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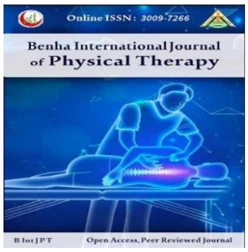

Original research

Assessment of motor control deficit and its association with shoulder proprioception in athletes with non-specific low back pain.

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Abstract:
Background: Athletes with low back pain (LBP) often face long-term functional limitations. Knowledge about the Discrepancy in motor control and proprioception between athletes with and without LBP is still lacking. **Purpose:** To compare Movement Control deficit (MCD), scapular upward rotation, and shoulder proprioception in elite swimmers with and without LBP and assess their correlation in athletes with CNSLBP. **Methods:** This cross-sectional observational study recruited active professional swimmers and was divided into two groups: Group A (N=40) with LBP lasting over 12 weeks, and Group B (N=40) without LBP. Both groups were assessed for MCD using tests with a Pressure Biofeedback Unit (PBU), scapular upward rotation and shoulder proprioception were assessed by bubble inclinometer. **Results:** Participants who had CNSLBP had significantly higher motor control deficits in all tests, greater upward rotation of the scapula at 120 abduction, and higher joint position error (JPE)($p<.001$). Correlation between MCD and upward rotation of scapula at 120 abductions, KLAT showed moderate positive significant correlations and PADT had moderate to strong negative significant correlations with dominant on both sides. **Conclusion:** Swimmers with CNSLBP had poorer motor control, with significant deficits in lumbar stability tests and increased JPE in shoulder rotations. Scapular upward rotation was significantly higher at 120° shoulder abduction in the CNSLBP group. Correlations showed that weaker core control affected scapular mechanics and proprioception, emphasizing the role of targeted exercises in improving stability.

Keywords: low Back Pain; Motor control deficit; Proprioception: Swimmer; scapular upward rotation.

Introduction

Worldwide, low back pain (LBP) is the majority prevalent musculoskeletal disorder. The global incidence of LBP reported in 2017 was 7.5%. It is the primary reason for reduced activity and work absence, and it has significant negative effects on the global socioeconomic system. Low back pain (LBP) is the preceding cause of years lived with disability (YLDs) internationally, necessitating immediate attention to address the growing burden on health and social systems[1]. Previous research showed that LBP patients experienced by athletes negatively affect their athletic performance and hence their overall quality of life. Conversely, athletes with low back pain (LBP) report less perceived disability and a smaller reduction in training volume compared to

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non-athletes. Different socialization experiences and pain management strategies among athletes can help identify potential underlying reasons[2].

Many athletes who suffer from low back pain (LBP) may face significant disability upon retiring from their sport. Hence, identifying modifiable risk factors is crucial for helping to reduce the prevalence of LBP in athletes. For example, those participating in sports that involve repetitive back rotation, like skiing and gymnastics, often have a high incidence of spondylolisthesis[3]. Research signals that the risk factors for low back pain in sports people are complicated, including the type of sport, cyclical stress, and training frequency. However, many of the recommended chance factors are derived from expert opinions, case studies, and unpublished clinical findings, leading to a lack of strong evidence connecting these factors to LBP in athletes[4].

A study revealed a positive correlation between LBP and factors such as previous LBP, and reduced lumbar flexion and extension in athletes. Additionally, moderate evidence suggests that hip flexor tightness and being overweight are also risk factors. However, there is insufficient evidence to establish a link between LBP and factors such as forward bending, past injuries, weekly training volume, years of activity, age, and gender in athletes

Dysfunctions in the lower part of the body could affect the function of the upper part of the body and similarly vice versa. Regions of the body are interconnected and may affect symptoms regardless of their proximity. The response to any dysfunction is not confined to the local or adjacent areas of the body; it can trigger a broader neuromusculoskeletal reaction. People with lower extremity weakness are more likely to experience shoulder overuse problems[4].

