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Investigation of Mollii Suit's effectiveness in children with cerebral palsy with different ambulance levels

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ABSTRACT

Aims: This study aimed to investigate the effects of the Mollii Suit method (MSM) on gross motor function, muscle tone, postural control and lower extremity selective motor control in children with cerebral palsy (CP) at different ambulance levels.

Methods: Children with CP were divided into two groups according to gross motor function classification system (GMFCS) levels. The first group consisted of 10 ambulatory children with spastic type CP from GMFCS levels I, II and III, and the second group consisted of 10 non-ambulatory children with spastic type CP from GMFCS levels IV and V. Both groups attended 6 weeks of routine physiotherapy sessions, 3 days a week, 60 minutes MSM. Gross motor function was assessed using the Gross Motor Function Measure-66 (GMFM-66); muscle tone was evaluated with the Modified Ashworth Scale (MAS); postural control was measured using the modified functional reach test (mFRT) and the Trunk Impairment Scale (TIS); and selective motor control was assessed with the selective control assessment of the lower extremity (SCALE). All evaluations were made at the beginning and end of the treatment (6 weeks later).

Results: A significant increase in total GMFM score was observed for all individuals after the intervention. In children with ambulatory CP, the TIS score showed a significant increase, whereas no significant change was observed in the other group. While the increase in mFRT score was not significant for both groups and the increase in SCALE score was significant for the non-ambulatory group. In the MAS score, there was no difference between the two groups.

Conclusion: This study has shown that MSM affects motor function, body control and selective motor control in children with CP. Based on these results, we think that the use of MSM in addition to rehabilitation in children with CP may be effective and hopeful.

Keywords: Cerebral palsy, Mollii Suit, spasticity, motor function, postural control, selectivity

INTRODUCTION

Cerebral palsy (CP) is the most common physical disability in childhood[1] and is currently defined as a permanent, nonprogressive disorder of movement, posture, and motor function resulting from a lesion or abnormality in the developing brain.[2] The epidemiological profile of CP has evolved over time. Although its prevalence has remained relatively stable for many years at approximately 2-3 cases per 1,000 live births,[3] notable advancements in early diagnosis, prevention, and treatment over the past decade have contributed to changes in incidence, prognosis, and treatment responsiveness.[1] CP results from damage to various regions of the brain, with the location and extent of the lesion influencing the severity, distribution, and type of motor impairments, such as muscle spasticity. In addition to motor dysfunction, individuals with CP frequently experience associated impairments, including sensory, cognitive, perceptual, and communication deficits, as well as secondary musculoskeletal complications and pain.[4]

Motor rehabilitation approaches for individuals with CP encompass a wide range of interventions, including conventional rehabilitation techniques (e.g., range of motion exercises, neurodevelopmental treatments, muscle strengthening and stretching, aerobic and biofeedback-based exercises, gait training, and the use of orthoses), intensive rehabilitation programs [such as constraint-induced movement therapy (CIMT) and hand-arm bimanual intensive therapy (HABIT)], physical and sports activities, as well as technology-assisted methods.[5] Among these, electrical stimulation is frequently employed and has been shown to contribute to the reduction of spasticity while enhancing functional capacity, muscle strength, and joint range of motion.[6] One specific technique that has gained increasing attention in recent years is transcutaneous electrical nerve stimulation (TENS). TENS functions by delivering electrical impulses to the nervous system, thereby modulating or altering neuronal activity. It is utilized in a variety of

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clinical domains, including neuromotor rehabilitation,[7] pain management,[8] the treatment of defecatory and urinary dysfunctions,[9,10] and cognitive modulation.[11] Furthermore, TENS can be integrated with other rehabilitation modalities to enhance the overall effectiveness of treatment strategies.[11]

The Mollii Suit method (MSM) (Exoneural Network AB, Danderyd, Sweden) is a wearable system that integrates TENS into a full-body garment equipped with strategically placed electrodes. These electrodes are designed to replicate the natural electrical signals of the nervous system, facilitating controlled muscle fiber contraction and relaxation. The primary aim of MSM is to reduce spasticity while enhancing flexibility and range of motion. The embedded electrodes provide targeted stimulation to specific muscle groups, allowing for precise and individualized therapeutic intervention. This selective stimulation approach enables accurate localization of affected areas, thereby supporting customized treatment plans tailored to the needs of each user. The suit is operated via a control unit that can be programmed according to individual therapeutic requirements, and these programs can be saved for repeated use, eliminating the necessity for continuous reprogramming.[12]

Developed to enhance motor function by reducing spasticity and pain, the Mollii Suit method is based on the principle of reciprocal inhibition, wherein stimulation of the antagonist muscle at low frequencies and intensities leads to the inhibition of the spastic muscle. Clinical studies conducted in pediatric populations have reported no discomfort or adverse effects associated with the use of this method.[13-18] In one study, children described the suit as making them feel like superheroes, contributing to a sense of well-being and motivation.[19] Parents also expressed optimism, noting that the method could serve as a promising alternative to conventional treatments.[16] In a pilot study conducted by Hedin et al.,[15] 16 individuals with CP of varying severity levels received 60-minute treatment sessions every other day for a period of six weeks. The results demonstrated a significant reduction in spasticity and an improvement in joint range of motion.

