

Difference Analysis		Mean ± St. Dev.	Median	KW	P
Hip Flexion (Right)	**Manipulation Group**	1,35±4,28	2	5,097	0,078
	Mobilization Group	1,80±2,44	2		
	Control Group	0,25±1,74	1		
Hip Flexion (Left)	**Manipulation Group**	0,40±4,33	1,5	2,721	0,256
	Mobilization Group	1,35±2,74	2		
	Control Group	0,15±2,35	0		
Hip Extension (Right)	**Manipulation Group**	0,60±2,70	1	0,781	0,677
	Mobilization Group	0,55±1,73	1		
	Control Group	0,25±1,45	0		
Hip Extension (Left)	**Manipulation Group**	1,25±2,59	1	7,768	**0,021**
	Mobilization Group	0,95±2,01	1		
	Control Group	-0,50±1,79	0		
Hip Abduction (Right)	**Manipulation Group**	-0,75±2,95	-0,5	10,349	**0,005**
	Mobilization Group	1,50±2,01	2		
	Control Group	0,30±1,26	1		
Hip Abduction (Left)	**Manipulation Group**	0,90±2,86	1,5	3,380	0,185
	Mobilization Group	1,25±1,52	1,5		
	Control Group	0,10±1,94	0		
Hip Adduction (Right)	**Manipulation Group**	0,15±1,31	0	2,705	0,259
	Mobilization Group	0,85±1,63	1		
	Control Group	-0,20±2,04	0		
Hip Adduction (Left)	**Manipulation Group**	0,15±1,35	0	3,171	0,205
	Mobilization Group	0,75±2,20	1		
	Control Group	-0,35±2,30	-0,5		
Hip External Rotation (Right)	**Manipulation Group**	2,25±2,65	2	7,012	**0,030**
	Mobilization Group	2,05±1,43	2		
	Control Group	0,45±1,96	1		
Hip External Rotation (Left)	**Manipulation Group**	1,95±2,78	2	10,411	**0,005**
	Mobilization Group	2,05±1,50	2		
	Control Group	0,40±3,56	0		
Hip Internal Rotation (Right)	**Manipulation Group**	0,85±2,54	1	1,532	0,465
	Mobilization Group	0,90±2,05	1		
	Control Group	-0,20±3,17	0,5		
Hip Internal Rotation (Left)	**Manipulation Group**	0,95±1,79	0	5,771	0,056
	Mobilization Group	0,80±1,74	0,5		
	Control Group	-0,30±1,56	0		
Lumbar Flexion	**Manipulation Group**	4,20±3,62	4,5	16,996	**<0,001**
	Mobilization Group	2,00±2,45	2		
	Control Group	0,15±1,95	0		
Lumbar Extension	**Manipulation Group**	3,10±2,34	3	22,864	**<0,001**
	Mobilization Group	3,05±2,39	3		
	Control Group	0,35±1,53	1		
Lumbar Lateral Flexion (Right)	**Manipulation Group**	2,15±2,23	2	5,798	0,055
	Mobilization Group	1,40±0,94	2		
	Control Group	0,80±1,32	1		
Lumbar Lateral Flexion (Left)	**Manipulation Group**	1,60±3,00	3	3,635	0,162
	Mobilization Group	1,65±1,35	2		
	Control Group	1,05±1,32	1		
T-Test (Seconds)	**Manipulation Group**	-0,41±0,30	-0,4	40,075	**<0,001**
	Mobilization Group	0,25±0,13	0,2		
	Control Group	0,07±0,19	0		
10 Meter Sprint (Seconds)	**Manipulation Group**	-0,12±0,09	-0,1	38,593	**<0,001**
	Mobilization Group	0,15±0,10	0,1		
	Control Group	0,00±0,08	0		
Vertical Jump (cm)	**Manipulation Group**	-2,55±6,50	-2,5	6,521	**0,038**
	Mobilization Group	1,30±2,43	1,5		
	Control Group	1,50±1,47	2		
Horizontal Jump (cm)	**Manipulation Group**	4,85±8,80	4,5	14,897	**<0,001**
	Mobilization Group	9,45±3,39	10		
	Control Group	3,38±4,48	3		

Kruskal Wallis Test, *p<0.05.