The sensorimotor system is crucial for the functional stability of the athletic shoulder joint, as it manages both static and dynamic elements of afferent proprioceptive information of joint position sense and efferent action of dynamic joint stabilizers[5]**.** Furthermore, sensorimotor systems manage the interaction between both active and passive stability elements to match the higher demand of functional activity of the athletic shoulder especially in overhead athletes. This important system works on sensory, motor, and higher integrating and processing elements of the central nervous system. It has been reported that shoulder pain is prevalent in youth swimmers (51%) and it may be affected by dry land worming up preventive activities[5], any shoulder injury doesn't affect the stability function of the shoulder as frequently reported in its static and dynamic components only but also affects how the sensorimotor system integrates and functions to mediate the overall shoulder pattern or higher performance in athletes. This intern may derive abnormal movement patterns which may be associated with either distal or proximal injury[6,7].

Repetitive motion, like that associated with swimming, can reduce the sensitivity of mechanoreceptors in spinal ligaments. These receptors commonly activate muscles through reflex pathways. Following repetitive motion, defensive muscle activation is reduced, usually for many hours after the exercise ends. Athletes may be more at risk of injury during this period[8]**.** Therefore, the prevention of LBP in competitive swimmers is important. Therefore, the aim of this study is two-fold :the first is to find the Discrepancies in Movement Control Dysfunction) MCD) and shoulder proprioception between Swimmers with and without LBP. The second is to assess the association between motor control test scores and shoulder proprioception in Swimmers with LBP.

Methods

This is a cross-section observational study that included active professional swimmers with and without LBP.

Sample Size calculation:

Using G*power software ver. 3.1.2 (Franz Faul, University of Kiel, Kiel, Germany), the sample size was calculated based on a power of 0.80 and an alpha level of 0.05. For measuring the correlation between two variables and effect size (r = 0.3), it was determined that 80 participants would be required. A target sample size of 80 participants was selected to ensure adequate power[9].

Participants:

The active professional swimmers were divided into two groups: Group A (CNSLBP, N=40) included swimmers experiencing chronic nonspecific low back pain (CNSLBP) persisting for over 12 weeks during training or competition, while Group B (Healthy, N=40) consisted of swimmers without NSLBP. Both groups were assessed for motor control deficits using four tests with a Pressure Biofeedback Unit (PBU) and shoulder proprioception using a bubble inclinometer. Additionally, Group A was assessed for the degree of pain using the Visual Analogue Scale and pain duration based on their history. Before the assessment procedures, all participants were informed about the practical procedures and signed the informed consent for their approval to participate.

Inclusion and exclusion criteria:

For group (A), active swimmers aged 10 to 20 years who have been practicing swimming for at least one year, train 3 to 6 times per week, and have experienced chronic nonspecific low back pain (CNSLBP), eternal extra than 12 weeks, either during training or competition. In inclusion for group (B), the criteria are the same except that they don't have or experienced previously low back pain. On the other hand, if they had a previous history of back pain due to conditions such as tumors, radicular pain, or fractures; any recent shoulder injury or pain due to structural issues like tendinopathy or acute injuries that could influence the results; neurological disorders that may impact their performance; or if they are para swimmers with disabilities, as these factors may affect the study outcomes.

Individuals were excluded if they had a previous history of back pain due to conditions such as tumors, radicular pain, or fractures; any recent shoulder injury or pain due to structural issues like tendinopathy or acute injuries that could influence the results; neurological disorders that may impact their performance; or if they are para swimmers with disabilities, as these factors may affect the study outcomes.

Ethics approval and consent to participate:

The research's protocol received approval by the research ethical committee of the faculty of physical therapy, Cairo University (3/9/2023, P.T.REC/012/004778). Participants signed informed consent for their approval to participate in this study after a comprehensive illustration of the study's aim and procedures.