MSM has been utilized in the treatment of pain and spasticity in individuals with conditions such as CP, stroke, ataxia, and fibromyalgia. However, these studies have employed diverse methodologies, and the findings have demonstrated variability and inconsistencies across outcomes.[16-18,20] The majority of existing studies on the Mollii Suit have been conducted with limited samples or on homogeneous GMFCS groups. This limits the generalizability of its effectiveness in children with different motor function levels (GMFCS I-V). Furthermore, the Mollii Suit's operating principle is to modulate the neuromuscular system via low-frequency TENS. This mechanism may respond differently depending on GMFCS levels. Therefore, this study aimed to examine the effects of MSM on gross motor function, muscle tone, postural control, and selective motor control of the lower extremities in children with CP, according to ambulation status.

METHODS

This study was designed as an experimental clinical trial with two parallel arms. Ethical approval was obtained from the Gazi University Ethics Committee (Date: 13.06.2024, Decision No: 2024-989). The study was conducted in accordance with the principles outlined in the Declaration of Helsinki, and informed consent was obtained from all participants and their legal guardians.

The study was carried out between July 10, 2024, and November 30, 2024, at the Developmental Physiotherapy and Pediatric Rehabilitation Unit within the Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Gazi University. Children diagnosed with spastic CP who were referred by a pediatric neurologist were assessed for eligibility. Only children whose parents provided both verbal and written informed consent were included in the study.

Inclusion criteria were: (1) voluntary participation, (2) diagnosis of spastic CP, and (3) age between 4 and 18 years. Exclusion criteria included: (1) receiving *Botulinum* toxin A treatment within the past 3 months, (2) undergoing any surgical intervention within the past 6 months, or (3) having an implanted invasive medical device (e.g., baclofen or insulin pumps).

The required sample size was determined using G*power software (version 3.1.9, Universität Düsseldorf, Düsseldorf, Germany).[21] Based on a power of 90%, a significance level of 0.05, and a minimally clinically important difference (MCID) of 1.6 on the Gross Motor Function Measure (GMFM), a sample size of 10 participants per group was calculated.[22,23] Accordingly, a total of 20 children with CP were included in the study, with 10 participants allocated to each group.

Measurements

All assessments were performed one day before and one day after the intervention by a pediatric physiotherapist with 10 years of experience in the field. During the initial evaluation, demographic data-including age, weight, height, and type of CP-were recorded. Motor function, muscle tone, trunk impairment and selective motor control were evaluated respectively. Motor function was classified using the Gross Motor Function Classification System (GMFCS) developed by Palisano et al.,[24] while motor performance was assessed using the Gross Motor Function Measure-66 (GMFM-66), a validated short form of the original scale.[25] The GMFM-66 evaluates motor activities across five domains: lying and rolling, sitting, crawling and kneeling, standing, and walking/running/jumping. Each item is scored on a 4-Point Ordinal Scale ranging from 0 (does not initiate the movement) to 3 (completes the movement independently).

Muscle tone was assessed using Modified Ashworth Scale (MAS), a widely used tool for evaluating spasticity. Bilateral assessments of the hamstring and gastrocnemius muscles were performed with the participant in a supine position, with the head in the midline and limbs in a relaxed position. Resistance encountered during passive movement of the antagonist muscles was graded on a scale from 0 to 4.[26,27]

Trunk stability during reaching was measured using the modified functional reach test (mFRT). This test assessed lateral reach from a seated position, with the distance measured from the tip of the third metacarpal while the participant reached laterally toward the wall.[28,29] Functional assessment of trunk control was further evaluated using the Trunk Impairment Scale (TIS), which includes three subscales; static sitting balance, dynamic sitting balance, and trunk coordination. The scale is scored on a total of 0-23 points, with higher scores indicating better trunk control.[30]

Selective motor control of the lower extremities was assessed using the selective control assessment of the lower extremity (SCALE). This reliable and valid instrument scores selective voluntary joint movements on a scale from 0 to 2, with higher scores indicating better motor control.[31]

Treatment Protocol

Children with CP included in the study were stratified into two groups based on the GMFCS levels. The first group consisted of ambulatory children classified as GMFCS levels I, II, or III, while the second group included non-ambulatory children classified as GMFCS levels IV and V.

All participants attended Neurodevelopmental Therapy (NDT) sessions twice a week throughout the six-week intervention period. To avoid fatigue, both groups attended 60-minute MSM sessions three times a week on days they were not attending NDT programs. The Mollii Suit is a neuromodulatory garment composed of a jacket and pants, incorporating a noninvasive, detachable control unit that delivers electrical impulses through 58 embedded electrodes. These electrodes are flexible, breathable, and strategically positioned over specific muscle groups to ensure direct contact with the user's skin.

The stimulation parameters were set as follows: pulse width of 25-175 microseconds, frequency of 20 Hz, voltage of 20 V, and a square wave pulse shape.[13,14,18] During each session, children were instructed to remain seated or lying down to minimize external interference and ensure the consistent efficacy of the intervention.

After completing a total of 18 sessions over six weeks, post-intervention assessments were conducted, and the treatment protocol was concluded.