Table 4. Post – hoc Analysis

Post – hoc Analysis		Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Hip Abduction (Right)	**Control – Manipulation Group**	-5,150	5,463	-,943	,346	1,000
	Control – Mobilization Group	11,975	5,463	2,192	0,28	,085
	Manipulation – Mobilization Group	-17,125	5,463	-3,135	,002	,005
Hip Extension (Left)	**Control – Manipulation Group**	14,350	5,435	2,640	,008	,025
	Control – Mobilization Group	11,375	5,435	2,093	0,36	,109
	Manipulation – Mobilization Group	2,975	5,435	,547	,584	1,000
Hip External Rotation (Right)	**Control – Manipulation Group**	11,700	5,420	2,159	0,31	,093
	Control – Mobilization Group	13,050	5,420	2,408	,016	,048
	Manipulation – Mobilization Group	-1,350	5,420	-,249	,803	1,000
Hip External Rotation (Left)	**Control – Manipulation Group**	13,775	5,455	2,525	,012	,035
	Control – Mobilization-Group	16,375	5,455	3,002	,003	,008
	Manipulation – Mobilization Group	-2,600	5,455	-,477	,634	1,000
Lumbar Flexion	**Control – Manipulation Group**	22,625	5,494	4,118	<,001	,000
	Control – Mobilization Group	12,250	5,494	2,230	,026	,077
	Manipulation – Mobilization Group	10,375	5,494	1,888	,059	,177
Lumbar Extension	**Control – Manipulation Group**	23,525	5,450	4,316	<,001	,000
	Control – Mobilization Group	21,475	5,450	3,940	<,001	,000
	Manipulation – Mobilization Group	2,050	5,450	,376	,707	1,000
T – Test (sec.)	**Control – Manipulation Group**	-22,324	5,521	-4,044	<,001	,000
	Control – Mobilization Group	12,125	5,521	2,196	0,28	,084
	Manipulation – Mobilization Group	-34,450	5,521	-6,240	<,001	,000
10 meter sprint (sec.)	**Control – Manipulation Group**	-15,575	5,519	-2,858	,004	,013
	Control – Mobilization Group	18,475	5,519	3,348	<,001	,002
	Manipulation – Mobilization Group	-34,250	5,519	-6,206	<,001	,002

When we made an intra-group comparison, we found a statistically significant difference in the manipulation group: right hip external rotation (p=0.002), left hip external rotation (p=0.004), lumbar flexion (p<0.001), lumbar extension (p<0.001), right lumbar lateral flexion (p<0.001), T-test (p<0.001), 10-meter sprint test. In the mobilization group, left hip abduction (p=0.005), right hip external rotation (p=0.004), lumbar flexion (p=0.005), lumbar extension (p<0.001), right lumbar lateral flexion (p<0.001) were statistically different. A statistically significant difference was found between left lumbar lateral flexion (p<0.001), T-test (p<0.001), 10-meter sprint (p<0.001), and horizontal jump (p<0.001) tests.

When the difference between the groups is analyzed, the left hip extension values of the manipulation and mobilization groups increased after the test, while the control group showed a decrease (p=0.021). According to the post-hoc analysis, the difference is due to the control group patients. The right hip abduction values of the control and mobilization groups increased after the test, while the manipulation group showed a decrease (p=0,005). According to the post-hoc analysis, a significant difference was found between all groups. When right hip external rotation was analyzed, post-test values of all groups increased compared to pre-test values, and the highest increase belonged to the manipulation group (p=0.03). According to the post-hoc analysis, the difference was due to the control group. When the external rotation of the left hip was examined, the post-test values of all groups increased compared to the pre-test values, and the highest increase belonged to the mobilization group (p=0,005). According to the post-hoc analysis, the difference was due to the control group. In lumbar flexion measurements, the post-test values of all groups increased compared to the pre-test values, and the highest increase was in the manipulation group (p=0,005). According to the post-hoc analysis, a difference was found between all groups. When the lumbar extension measurements were analyzed, the post-test values of all groups increased compared to the pre-test values, and the highest increase belonged to the manipulation group (p=0.005). According to the post-hoc analysis, the difference was due to the control group (Table 3).

When the 10-meter sprint, T-test, and vertical jump values were analyzed for the difference between groups, it was observed that the post-test values of the mobilization and control groups increased compared to the pre-test values. In contrast, a decrease was observed in the manipulation group (p<0,001). According to the post-hoc analysis, the difference is due to the manipulation group. When the 10-meter sprint measurements were examined, the post-test values of the mobilization and control groups increased compared to the pre-test values, while a decrease was observed in the manipulation group. The highest increase belongs to the mobilization group (p<0.001). According to the post-hoc analysis, the difference is due to the manipulation group. Looking at the vertical jump measurements, the post-test values of the mobilization and control groups increased compared to the pre-test values, while a decrease was observed in the manipulation group. The highest increase belongs to the mobilization group (p<0.038). According to the post-hoc analysis, the difference is due to the manipulation group. In horizontal jump measurements, post-test values of all groups increased compared to pre-test values. The highest increase belongs to the mobilization group (p<0,001). According to the post-hoc analysis, the difference was due to mobilization (Table 4).