Procedures:

Assessment of Pain intensity

For group A was measured using the Visual Analogue Scale (VAS), where participants pointed to a point on a 10-cm line, with one end labeled "no pain" (0 cm) and the other "worst pain" (10 cm), providing a subjective measure of pain intensity[10]. Pain duration was evaluated by asking participants about the onset and duration of their pain.

Assessment of Motor Control Deficit

To assess motor control deficits, a Pressure Biofeedback Unit (PBU) was used in four motor control tests Active Straight Leg Raising (ASLR), Bent Knee Fall Out Test (BKFO), Knee Lift Abdominal Test (KLAT), and Prone Abdominal Drawing Test.

Active Straight Leg Raising (ASLR), The PBU was filled to 40 mmHg and positioned horizontally beneath the participant's lumbar spine, with its lower edge aligned with the level of the posterior superior iliac spines. While the participant was in a supine position, they were instructed to lift one stretched <20 cm over the mat, as indicated by a ruler. The participant then held this position for 20 seconds, following feedback from the examiner[11].

Bent Knee Fall Out Test (BKFO), The patient was asked to lie in a supine position on a mat with a partial crook position, one knee flexed at 120°, and the other lower limb in a straight position. Two connected PBUs were inflated to a pressure of 40 mmHg and placed under the center of the back at the L3 level, aligned along the spine to ensure uniform lumbar tactile feedback. However, only data from the PBU placed under the moving limb was considered. The participants were instructed to slowly abduct and laterally rotate their hips to approximately 45°, preserving their foot proved beside their extended knee, then recover to the initial position[11].

Knee Lift Abdominal Test (KLAT), The PBU was filled to 40 mmHg and positioned horizontally under the participant's spine, with the lower edge aligned at the level of the posterior superior iliac spines. The participants were placed in a crook position and instructed to lift one foot off the mat until achieving a 90° flexion at both the hip and knee. Simultaneously, they were asked to retain a neutral position of the lumbar spine[11].

Prone Abdominal Drawing Test The individuals were commanded to lie in a prone position on the placemat with their arms beside their torso. The pump-up bag was placed between the anterior superior iliac spine and the umbilicus. Prior to initiating the contraction, the bag was filled to 70 mmHg, and the participants were instructed to take deep breaths, focusing primarily on using their abdominal wall. After completing two normal breaths, the inflatable bag was readjusted to 70 mmHg. The participants were then asked to accomplish three contractions following the verbal order: "Draw in your abdomen without moving your lumbar spine or pelvis and hold that position until I tell you otherwise." The examiner used palpation to check whether the participants moved their spine or pelvis during the 10-second hold[11].

These tests measured the participant's ability to maintain lumbar spine stability while performing movements, with excessive pressure deviations indicating poor motor control [11].

Assessment of scapular upward rotation and shoulder proprioception

The bubble Inclinometer was used to assess scapular upward rotation during shoulder abduction. This method involves measuring rotation at various degrees of abduction (90°, 120°) as previously described. For shoulder proprioception, the joint position sense (JPS) during internal and external rotations at 90° of abduction, the subject was asked to reposition the shoulder joint to 45° internal and external rotations with the subject blindfolded to eliminate visual cues[12, 13].

Data Analysis

Each dependent variable, together with the demographic variables of age, weight, height, and BMI, had descriptive statistics, such as the mean and standard deviation, calculated. The chi-square test was used for between-group comparisons for gender distribution. Hence the dependent variables were normally distributed, except for the data related to the JPE, Pearson Correlation Coefficient was used to explore the relationship between motor control deficits (MCD) and scapular upward rotation at both 90 and 120 degrees of both dominant and non-dominant sides. On the other hand, the Spearman Correlation coefficient was used to assess the correlation between MCD and measures of JPE in internal and external rotation ROM of both dominant and non-dominant sides. An Independent T-test was conducted to compare MCD, Scapular upward rotation, and JPE between swimmers with NSLBP and those without. Data analysis was performed using IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., 2015). The significance p value ≤ 0.05 was considered statistically significant.