Statistical Analysis

Data analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 28.0 (SPSS Inc., Chicago, IL, USA). The distribution of variables was assessed using both visual methods (histograms and probability plots) and analytical tests (Kolmogorov-Smirnov and Shapiro-Wilk tests). Continuous variables were presented as mean±standard deviation (SD), while categorical variables were expressed as frequencies and percentages.

For variables that met the assumptions of normality, between-group comparisons were conducted using the independent samples T test, and within-group comparisons were performed using the paired samples T test. For nonnormally distributed data, between-group comparisons were analyzed using the Mann-Whitney U test, and within-group differences were assessed using the Wilcoxon signed-rank test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The demographic and clinical characteristics of the participants are summarized in Table 1. The mean age of participants in group 1 was 6.70±0.51 years, while the median age in group 2 was 6 years. Female representation was 60% (n=6) in group 1 and 30% (n=3) in group 2. There were no statistically significant differences between the groups regarding baseline characteristics such as age, height, weight, and gender (p>0.05).

Table 1. Descriptive characteristics of the childrens (n=20)

	Group 1 (ambulatory) (n=10)	Group 2 (nonambulatory) (n=10)	p-value
Age (years)	6.70±0.51	6 (5-11)	0.631
Gender (female), n (%)	6 (60%)	3 (30%)	0.280
Gender (male), n (%)	4 (40%)	7 (70%)	0.380
Height (cm)	113.00±3.40	105.5 (100-146)	0.393
Weight (kg)	19.35±1.30	17 (14-36)	0.912
GMFCS level I-II-III	1-5-4	-	<0.001
GMFCS level IV-V	-	7-3	

Independent samples T test was used (p<0.05). GMFCS: Gross motor function classification system

In the ambulatory CP group, significant improvements were observed in both GMFM-T (p=0.026) and TIS scores (p=0.019), whereas the increases in mFRT, SCALE and MAS scores were not statistically significant (p>0.05). In the non-ambulatory CP group, GMFM-T (p=0.020) and SCALE (p=0.012) scores improved significantly, while changes in mFRT, TIS and MAS scores remained non-significant (p>0.05). Within-group comparisons are presented in Table 2.

Table 2. Within-group comparison before and after intervention

Group 1	Before intervention	After intervention	p-value
GMFM-T	77.63±4.86	82.29±4.55	0.026
SCALE	6.80±1.42	7.90±1.78	0.418
mFRT (cm)	23.95±1.77	25.70±1.86	0.437
TIS	26.80±3.83	35.90±4.48	0.019
MAS right gastrocnemius	2.5 (0-4)	2.5 (0-4)	0.655
MAS left gastrocnemius	2.5 (1-3)	2.5 (2-4)	0.180
MAS right hamstring	1 (0-3)	2 (0-2)	1.000
MAS left hamstring	1.5 (0-3)	1.5 (0-3)	0.739
Group 2	**Before intervention**	**After intervention**	**p-value**
GMFM-T	26.32±5.75	33.38±6.85	0.020
SCALE	3.20±0.90	5.30±1.46	0.012
mFRT (cm)	10.40±2.40	12.30±2.54	0.094
TIS	5.90±1.74	7.70±2.12	0.105
MAS right gastrocnemius	3 (1-4)	2.5 (1-4)	0.068
MAS left gastrocnemius	2.5 (0-4)	2 (0-4)	0.414
MAS right hamstring	3 (1-4)	2.5 (1-4)	0.102
MAS left hamstring	2 (0-4)	2 (0-4)	0.705

Paired samples T test and Wilcoxon rank test were used (p<0.05). GMFM-T: Gross motor function total score, SCALE: Selective control assessment of lower extremity, mFRT: Modified functional reach test, TIS: Trunk Impairment Scale, MAS: Modified Ashworth Scale

Between-group comparisons revealed no significant differences in the changes for GMFM-T, SCALE, or mFRT (p>0.05). However, the improvement in TIS scores was significantly greater in the ambulatory group compared to the non-ambulatory group (p=0.040). Between-group comparisons are shown in Table 3.

Table 3. Comparison of differences between groups

	Group 1 (ambulatory)	Group 2 (non-ambulatory)	p-value
GMFM-T	4.65±1.74	7.06±2.51	0.443
SCALE	1.10±1.29	2.10±0.67	0.505
mFRT	1.75±2.15	1.90±1.01	0.950
TIS	9.10±3.19	1.80±0.99	0.040

Independent sample T test was used (p<0.05). GMFM-T: Gross motor function total score, SCALE: Selective control assessment of lower extremity, mFRT: Modified functional reach test, TIS: Trunk Impairment Scale

DISCUSSION

This study represents the first investigation into the effects of the MSM on gross motor function, muscle tone, postural control, and lower extremity selective motor control in both ambulatory and non-ambulatory children with CP. No adverse effects or negative feedback were encountered during the evaluations and intervention. Our findings demonstrate that a six-week intervention with MSM led to significant improvements in gross motor function and trunk control among ambulatory children with CP, as well as enhanced lower extremity selective motor control in their non-ambulatory children. Based on these results, we suggest that incorporating a six-week MSM protocol into standard rehabilitation programs may effectively enhance motor function in children with CP regardless of ambulatory status. Furthermore, while six weeks of MSM appeared sufficient to promote trunk control development in ambulatory children, this duration may be inadequate for similar improvements in non-ambulatory children. Consequently, we recommend future research to explore the effects of prolonged MSM interventions on trunk control in non-ambulatory children with CP.