DISCUSSION

The quadriceps femoris muscle receives its innervation from the L2, L3, and L4 spinal segments, and the femoral nerve is formed by the nerves arising from these segments. L3 is defined as the main feeder of the quadriceps femoris muscle. Sanders et al. investigated the effect of spinal manipulation applied to the L2-S1 segments on the isokinetic strength of the knee extensors and flexors in a study conducted on 21 asymptomatic participants in 2015. Although spinal manipulation was shown to increase isokinetic strength, these findings did not gain statistical value [20]. Pollard and Ward showed that spinal manipulation of the L3-L4 segment caused a short-term increase in the strength of the quadriceps femoris muscle in their study on 30 individuals between 18 and 34 [21]. Grindstaff et al. compared the effect of lumbopelvic manipulation on the activation of the quadriceps femoris muscle in 42 healthy individuals and showed that the strength of the quadriceps femoris muscle increased by 3% and activation by 5% in the manipulation group[21]. Ahn et al. investigated the effect of grade III-IV spinal mobilization and TENS (Transcutaneous Electrical Stimulation) treatments applied to the L2-L3 segment on muscle strength and proprioception in their study on 26 professional volleyball players with chronic knee pain. They reported that proprioception was significantly improved only during knee extension in the LJM group, and the difference in knee extension between the groups was also significant[22].

Spinal manipulation therapy is thought to regulate the abnormal input to the central nervous system and the processing of this abnormal input, thus ensuring the biomechanical and neural integrity of the joint complex. Another theory is that it regulates afferent information with the bombardment that occurs in mechanoreceptors after manipulation, according to Korr's stimulated segment theory.[23] To measure the effect of spinal manipulation on the cortical system and maximum voluntary contraction, Niazi et al. conducted a study with healthy individuals in 2014. They observed that the H-reflex and maximum voluntary contraction strength increased. They reported that spinal manipulation increases motor neuron excitability by stimulating low-threshold 1a afferent fibers[24]. Perry and Green showed that spinal mobilization applied to the L4-L5 segment caused changes in the peripheral nervous system in 45 healthy individuals. According to this study, spinal mobilization stimulates the dorsal periaqueductal region and the sympathetic nervous system, causing an increase in motor facilitation[25]. We expected to see the rise in sportive performance by affecting the sympathetic and central nervous system and increasing motor neuron excitability.

Team sports such as volleyball and basketball involve a lot of running, sprinting, changing direction, and jumping. The strength of the quadriceps femoris and hamstring muscles is vital for athlete efficiency and injury prevention.[26] In addition, volleyball players are exposed to much more tendon loading in simple positioning and jumping than in other sports[27]. Vertical jumps involve 49% of the knee, 28% of the hip, and 23% of the ankle involved[28]. Tsiokanos et al., in their study on 32 healthy men, measured the effect of hip extensors, knee extensors, and ankle plantar flexors on vertical jump and reported that hip and knee extensors positively affected jump values[29]. However, there was no correlation between isokinetic knee strength and sprint and T-Test values[30]. Likewise, Cronin and Hansen reported that knee extensor strength did not correlate with sprint performance in their study conducted on 26 rugby players in 2005[31]. On the other hand, Dowson et al., in their study, showed that eccentric and concentric knee extension strength had a statistically significant effect on 0-15 meters and 30-35 meters sprint measurements[32]. Olson et al. measured the impact of lumbar spinal manipulation at the L3 level on sprint performance and hip flexibility in 12 asymptomatic cyclists. Still, they did not observe an increase in hip flexion or sprint performanceç[33]. Previous studies on spinal manipulation have shown that lumbar spinal manipulation increases hip ROM.[34] Sandell et al. applied non-specific lumbar spinal manipulation to male runners aged between 17 and 20 years and observed an increase in hip extension[35]. Villers et al. applied lumbar facet mobilization at the L4 - L5 level to 33 participants and observed an increase in the range of motion in the segments affected by the hamstring muscle[36]. Szlezak et al. applied grade III posterior-anterior spinal mobilization to the lumbar facet joints unilaterally at a frequency of 2 Hz with 36 healthy participants and observed an increase in the straight leg raising test[37]. Vieira-Pellenz et al. evaluated the short-term effects of spinal manipulation on pain perception, spinal mobility, and height between two vertebrae in male patients with degenerative disc disease. Hip flexion and lumbar flexion increased during the passive straight leg raising test[38]. Pollard and Ward compared the effect of cervical manipulation and lumbar spinal manipulation on hip flexion range of motion. They reported that cervical manipulation increased hip flexion while no effect was observed in the lumbar manipulation group[39]. In our study, we observed an increase in hip flexion, abduction, and external rotation after spinal mobilization application, as there are examples in the literature. In addition, we observed an increase in hip external rotation after spinal manipulation application. As a result of mobilization applied at the L3 level, we observed an increase in the range of motion of these joints due to the activation of the quadriceps femoris muscle, whose primary function is to assist knee extension and secondary function is to assist hip external rotation. Still, we could not determine the reason for the difference between mobilization and manipulation. Since this study was performed in healthy individuals, we believe further studies in individuals with external rotation, abduction, and flexion limitations may give us information about this issue.