Results

Subject characteristics:

Both groups were well matched in their demographic characteristics and gender distribution percentage, as shown in Table **(1,2)** for both groups and the analysis showed no significant differences between the groups in terms of age, weight, height, and BMI ($p > 0.05$).

Table (1): Comparison of age, weight, height, and BMI between groups A and B.

	Group A	Group B	MD	t- value	p-value	Sig
	$\bar{X}$ ± SD	$\bar{X}$ ± SD				
Age (years)	13.15 ± 2.12	13.23 ± 2.18	-0.08	-0.16	0.876	**NS**
Weight (kg)	49.96 ± 15.17	49.26 ± 10.90	0.7	0.24	0.814	**NS**
Height (cm)	160.23 ± 15.45	157.08 ± 12.61	3.15	0.99	0.321	**NS**
BMI (kg/m²)	19.03 ± 3.25	19.76 ± 2.53	-0.73	-1.13	0.263	**NS**

$\bar{X}$: Mean　SD: Standard deviation　MD: Mean difference
t value: Unpaired t value　p-value: Probability value　NS: Nonsignificant

Table (2): The frequency distribution and chi-squared test for comparison of sex distribution between groups A and B.

	Group A	Group B	χ^2 value	p-value	Sig
Females	10 (25%)	11 (27.5%)	0.07	0.799	NS
Males	30 (75%)	29 (72.5%)			

χ^2: Chi squared value p-value: Probability value NS: Nonsignificant

Regarding motor control, Participants who had CNSLBP (group A), experienced significantly higher motor control deficits than the healthy participant (group B) in ASLR, BKFO, KLAT, and PADT tests ($p < 0.001$), as shown in **Table (3)**.

Table (3): Comparison of ASLR, BKFO, KLAT, and PADT between groups A and B.

Pressure (mmHg)	Group A $\bar{X}$ ± SD	Group B $\bar{X}$ ± SD	MD	t- value	p-value	Sig
ASLR	47.86 ± 5.77	40.58 ± 3.93	7.28	6.90	<0.001	**S**
BKFO	48.42 ± 5.95	41.19 ± 5.02	7.23	5.88	<0.001	**S**
KLAT	53.21 ± 6.83	45.63± 5.82	7.58	5.34	<0.001	**S**
PADT	61.76 ± 4.11	66.32± 3.44	-4.56	-5.38	<0.001	**S**

$\bar{X}$: Mean SD: Standard deviation MD: Mean difference
t value: Unpaired t value p-value: Probability value S: Significant

The comparison of scapular upward rotation between Group A and Group B revealed no significant differences in both dominant and non-dominant scapular upward rotation at 90º shoulder abduction, with p-values of 0.402 and 0.101, respectively. On the other hand, at 120º shoulder abduction, there is a significant difference between groups in group A both dominant (40.48 ± 6.91 degrees vs. 36.73 ± 6.71 degrees, p = 0.016) and non-dominant (39.43 ± 6.57 degrees vs. 35.73 ± 7.19 degrees, p = 0.019) scapular upward rotation compared to Group B as shown in Table 4

Table (4): Comparison of scapular upward rotation between groups A and B.

Scapular upward rotation (degrees)		Group A $\bar{X}$ ± SD	Group B $\bar{X}$ ± SD	MD	t- value	p-value	Sig
90º shoulder abduction	**Dominant**	22.20 ± 5.72	21.18 ± 5.16	1.02	0.84	0.402	**NS**
	Non- dominant	22.23 ± 5.03	20.25 ± 5.59	1.98	1.66	0.101	**NS**
120º shoulder abduction	**Dominant**	40.48 ± 6.91	36.73 ± 6.71	3.75	2.46	0.016	**S**
	Non- dominant	39.43 ± 6.57	35.73 ± 7.19	3.7	2.40	0.019	**S**

$\bar{X}$: Mean SD: Standard deviation MD: Mean difference
t value: Unpaired t value p-value: Probability value S: Significant NS: Nonsignificant

Regarding joint position error (JPE), the Mann-Whitney Test for between-group comparison revealed that Group A had a significantly higher joint position error (JPE) in both dominant and non-dominant internal (*p* < 0.001 and *p* =0.017, respectively) and external rotations (*p* < 0.001) as shown in **Table (5)**.