A significant improvement in gross motor function scores was observed in both groups following the application of the MSM for one hour, three times per week, over a six-week period. These findings align with previous research demonstrating positive outcomes with MSM applied thrice weekly for three weeks in children with spastic CP.[32] Similarly, Flodström et al.[18] reported increased GMFM scores in six children with CP who received MSM combined with activity for one hour every other day over a three-month period. Impaired sensory processing and integration are known contributors to motor dysfunction in CP.[33] TENS has been shown to preferentially activate large sensory fibers, primarily within the A-beta range, through cutaneous muscle stimulation, thereby enhancing sensorimotor cortex excitability.[34] This mechanism reduces deficits in somatosensory feedback, which may otherwise constrain motor performance.[34,35] Consequently, TENS normalizes sensory input by providing peripheral sensory stimulation, positively influencing sensorimotor integration and subsequently improving motor control and coordination.[36] Additionally, TENS may directly enhance muscle activity by stimulating motor nerves within targeted muscle groups via electrical currents,[37] thereby contributing to improved motor function.

Spasticity

Spasticity associated with CP is characterized by an increase in velocity-dependent tonic reflexes resulting from sensorimotor dysfunction caused by upper motor neuron lesions.[38] Previous studies investigating the effects of the MSM on spasticity have yielded inconsistent results. For instance, MSM applied three to four times weekly for four weeks in children with CP aged 4 to 17 years (GMFCS levels 1-4) demonstrated no significant changes in spasticity.[14] Similarly, Pennati et al.[13] reported no significant alteration in MAS scores following a single MSM session. Furthermore, a six-week MSM intervention involving 15 stroke patients and 12 children with CP also failed to elicit significant changes in spasticity measurements.[39] Consistent with these findings, the present study observed no statistically significant reduction in spasticity after administering MSM thrice weekly for six weeks in both ambulatory and non-ambulatory children with CP.

Despite the widespread use of TENS for spasticity management, the literature highlights a lack of consensus regarding optimal stimulation parameters necessary to effectively reduce spasticity.[38,40] In our study, assessments were conducted approximately 48 hours post-intervention, which may have limited detection of TENS's short-term effects on spasticity regulation. Given the absence of standardized timing for post-treatment evaluations, future research should focus on identifying optimal assessment intervals and include multiple evaluation points following successive treatment sessions.

Although our findings did not indicate significant changes in spasticity measured by MAS, it is important to note that MAS scores can reflect increased resistance due to changes in the elastic properties of muscle rather than purely neural contributions.[41] Clinically, spasticity treatment is recommended as part of a multidisciplinary approach targeting functional goals at the activity and participation levels.[42,43] While no significant reduction in resting spasticity was observed after a single MSM session in this study, repeated sessions over six weeks coincided with a notable decrease in spasticity during daily activities in approximately 60% of participants. These observations align with systematic review evidence supporting the efficacy of TENS applied during activity for spasticity management.[44] Therefore, the cumulative effect of repeated MSM sessions combined with active engagement may be critical to achieving meaningful reductions in spasticity, which may explain the absence of immediate effects following isolated treatments at rest.

Postural Control

Performance on the mFRT is closely associated with an individual's ability to effectively displace the center of gravity forward, as those with impaired balance or fear of falling often limit such displacement.[45] One of the primary postural deficits observed in children with CP is the inability to coordinate timely and sequential activation of postural muscles, particularly during functional activities.[46] Trunk control, including the capacity to execute selective trunk movements, is a critical component for maintaining postural stability and generating appropriate balance reactions.[47] However, spasticity and muscle weakness commonly seen in children with CP may contribute to diminished motor abilities, which typically require time and targeted interventions to improve.[48]

Although this study is the first to investigate the effects of wearable TENS on postural control, existing literature suggests that TENS combined with therapeutic exercise over extended durations positively influences postural stability.[49]

The present intervention, limited to six weeks with thrice-weekly sessions and without concurrent exercise during treatment, may have been insufficient to elicit measurable improvements in postural control. Therefore, future research should explore longer-duration MSM protocols, include multiple assessment time points, and examine the synergistic effects of MSM combined with exercise interventions to better determine its efficacy in enhancing postural control in children with CP.

In the literature, TENS has often been applied concurrently during the evaluation of postural control. It is suggested that this temporal synchronization may produce cumulative effects by integrating with other sensory inputs, thereby facilitating improvements in postural control.[50,51] In contrast, in our study, post-intervention assessments were conducted after the removal of the Mollii Suit, meaning that the children with CP were deprived of both electrical stimulation and the proprioceptive feedback provided by the garment. This methodological difference may partly explain the discrepancy between our findings and the positive effects of TENS on postural control reported elsewhere.