Deutschmann et al. divided 40 asymptomatic soccer players into four groups. They applied spinal lumbar manipulation to one group, sacroiliac manipulation to another group, sacroiliac, and lumbar manipulation to another group, and sham manipulation to the last group. Compared to the control group, it was observed that right and left rotation increased significantly in the lumbar manipulation group. The combination of these two techniques increased lumbar extension and right rotation. There was no flexion and lateral flexion increase in the lumbar spinal manipulation group.[40] In their literature review, Millan et al. reported that cervical manipulation momentarily increased spinal range of motion, but lumbar manipulation did not increase spinal range of motion[41]. Griffiths et al. investigated the immediate effect of thoracolumbar spinal manipulation on a range of motion in this region in 21 asymptomatic individuals. They observed an increase in the range of motion in the spinal manipulation group compared to the control and sham manipulation group[42]. In his 2015 study, Wiggett investigated the effect of cervical, lumbar, and thoracic manipulation applied to 40 ice hockey players on ice hockey puck striking speed and range of motion in the spine and observed an increase in lumbar extension and lateral flexion in the manipulation group[43]. We found significant differences in parameters other than left lumbar lateral flexion.

Stamos-Papastamos investigated the effect of lumbar manipulation and posteroanterior mobilization on the lumbar range of motion. They found no statistical significance in the lumbar range of motion in both manipulation and mobilization groups[44]. Shum et al. investigated the effect of posteroanterior grade III spinal mobilization at the L4 level on the lumbar range of motion in 19 individuals with chronic low back pain. They observed an increase in lumbar extension and flexion[45]. Chesterton et al. investigated the effect of unilateral and central posteroanterior spinal mobilization applied at the L4 - L5 level on the lumbar range of motion in 20 healthy participants. While an increase in lumbar range of motion was observed in both groups, the increase was more significant in the unilateral spinal mobilization group[46]. Sato et al. measured the immediate effect of segmental lumbar mobilization on lumbar range of motion with the help of radiography in a study with ten healthy individuals and showed that mobilization applied to the L3 - L4 segment increased lumbar range of motion. In contrast, no increase was observed in other segments[47]. Fiaad et al. conducted a study with 45 participants to investigate the effects of spinal manipulation, mobilization, and exercise on lumbar range of motion and other parameters and divided the participants into three groups. The first group received only exercise therapy, the second group received spinal manipulation and exercise therapy, and the third group received spinal mobilization and exercise therapy. It was observed that spinal manipulation applied to the L4-L5 region was superior to other groups in increasing the lumbar range of motion[48]. As examples in the literature, we observed that the posteroanterior spinal mobilization applied in our study caused an increase in lumbar flexion, extension, and lateral flexion. Although we did not perform any application in the control group, athletes were asked to exhibit maximum performance while evaluating healthy individuals. For this reason, there may be a significant difference in the measurements in the control group before and after. This difference is related to the motivation level of the athletes. Pollard and Ward observed that spinal manipulation applied at the L3-L4 level increased the strength of the quadriceps femoris muscle and other knee extensors in 30 asymptomatic individuals[49]. Laura and Mouch aimed to measure the values of chiropractic treatment, especially spinal manipulation, in a test battery consisting of 11 physical tests used to evaluate agility, balance, kinesthetic perception, strength, and reaction speed of asymptomatic athletes. They divided the athletes into two groups manipulation and control groups. In the manipulation group, a 6.12% improvement in the total test score was observed in the control group[50]. Muller investigated the effect of lumbar spinal manipulation on 40-meter sprint speed, agility, and vertical jump in 20 female ice hockey players and observed agility, sprint speed, and vertical jump in the manipulation group[51]. Alvarenga et al. investigated the effect of spinal manipulation on bilateral asymmetry, squat, and jump in a study of 13 asymptomatic athletes and showed that spinal manipulation affected asymmetry but not jump and squat[52]. Sandell et al. applied sacroiliac manipulation to 17 running athletes aged between 17 and 20 years and observed an increase in hip extension. It was stated that this may increase the running performance of runners[53]. As seen in the literature, we observed that the lumbar spinal manipulation applied in our study increased agility and 10-meter sprint speed but had no effect on vertical and horizontal jumping.

Alhashel et al. investigated the effect of Mulligan SNAG (Sustained Natural Apophyseal Glide) mobilization technique on vertical jump at lower lumbar levels in 18 healthy participants. They reported an increase in vertical jump in the mobilization group[54]. Chi-ngai et al. investigated the effect of mobilization applied to the L2 - L3 level on hip flexor strength and torque in 24 healthy participants. They showed that spinal mobilization applied to this region led to an increase in hip flexor muscle strength and torque[55].