Table 5. Comparison of internal and external rotation JPE between groups A and B.

JPE (degrees)		Group A	Group B	U- value	p-value	Sig
		Median (IQR)	Median (IQR)			
Internal rotation	Dominant	8.17 (9.67-4.50)	3.17 (4.83-1.08)	239.5	<0.001	S
	Non- dominant	3.67 (6.33-2.33)	2.33 (4-1.33)	552	0.017	S
External rotation	Dominant	5.00 (7.67-2.67)	1.83 (3.67-1)	421.5	<0.001	S
	Non- dominant	3.67 (6.17-1.75)	1.67 (2.92-1)	417.5	<0.001	S

IQR: Interquartile range U- value: Mann-Whitney test value
p values: Probability values NS: Non-significant S: Significant

Regarding the correlation between MCD tests and scapular upward rotation, at 90 shoulder abductions of dominant and non-dominant sides, Pearson correlations were weak and non-significant for all MCD tests. On the other hand, at 120 shoulder abduction of dominant and non-dominant sides, KLAT showed moderate positive significant correlations with dominant (r = 0.320; *p* = 0.044) and non-dominant (r = 0.346; *p* = 0.029) sides and PADT had moderate to strong negative significant correlations with dominant (r = -0.340; *p* = 0.032) and non-dominant (r = -0.417; *p* = 0.007) sides. However, ASLR and BKFO had weak and non-significant correlations with 120 shoulder abductions of dominant and non-dominant sides as shown in **Table (6)**.

Table 6. Correlation between motor control deficit and scapular upward rotation of group A:

Scapular upward rotation (degrees	ASLR		BKFO		KLAT		PADT	
	r-value	p-value	r-value	p-value	r-value	p-value	r-value	p-value
Dominant scapular upward rotation in 90° shoulder abduction	0.056	0.731	0.098	0.547	0.087	0.594	-0.006	0.972
Non-dominant scapular upward rotation in 90° shoulder abduction	0.114	0.482	-0.025	0.879	-0.021	0.900	-0.136	0.401
Dominant scapular upward rotation in 120° shoulder abduction	0.166	0.305	0.240	0.136	**0.320***	**0.044**	**-0.340***	**0.032**
Non-dominant scapular upward rotation in 120° shoulder abduction	0.171	0.291	0.208	0.199	**0.346***	**0.029**	**-0.417***	**0.007**

r value: Pearson correlation coefficient p-value: Probability value *: Significant at p < 0.05

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Regarding correlations between MCD tests and joint position error (JPE), Spearman revealed that MCD had weak and non-significant correlations with JPE of the external rotation of both the dominant and nondominant sides and internal rotation of the non-dominant side. However, the JPE of the internal rotation of the dominant side was the only variable that had a significant correlation with all MCD tests. There was a moderate to strong positive correlation with

ASLR, BKFO, and KLAT and (r = 0.449; *p* = 0.004, r = 0.374; *p* = 0.017, and r = 0.346; *p* = 0.007, respectively) and it was a negative moderate correlation with PADT (r = -0.350; *p* = 0.027) as shown in **Table (7)**.