A meta-analysis of seven randomized controlled trials demonstrates that TENS significantly reduces spasticity and enhances static balance and gait velocity, but does not yield significant improvements in dynamic balance.[52] The postural control assessments employed in our study predominantly measure dynamic balance components, aligning with the meta-analysis results. Furthermore, it is plausible that the effects of TENS dissipate immediately after cessation of stimulation, limiting efficacy to the duration of application. Participant characteristics and the specific stimulation parameters utilized may also influence the impact of TENS on postural control outcomes.

Selective Motor Control

This is defined by the National Institutes of Health Taskforce on Childhood Motor Disorders as the ability to isolate muscle activation in a specific pattern in response to voluntary movement or postural demands.[53] Although the precise etiology of impaired selective motor control remains unclear, it is established that voluntary movements are primarily mediated by the corticospinal tracts.[54] Impairment in selective motor control detrimentally affects motor function in children with CP more profoundly than in other neurological conditions.[55,56]

The underlying mechanisms contributing to the loss of selective motor control are complex and multifactorial. Proposed theories include the release of primitive flexor and extensor movement patterns originating from brainstem regions due to the absence of normal inhibitory control. Alternatively, selective motor control deficits may arise from a loss of descending inhibition of synergistic muscles or a failure of descending excitation to synergists to activate inhibitory spinal interneurons effectively.[57] These varying pathophysiological mechanisms may differentially impact the manifestation and severity of selective motor control impairments.

In the present study, selective motor control of the lower extremities showed significant improvement in the non-ambulatory group, whereas no notable change was observed in the ambulatory group. It is postulated that reductions in spasticity may contribute to enhancements in gross motor function and selective muscle control.[32] Although the decrease in spasticity observed in the non-ambulatory group was not statistically significant, this trend may have facilitated improvements in motor selectivity. Furthermore, previous research suggests that children with more severe impairments tend to exhibit greater gains following intervention,[56] which could explain the more pronounced improvement in lower extremity selective motor control observed in children with CP classified at GMFCS levels IV and V.

Gross motor function is considered a critical determinant of selective motor control,[55] and the loss of selective motor control has been proposed to more substantially hinder progress in gross motor capabilities.[55] Consistent with this, our findings demonstrated greater improvements in gross motor function within the non-ambulatory group compared to their ambulatory children, potentially accounting for the more marked development of selective motor control in this subgroup.

Limitations

Nevertheless, the study has limitations. Perspectives of the children and their caregivers regarding this intervention were not evaluated. Notably, the absence of a control group restricts the ability to definitively attribute observed effects to the intervention. Furthermore, the study design may introduce placebo effects, performance bias, and recall bias, which could potentially influence the outcomes. Future research should focus on assessing the efficacy of MSM in combination with targeted rehabilitation interventions aimed at improving activity performance across different clinical subtypes of spasticity. Larger-scale, longitudinal studies with extended follow-up periods are warranted to establish the true efficacy and optimal application parameters of this method.

CONCLUSION

Technology-assisted rehabilitation represents a valuable opportunity to enhance functional outcomes in children with CP. In this study, MSM delivered as a whole-body form of TENS, demonstrated meaningful improvements in motor function, postural control, and selective motor control in both ambulatory and non-ambulatory children with CP. These findings suggest that MSM can be considered a feasible and effective adjunct to conventional physiotherapy, particularly in populations with severe motor impairment who often have limited treatment options. The high adherence and motivation observed among participants and their families further support the practicality of incorporating MSM into clinical rehabilitation programs. Clinicians may therefore integrate MSM into routine practice to complement existing interventions, while future research should focus on optimizing stimulation protocols and confirming long-term benefits.

ETHICAL DECLARATIONS

Ethics Committee Approval

Ethical approval was obtained from the Gazi University Ethics Committee (Date: 13.06.2024, Decision No: 2024-989).

Informed Consent

Informed consent was obtained from all participants and their legal guardians.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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REFERENCES