Costa et al. compared the effect of static stretching and spinal manipulative therapy on the performance of golf athletes in 43 healthy golf athletes in their 2009 study and found that the spinal manipulation group was more advanced in performance[56]. Powers et al. investigated the effect of posteroanterior spinal mobilization and press-up exercise on lumbar extension and pain in 30 healthy individuals. They found that there was a decrease in pain and an increase in spinal extension in both groups but no statistical difference between them[57]. Corne divided 30 asymptomatic athletes into three groups; the first group received lumbar and spinal manipulation, the second group received only lower extremity manipulation, and the third group received lumbar spinal manipulation, pelvis and lower extremity manipulations and compared their effects on agility. There was an increase in agility parameters in all three groups, but the highest increase was realized in the third group with 1.86 seconds[58]. Thomas et al. applied spinal manipulation to 38 soccer players with an average age of 17 years to increase the strength of the lower extremities. They observed an increase in vertical jump, hand grip strength, and postural control in soccer players who received cervical and lumbosacral manipulation[59]. Lin and Piong showed that chiropractic practitioners increased the athletic performance of athletes using spinal manipulation and mobilization techniques, improved biomechanical athletic abilities, decreased risk of injury, and increased recovery speed in athletes receiving chiropractic treatment[60].

As a result of our measurements, the manipulation application was superior to both the mobilization application and the control group in the parameters of left hip extension, right hip external rotation, lumbar flexion, lumbar extension, T-Test (seconds), 10-meter sprint (seconds). In addition, mobilization treatments were superior to those of the control group. When the right hip abduction, left hip external rotation, and vertical and horizontal jump (cm) parameters were examined, the mobilization treatment was superior to both the manipulation and the control group.

When we compared the manipulation group with the control group, data were obtained in favor of manipulation in right hip abduction. They left hip external rotation, while results were obtained in favor of the control group in vertical and horizontal jumps. When we look at the literature, both manipulation and mobilization methods contribute to athletes. However, results similar or not similar to the literature were obtained in different parameters. In our study, subjects were evaluated using 20 different parameters. No superiority was observed when manipulation and mobilization applications were compared in ten different parameters. Only six parameters (hip extension (right), hip external rotation (right), lumbar flexion, extension, T-Test and 10 meter sprint) showed superiority in manipulation and four parameters (hip abduction (right), hip external rotation (left), vertical and horizontal jump) showed superiority in mobilization. We believe that manipulation and mobilization applied to the L3 segment in volleyball athletes may positively affect sports.

The strengths of our study are that the subjects participating in the survey were professional athletes; the groups were randomized by simple random sampling method; the groups were homogeneous since there was no statistically significant difference in the comparison of T0 data between the groups when age, height, hip flexion, hip abduction, hip adduction, hip adduction, hip external rotation, right hip internal rotation, horizontal jump parameters were examined; as a result of the literature review, the number of studies comparing manipulation and mobilization techniques in terms of sport is small. One of the weaknesses of our study is that the immediate effects of manipulation and mobilization applications were examined, and all of the participants were male.

CONCLUSION

The immediate effect of this application was examined, but the positive impact of manipulation and mobilization may be beneficial for athletes when applied before the competition and between halves. It is recommended that the study be conducted using longer application protocols, on different sports branches, on different age groups, on women, using various evaluation methods, and using different manipulation or mobilization concepts.

Conflicts of interest

The authors declare that they have no financial conflicts of interest regarding the topics included in the text.

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Authors' contributions

Conceptualization: [ICB, SHH, EBA]; Design: [ICB, SHH, EBA]; Writing: [ICB, SHH]; Investigation/Data collection: [ICB, SHH]