Table 7: Correlation between motor control deficit and JPE of group A:

JPE (degrees)	ASLR		BKFO		KLAT		PADT	
	r_s-value	p-value	r_s-value	p-value	r_s-value	p-value	r_s-value	p-value
Dominant internal rotation JPE (degrees)	**0.449***	**0.004**	**0.374***	**0.017**	**0.346***	**0.029**	**-0.350***	**0.027**
Non-dominant internal rotation JPE (degrees)	0.191	0.239	0.069	0.673	0.010	0.951	-0.298	0.062
Dominant external rotation JPE (degrees)	0.265	0.099	0.169	0.296	0.227	0.159	-0.152	0.349
Non-dominant external rotation JPE (degrees)	0.262	0.102	0.112	0.491	-0.012	0.940	-0.171	0.291

r_s value: Spearman correlation coefficient p-value: Probability value *: Significant at p < 0.05

Discussion

The current cross-section observational study involved active professional swimmers, both with and without low back pain (LBP). The the first is to :Intention of this study is two-fold find the differences in Movement Control and shoulder proprioception) Dysfunction (MCD between swimmers with and without LBP. The second is to assess the association between motor control test scores and shoulder proprioception in Swimmers with LBP. The findings of this study revealed that the CNSLBP players consistently showed greater difficulty in motor control of their back compared to the normal players, higher scapular upward rotation at 120 shoulder abduction, and higher joint position error (JPE). Also, there were correlations between MCD and both the scapular upward rotation, only at 120 of shoulder abduction of the dominant and non-dominant sides, and JPE of the internal rotation of the dominant side only.

The greater difficulty in motor control of the back of the players with CNSLBP compared to the normal players was identified by higher pressure changes in the PBU during the MCD tests. The MCD tests put a high demand on the spine while moving the lower limbs. Since sensorimotor systems manage the interaction between both active and passive stability elements to match the higher demand of functional activity, excessive pressure changes in the PBU during the MCD tests might be viewed as the lumbar spine moving uncontrollably while the lower limbs move during the testing. This highlights that swimmers complaining from NSLBP consistently showed greater difficulty in motor control which might affect their performance and attitude during training and competition[14]. This hypothesis is 5) who stated that ۱supported by Roussel et al., (Chronic low back pain has been demonstrated to result from damage to the passive spinal structures caused by impairments in dynamic stability. Noting that the control group performed better, suggesting stronger lumbar stability in those positions even though both groups had the same training and competition workload. This came in agreement with Grosdent et al (16) who said Poor lumbo-pelvic motor control, as indicated by tests like the BKFO, is accompanied by an increased

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risk of lower back pain. This suggests that improving motor control through targeted exercises could potentially reduce the incidence of lumbar pain.

Xu et al (17) research found that normally, to maintain core stability during regular tasks, the core muscles are recruited before the superficial muscles. Under pathological conditions, these muscles become dysfunctional, while superficial muscles are recruited to provide additional spinal stability. As a result, patients had chronic low back pain (CLBP) exhibit co-activation of agonist and antagonist muscles in the superficial layer. This compensatory mechanism serves as a strategy to reduce lumbar spine instability. While this activation strategy may be effective in the short term, it is not sustainable in the long run. In addition to the above O'Sullivan (18) did a study that investigated the prototypes of abdominal muscle enrolment during the abdominal drawing-in maneuver in individuals with chronic low back pain (CLBP). Data were collected using external electromyography from 12 physically active subjects with CLBP and 10 controls. The control group determined the capability to selectively activate the internal oblique with the least engagement of the upper rectus abdominis throughout the abdominal wall drawing-in action. However, the CLBP group was powerless to complete this. This finding may indicate the presence of neuromuscular dysfunction in the CLBP group.

The greater scapular upward rotation above 120 degrees of shoulder abduction in players with CNSLBP compared to healthy players may be linked to the MCD in CNSLBP. Low back pain (LBP) alters motor control, leading to changes in balance and trunk muscle activity[19]**.** In LBP, Latissimus Dorsi (LD) shows higher muscle activities bilaterally and gluteus maximus (GM) shows decreased muscle activities bilaterally compared to healthy **Laudner (20)**. There is a link between higher LD muscle activity and scapular dyskinesia among asymptomatic collegiate swimmers. They may develop higher scapular upward rotation and posterior tilt[21]. Also, **Mohamed et al., (19)** reported an increase in upward scapular rotation and a bilaterally significant increase in EMG of LD, and a significant decrease in EMG of GM in LBP.