1. Galea C, Mcintyre S, Smithers-Sheedy H, et al. Cerebral palsy trends in Australia (1995-2009): a population-based observational study. 2019; 61(2):186-193. doi:10.1111/dmcn.14011
2. PHDA CCM, PHDB HDM, MDC MP, PHDD ACM, MDE AP. Recommendations from the SCPE collaborative group for defining and classifying cerebral palsy.
3. Vitrikas K, Dalton H, Breish DJAfp. Cerebral palsy: an overview. *Am Fam Physician.* 2020;101(4):213-220.
4. Rosenbaum P, Paneth N, Leviton A, et al. A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl.* 2007;109:8-14.
5. Demont A, Gedda M, Lager C, et al. Evidence-based, implementable motor rehabilitation guidelines for individuals with cerebral palsy. *Neurology.* 2022;99(7):283-297. doi:10.1212/wnl.0000000000200936
6. Wright PA, Durham S, Ewins DJ, Swain ID. Neuromuscular electrical stimulation for children with cerebral palsy: a review. *Arch Dis Child.* 2012;97(4):364-371. doi:10.1136/archdischild-2011-300437
7. Chen P, Liu TW, Kwong PWH, et al. Bilateral transcutaneous electrical nerve stimulation improves upper limb motor recovery in stroke: a randomized controlled trial. *Stroke.* 2022;53(4):1134-1140. doi:10.1161/STROKEAHA.121.036895
8. Tahmasbi F, Ghaderpanah R, Sadrian S, Heris RM, Salehi-Pourmehr HJCPM, Reports R. Effects of transcutaneous electrical nerve stimulation (TENS) on chronic pain in older adults: a systematic review and meta-analysis. *Curr Physic Med Rehabil Rep.* 2023;11(2):242-253.
9. Tahmasbi F, Mosaddeghi-Heris R, Soleimanzadeh F, et al. Effects of posterior tibial nerve stimulation on fecal incontinence: an umbrella review. *Neuromodulation.* 2024;27(2):229-242.
10. Tahmasbi F, Hosseini S, Hajebrahimi S, Heris RM, Salehi-Pourmehr H. Efficacy of tibial nerve stimulation in neurogenic lower urinary tract dysfunction among patients with multiple sclerosis: a systematic review and meta-analysis. *Urol Res Pract.* 2023;49(2):100.
11. Van Dijk KR, Scherder EJ, Scheltens P, Sergeant J. Effects of transcutaneous electrical nerve stimulation (TENS) on non-pain related cognitive and behavioural functioning. *Rev Neurosci.* 2002;13(3):257-270. doi:10.1515/revneuro.2002.13.3.257
12. Perpetuini D, Russo EF, Cardone D, et al. Use and effectiveness of electrosuit in neurological disorders: a systematic review with clinical implications. *Bioengineering (Basel).* 2023;10(6):680. doi:10.3390/bioengineering 10060680
13. Pennati GV, Bergling H, Carment L, Borg J, Lindberg PG, Palmcrantz S. Effects of 60 min electrostimulation with the EXOPULSE Mollii Suit on objective signs of spasticity. *Front Neurol.* 2021;12:706610. doi:10.3389/fneur.2021.706610
14. Arkkukangas M, Hedberg Graff J, Denison E. Evaluation of the electro-dress Mollii® to affect spasticity and motor function in children with cerebral palsy: seven experimental single-case studies with an ABAB design. *Cogent Eng.* 2022;9(1):2064587. doi:10.1080/23311916.2022.2064587
15. Hedin H, Wong C, Sjödén A. The effects of using an electrodress (Mollii®) to reduce spasticity and enhance functioning in children with cerebral palsy: a pilot study. *Eur J Physiother.* 2022;24(3):134-143. doi:10.1080/21679169.2020.1807602
16. Jonasson LL, Sörbo A, Ertzgaard P, Sandsjö L. Patients' experiences of self-administered electrotherapy for spasticity in stroke and cerebral palsy: a qualitative study. *J Rehabil Med.* 2022;54:jrm00263. doi:10.2340/jrm.v53.1131
17. Nordstrom B, Prellwitz M. A pilot study of children and parents experiences of the use of a new assistive device, the electro suit Mollii. *Assist Technol.* 2021;33(5):238-245. doi:10.1080/10400435.2019.1579267
18. Flodström C, Viklund Axelsson SA, Nordström B. A pilot study of the impact of the electro-suit Mollii® on body functions, activity, and participation in children with cerebral palsy. *Assistive Technology.* 2022;34(4):411-417. doi:10.1080/10400435.2020.1837288
19. Nordstrom B, Prellwitz MJAT. A pilot study of children and parents experiences of the use of a new assistive device, the electro suit Mollii. *Assist Technol.* 2021;33(5):238-245. doi:10.1080/10400435.2019.1579267
20. Rubio-Zarapuz A, Apolo-Arenas MD, Clemente-Suárez VJ, et al. Acute effects of a session with the EXOPULSE Mollii Suit in a fibromyalgia patient: a case report. *Int J Environ Res Public Health.* 2023;20(3):2209. doi:10.3390/ijerph20032209
21. Faul F, Erdfelder E, Lang AG, Buchner A. G*power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods.* 2007;39(2):175-191. doi:10.3758/bf03193146
22. Oeffinger D, Bagley A, Rogers S, et al. Outcome tools used for ambulatory children with cerebral palsy: responsiveness and minimum clinically important differences. *Develop Med Child Neurol.* 2008; 50(12):918-925. doi:10.1111/j.1469-8749.2008.03150.x
23. Beck TW. The importance of a priori sample size estimation in strength and conditioning research. *J Strength Condit Res.* 2013;27(8):2323-2337. doi:10.1519/JSC.0b013e318278eea0
24. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol.* 1997;39(4):214-223. doi:10.1111/j.1469-8749.1997.tb07414.x
25. Palisano RJ, Rosenbaum P, Bartlett D, Livingston MH. Content validity of the expanded and revised Gross Motor Function Classification System. *Dev Med Child Neurol.* 2008;50(10):744-750. doi:10.1111/j.1469-8749.2008.03089.x
26. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth Scale of muscle spasticity. *Phys Ther.* 1987;67(2):206-207. doi:10.1093/ptj/67.2.206
27. Numanoğlu A, Günel MK. Intraobserver reliability of modified Ashworth Scale and modified Tardieu scale in the assessment of spasticity in children with cerebral palsy. *Acta Orthop Traumatol Turc.* 2012;46(3):196-200. doi:10.3944/aott.2012.2697
28. Bartlett D, Birmingham T. Validity and reliability of a pediatric reach test. *Pediatr Phys Ther.* 2003;15(2):84-92. doi:10.1097/01.PEP.0000067885.63909.5C
29. Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. *J Gerontol.* 1990;45(6):M192-M197. doi:10.1093/geronj/45.6.m192
30. Heyrman L, Molenaers G, Desloovere K, et al. A clinical tool to measure trunk control in children with cerebral palsy: the Trunk Control Measurement Scale. *Res Dev Disabil.* 2011;32(6):2624-2635. doi:10.1016/j.ridd.2011.06.012
31. Fowler EG, Staudt LA, Greenberg MB, Oppenheim WL. Selective Control Assessment of the Lower Extremity (SCALE): development, validation, and interrater reliability of a clinical tool for patients with cerebral palsy. *Dev Med Child Neurol.* 2009;51(8):607-614. doi:10.1111/j.1469-8749.2008.03186.x
32. Bakaniene I, Urbonaviciene G, Janaviciute K, Prasauskiene A. Effects of the Inerventions method on gross motor function in children with spastic cerebral palsy. *Neurol Neurochir Pol.* 2018;52(5):581-586. doi:10.1016/j.pjnns.2018.07.003
33. Barakat M, Elmeniawy G, Abdelazeim F. Sensory systems processing in children with spastic cerebral palsy: a pilot study. *Bullet Fac Physic Ther.* 2021;26(1):27. doi:10.1186/s43161-021-00044-w
34. Ng SS, Hui-Chan CW. Does the use of TENS increase the effectiveness of exercise for improving walking after stroke? A randomized controlled clinical trial. *Clin Rehabil.* 2009;23(12):1093-1103. doi:10.1177/0269215509342327
35. Cuypers K, Levin O, Thijs H, Swinnen SP, Meesen RL. Long-term TENS treatment improves tactile sensitivity in MS patients. *Neurorehabil Neural Repair.* 2010;24(5):420-427. doi:10.1177/1545968309356301
36. Ni L, Yao Z, Zhao Y, et al. Electrical stimulation therapy for peripheral nerve injury. *Front Neurol.* 2023;14:1081458. doi:10.3389/fneur.2023.1081458
37. Alenazy M, Daneshgar Asl S, Petrigna L, et al. Treatment with electrical stimulation of sensory nerves improves motor function and disability status in persons with multiple sclerosis: a pilot study. *J Electromyogr Kinesiol.* 2021;61:102607. doi:10.1016/j.jelekin.2021.102607
38. Garcia MAC, Vargas CD. Is somatosensory electrical stimulation effective in relieving spasticity? A systematic review. *J Musculoskelet Neuronal Interact.* 2019;19(3):317-325.