REFERENCES

1. Kılıç, Ö., Maas, M., Verhagen, E., Zwerver, J., & Gouutebarge, V. (2017). Incidence, aetiology and prevention of musculoskeletal injuries in volleyball: A systematic review of the literature. European Journal of Sport Science, 17(6), 765-793.
2. Valenzuela, P. L., Pancorbo, S., Lucia, A., & Germain, F. (2019). Spinal Manipulative Therapy Effects in Autonomic Regulation and Exercise Performance in Recreational Healthy Athletes A Randomized Controlled Trial. Spine (Phila Pa 1976), 44(9), 609-614.
3. Botelho, M. B., Alvarenga, B. A., Molina, N., Ribas, M., & Baptista, A. F. (2017). Spinal Manipulative Therapy and Sports Performance Enhancement: A Systematic Review. Journal of Manipulative and Physiological Therapeutics, 40(7), 535-543.
4. Smith, D. L. (2001). Biodynamic performance and strength through chiropractic. ICA Review, 57(1), 39-42.
5. Kelsick, W. E. (2003). The pre-participation examination. Canadian Chiropractor, 8(5), 33.
6. Miners, A. L. (2010). Chiropractic treatment and the enhancement of sport performance: a narrative literature review. The Journal of the Canadian Chiropractic Association, 54(4), 210-221.
7. Thomas, E., Petrucci, M., Barretti, M., Messina, G., Cavallaro, A. R., & Bianco, A. (2022). Effects of osteopathic manipulative treatment of the pivots on lower limb function in young professional football players. Journal of Bodywork and Movement Therapies, 32, 1-6.
8. Çimenli, Ö., Koç, H., Çimenli, F., & Kaçoğlu, C. (2016). Effect on an eight-week pylometric training on different surfaces on the jumping. Journal of Physical Education and Sport, 16(1), 162-169
9. Pauole, K., Madole, K., Garhammer, J., Lacourse, M., & Rozenek, R. (2000). Reliability and Validity of the T-Test as a Measure of Agility, Leg Power and Leg Speed in College-Aged Men and Women. Journal of Strength and Conditioning Research, 14(4), 443-450.
10. Fatouros, I. G., Jamurtas, A. Z., Leontsini, D., Taxildaris, K., Aggelousis, N., Kostopoulos, N., & Buckenmeyer, P. (2000). Evaluation of Pylometric Exercise Training, Weight Training and Their Combination on Vertical Jumping Performance and Leg Strength. Journal of Strength and Conditioning Research, 14(4), 470-476.
11. Johnson, T. E., Brown, L. E., Coburn, J. W., Judelson, D. A., & Khamoui, T. T. (2010). Effect of Four Different Starting Stances on Sprint Time in Collegiate Volleyball Players. Journal of Strength and Conditioning Research, 24(10), 2641-2646.
12. Otman, S., & Köse, N. (2016). Tedavi Hareketlerinde Temel Değerlendirme Prensipleri. Ankara: Hipokrat Kitapevi.
13. Pickar, J. G. (2002). Neurophysological effects of spinal manipulation. The Spine Journal, 2(5), 357-371.
14. Kültür, T., Çiftçi, A., Okumuş, M., Doğan, M., Arıkan Durmaz, Ş., Neşelioğlu, S., & Erel, Ö. (2020).

Evaluation of the effect of chiropractic manipulative treatment on oxidative stress in sacroiliac joint dysfunction. Turkish journal of physical medicine and rehabilitation, 66(2), 176–183.

15. Funabashi, M., Nougarou, F., Descarreux, M., Prasad, N., & Kawchuk, G. N. (2016). Lower Limb Neuromuscular Asymmetry in Volleyball and Basketball Players. Journal of Human Kinetics, 42(9), 635-643.
16. Gelalis, K. G., Xenakis, T., Gioftsos, G., Dimitriadis, Z., & Sakellari, V. (2017). Spinal mobilization vs conventional physiotherapy in the management of chronic low pack pain due to spinal disc degeneration. Journal of Manual Manipulative Therapy, 25(2), 66-73.
17. Hanrahan, S., Van Lunen, B. L., Tamburello, M., & Walker, M. L. (2005). The Short-Term Effects of Joint Mobilizations on Acute Mechanical Low Back Dysfunction in Collegiate Athletes. Journal of athletic training, 40(2), 88–93.