This study measured the joint position error as the absolute Discrepancy between the target angle and the observed angle and calculated the error score to indicate the joint position sense as a measure of proprioception. The results supported the notion that patients with low back pain had poor proprioception in their back[21] which reflected on MCD and also on shoulder proprioception. Whether proprioception deficits were in another body area for those patients needs further research to confirm or exclude. This proprioception deficit was previously treated by lumbar motor control exercise which produced a reduction in the joint position error and may retain normal shoulder proprioception[22,23]**.** This was explained as a main feature of CNSLBP patients in the form of a Lagged response to external disruptions, which may predispose to injury, especially in high-performance athletes, as longer reaction time is needed for deep core muscles to be physically engaged.

The findings related to the correlation between MCD, and scapular upward rotation highlight the role of abdominal muscle tests, related to motor control, in scapular mechanics above 120º abduction which represents the key range of significant positive correlation as presented above. This significant correlation between abdominal muscle tests and scapular upward rotation above 120 degrees came in agreement with **Yun and Kim. (24)** study that reported at 135° shoulder abduction range of motion showed significantly higher EMG activity of rectus abdominis, left outer oblique abdominis, and right inner oblique abdominis, and transverse abdominis muscles

Nichols, et al (2015) (**25**) reported that elite swimmers require enhanced capabilities to apply force efficiently, maximize propulsive effectiveness, and sustain a higher proportion of their peak power throughout a race. Efficient thrust generation is facilitated by maintaining a streamlined body position in harmony with the optimal orientation of drag and lift forces. Additionally, water resistance is significantly influenced by the swimmer's underwater body alignment and posture. By adopting a more horizontal body position, swimmers can improve stroke mechanics and consequently increase their speed. Both stroke length and stroke rate play vital roles in determining overall swimming velocity. This may explain the reason why CNSLBP swimmers have high bilateral scapular upward rotation above 90 besides internal and external

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rotation in both shoulders whether dominant and non-dominant. The CNSLBP players have high numbers in motor control tests which may develop imperfect lumbar spine control during swimming and in turn may affect the horizontal position of swimmers on the water surface. This significant correlation between motor control tests and internal rotation proprioception can be explained according to the patient's lifestyle and compensatory mechanisms secondary to their complaint. Participants with CNSLBP adopt a stiffening strategy to increase spine stability and reduce the exacerbation of existing pain Stokes[26].

Limitations

This study might have some limitations.

First, the experiment was performed on participants with chronic nonspecific low back pain and cannot be generalized for other groups of low back pain patients. In addition, the scapula was evaluated in the frontal plane only, and there is a possibility that the scapular position could change in other planes. Further studies are needed to assess several factors related to the association between MCD and impaired proprioception in other body parts for those players in addition to its correlation with other factors such as dynamic balance and athletic performance.

Conclusion

This study assessed motor control deficit (MCD) and its association with shoulder proprioception in swimmers with chronic non-specific low back pain (CNSLBP). Findings revealed that the CNSLBP swimmers had poorer motor control, with significant deficits in lumbar stability tests and increased joint position errors (JPE) in shoulder rotations. Scapular upward rotation was significantly higher at 120° shoulder abduction in the CNSLBP group, likely due to altered muscle activation patterns. Correlations showed that weaker core control affected scapular mechanics and proprioception, emphasizing the role of targeted exercises in improving stability.

DECLARATIONS

- **Consent to publish:** I certify that each author has given their consent to submit the work.
- **Competing interests:** None.
- **Funding:** No fund.

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