39. Ertzgaard P, Alwin J, Sörbo A, Lindgren M, Sandsjö L. Evaluation of a self-administered transcutaneous electrical stimulation concept for the treatment of spasticity: a randomized placebo-controlled trial. *Eur J Phys Rehabil Med.* 2018;54(4):507-517. doi:10.23736/S1973-9087.17.04791-8
40. Fernández-Tenorio E, Serrano-Muñoz D, Avendaño-Coy J, Gómez-Soriano J. Transcutaneous electrical nerve stimulation for spasticity: a systematic review. *Neurologia (Engl Ed).* 2019;34(7):451-460. doi:10.1016/j.nrl.2016.06.009
41. Andringa A, van Wegen E, van de Port I, Kwakkel G, Meskers C. Measurement properties of the neuroflexor device for quantifying neural and non-neural components of wrist hyper-resistance in chronic stroke. *Front Neurol.* 2019;10:730. doi:10.3389/fneur.2019.00730
42. Sunnerhagen KS, Olver J, Francisco GE. Assessing and treating functional impairment in poststroke spasticity. *Neurology.* 2013;80(3 Suppl 2):S35-S44. doi:10.1212/WNL.0b013e3182764aa2
43. Naro A, Leo A, Russo M, et al. Breakthroughs in the spasticity management: are non-pharmacological treatments the future? *J Clin Neurosci.* 2017;39:16-27. doi:10.1016/j.jocn.2017.02.044
44. Mills PB, Dossa F. Transcutaneous electrical nerve stimulation for management of limb spasticity: a systematic review. *Am J Phys Med Rehabil.* 2016;95(4):309-318. doi:10.1097/PHM.0000000000000437
45. de Waroquier-Leroy L, Bleuse S, Serafi R, et al. The functional reach test: strategies, performance and the influence of age. *Ann Phys Rehabil Med.* 2014;57(6-7):452-464. doi:10.1016/j.rehab.2014.03.003
46. de Graaf-Peters VB, Blauw-Hospers CH, Dirks T, Bakker H, Bos AF, Hadders-Algra M. Development of postural control in typically developing children and children with cerebral palsy: possibilities for intervention? *Neurosci Biobehav Rev.* 2007;31(8):1191-1200. doi:10.1016/j.neubiorev.2007.04.008
47. Karthikbabu S, Solomon JM, Manikandan N, Rao BK, Chakrapani M, Nayak A. Role of trunk rehabilitation on trunk control, balance and gait in patients with chronic stroke: a pre-post design. *Neurosc Med.* 2011;2(2):61-67.
48. Kim HS, Hwang JH, Jeong ST, et al. Effect of muscle activity and *Botulinum* toxin dilution volume on muscle paralysis. *Develop Med Child Neurol.* 2003;45(3):200-206. doi:10.1017/s0012162203000380
49. Park J, Seo D, Choi W, Lee S. The effects of exercise with TENS on spasticity, balance, and gait in patients with chronic stroke: a randomized controlled trial. *Med Sci Monit.* 2014;20:1890-1896. doi:10.12659/MSM.890926
50. Gravelle DC, Laughton CA, Dhruv NT, et al. Noise-enhanced balance control in older adults. *Neuroreport.* 2002;13(15):1853-1856. doi:10.1097/00001756-200210280-00004
51. Laufer Y, Dickstein R. TENS to the lateral aspect of the knees during stance attenuates postural sway in young adults. *Scient World J.* 2007;7:1904-1911. doi:10.1100/tsw.2007.279
52. Lin S, Sun Q, Wang H, Xie G. Influence of transcutaneous electrical nerve stimulation on spasticity, balance, and walking speed in stroke patients: a systematic review and meta-analysis. *J Rehabil Med.* 2018;50(1):3-7. doi:10.2340/16501977-2266
53. Sanger TD, Chen D, Delgado MR, Gaebler-Spira D, Hallett M, Mink JW. Definition and classification of negative motor signs in childhood. *Pediatrics.* 2006;118(5):2159-2167. doi:10.1542/peds.2005-3016
54. Cahill-Rowley K, Rose J. Etiology of impaired selective motor control: emerging evidence and its implications for research and treatment in cerebral palsy. *Develop Med Child Neuol.* 2014;56(6):522-528. doi:10.1111/dmcn.12355
55. Ostensjø S, Carlberg EB, Vøllestad NK. Motor impairments in young children with cerebral palsy: relationship to gross motor function and everyday activities. *Develop Med Child Neurol.* 2004;46(9):580-589. doi:10.1017/s0012162204000994
56. Voorman JM, Dallmeijer AJ, Knol DL, Lankhorst GJ, Becher JG. Prospective longitudinal study of gross motor function in children with cerebral palsy. *Arch Physic Med Rehabil.* 2007;88(7):871-876. doi:10.1016/j.apmr.2007.04.002
57. Rose J. Selective motor control in spastic cerebral palsy. *Develop Med Child Neurol.* 2009;51(8):578-579. doi:10.1111/j.1469-8749.2009.03401.x