18. Turki, O., Dhahbi, W., Padulo, J., Khalifa, R., Ridene, S., Alamr, K., . . . Chamari, K. (2019). Warm-Up With Dynamic Stretching: Positive Effects on Match-Measured Change of Direction Performance in Young Elite Volleyball Players. International Journal of Sports Physiology and Performance, 15(4), 528-533.
19. Dalrympe, K. J., Davis, S. E., Dwyer, G. B., & Moir, G. (2010). Effect of Static and Dynamic Stretching on Vertical Jump Performance in Collegiate Women Volleyball Players. Journal of Strength and Conditioning Research, 24(1), 149-155.
20. Sanders, G. D., Nitz, A. J., Abel, M. G., Symons, T. B., Shapiro, R., Black, W. S., & Yates, J. W. (2015). Effects of Lumbosacral Manipulation on Isokinetic Strength of the Knee Extensors and Flexors in Healthy Subjects: A Randomized, Controlled, Single-Blind Crossover Trial. Journal of Chiropractic Medicine, 240-248.
21. Pollard, H. P., & Ward, G. (1996). Strength change of quadriceps femoris following a single manipulation of the L3/4 vertebral motion segment. Journal of Manipulative & Physiological Therapeutics, 21(9), 611-616.
22. Ahn, I., & An, H. (2021). Effects of Lumbar Mobilization and Transcutaneous Electrical Nerve Stimulation on Proprioception and Muscular Strength in Volleyball Players with Chronic Knee Pain. Journal of International Academy of Physical Therapy Research, 12(1), 2279-2285.
23. Pickar, J. G., & Bolton, P. S. (2012). Spinal manpulative therapy and somatosensory activation. Journal of Electromyography and Kinesiology, 22(5), 787-794.
24. Niazi, I. K., Türker, K. S., Flavel, S., Kinget, M., Duehr, J., & Haavik, H. (2015). Changes in H-reflex and V-waves following spinal manipulation. Experimental Brain Research, 233(4), 1165-1173.
25. Perry, J., & Green, A. (2008). An investigation into the effects of a unilaterally applied lumbar mobilisation technique on preipheral sympathetic nervous system activity in the lower limbs. Manual Therapy, 13(6), 492-499.
26. Dervisevic, E., & Hadzic, V. (2012). Quadriceps and hamstring strength in team sports: Basketball, football and volleyball. Isokinetics and Exercise Science, 20(4), 293-300.
27. Magalhaez, J., Oliviera, J., Ascensao, A., & Soares, J. (2004). Concentric quadriceps and hamstrings isokinetic strength in volleyball and soccer players. The Journal of Sports Medicine and Physical Fitness, 44, 119-125.
28. Schons, P., Da Rosa, R., Fischer, G., Berriel, G. P., Fritsch, C. G., Nakamura, F. Y., . . . Peyre-Tartaruga, L. A. (2018). The relationship between strength asymmetries and jumping performance in professional volleyball players. Sports Biomechanics, 18(6), 515-526.
29. Tsiokanos, A., Kellis, E., Jamurtas, A., & Kellis, S. (2002). The relationship between jumping performance and isokinetic strength of hip and knee extensors and ankle plantar flexors. Isokinetics and Science, 10, 107-115.
30. Yapıcı, A. (2016). Evaluation of the relationship between isokinetic strength and field performance in professional male volleyball players. European Journal of Physical Education and Science, 2(6), 15-20.
31. Cronin, B., & Hansen, T. (2005). Strength and power predictors of sports speed. The Journal of Strength & Condititoning Research, 19(2), 349-357.
32. Dowson, M. N., Nevill, M. E., Lakomy, H. K., Nevill, A. M., & Hazeldine, R. J. (1998). odelling the relationship between isokinetic muscle strength and sprint running performance. Journal of Sports Science, 16, 257-265.
33. Olson, E., Bodziony, M., Ward, J., Coats, J., Koby, B., & Goehry, D. (2014). Effect of Lumbar Spine Manipulation on Asymptomatic Cyclist Sprint Performance and Hip Flexibility. Journal of Chiropractic Medicine, 13(4), 230-238.
34. Ganer, N. (2015). Effect of Thoracic Spinal Manipulation on Lower Limb Neurodynamics in Healthy Young

Adult: Neural Link to Regional Interdependence. International Journal of Health Sciences and Research, 10(5), 157-164.

35. Sandell, J., Palmgren, P. J., & Björndahl, L. (2008). Effect of chiropractic treatment on hip extension ability and running velocity among young male running athletes. Journal of Chiropractic Medicine, 7(2), 39-47.
36. Villers, J., Cardenas, A., Gipson, T., & Man, E. (2022). The immediate effect of adding lumbar mobilization to a static stretching program on hamstring range of motion: an exploratory study. Journal of Sports Science and Medicine, 21(2), 253-259.
37. Szlezak, A. M., Georgilopoulos, P., Bullock-Saxton, J. E., & Steele, M. C. (2011). The immediate effect of unilateral Z-joint mobilisation on posterior chain dynamics: a randomized controlled study. Manual Therapy, 16(6), 609-613.
38. Vieria-Pellenz, F., Oliva-Pascual-Vaca, A., Rodriguez-Blanoco, C., Heredia-Rizo, A., Ricard, F., & Almazan-Campos, G. (2014). Short-Term Effect of Spinal Manipulation on Pain Perception, Spinal Mobility and Full Height Recovery in Male Subjects with Dejenerative Disc Disease: A Randomized Controlled Trial. Archives of Physical Medicine and Rehabilitation, 95(9), 1613-1619.
39. Pollard, H. P., & Ward, G. (1998). The effect of upper cervical or sacroiliac manipulation on hip flexion range of motion. Journal of Manipulative & Physiological Therapeutics, 21(9), 611-616.
40. Deutschmann, K. C., Jones, A. D., & Korporaal, C. M. (2015). A non-randomised experimental feasibility study into the immediate effect of three different spinal manipulative protocols on kicking speed performance in soccer players. Chiropractic & Manual Therapies, 23(1), 1.
41. Millan, M., Lebouf-Yde, C., Budgell, B., Descarreux, M., & Amorim, M. (2012). The effect of spinal manipulative therapy on spinal range of motion: a systematic literature review. Chiropractic & Manual Therapies, 20(1), 23.
42. Griffths, F. S., McSweeney, T., & Edwards, D. J. (2019). Immediate effects and associations between interoceptive accuracy and range of motion after a HVLA thrust on the thoracolumbar junction: A randomised controlled trial. Journal of Bodywork and Movement Therapies, 23(4), 818-824.
43. Wiggett, M. (2015). The immediate effect of spinal manipulative therapy on drag flicking performance of field hockey players. DUT Open Scholar.
44. Stamos-Papastomos, N., Petty, N., & Williams, J. M. (2011). Changes in bending stiffness and lumbar spine range of movement following lumbar mobilization and manipulation. Journal of Manipulative and Physiological Therapy, 34(1), 46-53.
45. Shum, G. L., Tsung, B. Y., & Lee, R. Y. (2013). The immediate effect of posteroanterior mobilization on reducing back pain and the stiffness of the lumbar spine. Archives of Physical Medicine and Rehabilitation, 94(4), 673-679.
46. Chesterton, P., Payton, S., & McLaren, S. (2018). Acute effects of centrally- and unilaterally- applied posterior-anterior mobilizations of the lumbar spine on lumbar range of motion, hamstring extensibility and muscle activation. Journal of Back and Musculoskeletal Rehabilitation, 1, 1-11.
47. Sato, T., Koumori, K., & Uchiyama, P. T. (2012). Preliminary Study of the Immediate Effect of Spinal Segmental Mobilization on Improve Lumbar Range of Motion. Journal of Physical Therapy Science, 24(5), 431-434.
48. Fiaad, M. N., Elsayed, W. H., NassifTakla, M. K., & Zawahry, A. M. (2020). Effect on mulligan mobilization versus spinal manipulation on management of non-spesific low back pain. Journal of Advance Pharmacy Education & Research, 10(1), 70-75.
49. Pollard, H. P., & Ward, G. (1996). Strength change of quadriceps femoris following a single manipulation of the L3/4 vertebral motion segment. Journal of Manipulative & Physiological Therapeutics, 21(9), 611-616.
50. Lauro, A., & Mouch, B. (1991). Chiropractic effects on athletic ability. Journal of Chiropractic Research and Clinical Investigation, 6(4), 84-87.
51. Muller, A. (2021). The immediate effect of lumbar spinal manipulative therapy on performance in female field hockey players.
52. Alvarenga, B., Botelho, M., Lara, J., Joao, F., & Veloso, A. (2019). Preliminary Feasibility Study to Measure the Immediate Changes of Bilateral Asymmetry After Lumbar Spinal Manipulative Therapy in Asymptomatic AthleteS. Journal of Chiropractic Medicine, 18(3), 205-212.
53. Sandell, J., Palmgren, P. J., & Björndahl, L. (2008). Effect of chiropractic treatment on hip extension ability and running velocity among young male running athletes. Journal of Chiropractic Medicine, 7(2), 39-47.

54. Alhashel, A., Alamri, E., & Sparkes, V. (2018). Effects of the Mulligan sustained natural apophyseal glide (snag) mobilization on trunk muscle activity and vertical jump performance in healthy subjects. Orthopaedic Proceedings, 55, 101.
55. Chi-ngai, L., Thomas, C. T., & Chi-Kong, C. (2016). The Effect of Passive Lumbar Mobilization on Hip Flexor Strength-A Pilot Study. Indian Journal of Physiotherapy and Occupational Therapy, 10(2), 81-87.
56. Costa, S. M., Chibana, Y. E., Giavarotti, L., Compagnoni, D. S., Shiono, A. H., Satie, J. S., & Bracher, E. S. (2009). ffect of spinal manipulative therapy with stretching compared with stretching alone on full-swing performance of golf players: a randomized pilot trial. Journal of Chiropractic Medicine, 8, 165-170.
57. Powers, C. M., Beneck, G. J., Kulig, K., Landel, R., & Fredericson, M. (2008). Effects of a Single Session of Posterior-to-Anterior Spinal Mobilization and Press-up Exercise on Pain Response and Lumbar Spine Extension in People With Nonspecific Low Back Pain. Physical Therapy & Rehabilitation Journal, 88(4), 485-493.
58. Corne, L. (2016). The Effects of Lumbar Spine Manipulation Versus Lower Extremity Manipulation on Agility in Asymptomatic Athletes. Johannesburg: ProQuest Dissertations Publishing.
59. Thomas, E., Petrucci, M., Baretti, M., Messina, G., Cavallaro, A. R., & Bianco, A. (2022). Effects of osteopatic manipulative treatment of the pivots on lower limb function in young professional football players. Journal of Bodywork and Movement Therapies, 32, 1-6.
60. Lin, A. F., Piong, S. Z., Han, W. M., Li, P., Chu, V. K., Chun-Pu, E., & Chu, A. (2023). Unlocking Athletic Potential: The Integration of Chiropractic Care into the Sports Industry and Its Impact on the Performance and Health of Athletes and Economic Growth in China and Hong Kong. Cureus, 15(4).