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The relationship between isokinetic muscle strength ratios and clinical measures of shoulder stabilization and segmental power: a preliminary study

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ABSTRACT

Aims: This study aimed to investigate the relationships between various isokinetic strength ratios-including conventional concentric (CVRC) with separate velocities, conventional eccentric (CVRE), functional deceleration ratio (FDR), and mixed ratios (MR, MR_cross)-and two clinical performance measures; closed kinetic chain upper extremity stability test (CKCUEST) and Unilateral Seated Shot Put Test (USSPT).

Methods: Thirty-two asymptomatic young adults (18-40 years) were assessed using an isokinetic dynamometer (Cybex NORM®, Humac, CA, USA). Seven isokinetic ratios were calculated from peak torque values. CKCUEST and USSPT were used to measure upper extremity stabilization and power, respectively. Normality was tested via Shapiro-Wilk and histogram analysis. Pearson correlation was applied for CKCUEST, and Spearman correlation for USSPT.

Results: No isokinetic ratio was significantly correlated with CKCUEST. For USSPT, CVRC_240 showed the strongest negative correlation (ρ=-0.585, p<0.001), followed by MR_cross (ρ=0.467, p=0.007), CVRC_120 (ρ=-0.422, p=0.016), and CVRC_60 (ρ=-0.378, p=0.033).

Conclusion: CVRC_240 and MR cross ratios demonstrated moderate associations with segmental upper extremity power. These findings support their use as performance markers for ballistic functional tasks, while their lack of correlation with stabilization tests suggests different neuromechanical determinants.

Keywords: Muscle strength, shoulder joint, athletic performance, athletic trainers, athletic injuries

INTRODUCTION

The shoulder is a highly mobile and complex joint system that requires a delicate balance between mobility and stability to ensure functional performance during daily and athletic activities. Among its components, the glenohumeral joint plays a central role in allowing multiplanar movement while relying heavily on dynamic neuromuscular control to maintain stability. Unlike joints with inherent structural congruity, the glenohumeral articulation depends more on surrounding musculature and sensorimotor input to preserve joint centration under load and during high-velocity movements.[1]

Muscle performance balance is critical for functional joint integrity, particularly between the rotator cuff's external and internal rotators. Previous studies have emphasized the importance of the strength ratios between these muscle groups in maintaining joint control and preventing overuse injuries. Isokinetic dynamometry has become a widely accepted method for quantifying this muscle performance, providing objective data across different contraction types (concentric, eccentric) and angular velocities (e.g., 60°/s, 240°/s).[2-4]

Over the years, different muscle strength ratios have been used to interpret shoulder performance and identify potential muscular imbalances. The conventional ratio (ER/IR), usually calculated using peak torques from concentric contractions, is one of the most commonly used indices. However, functional ratios-which compare eccentric external rotator strength to concentric internal rotator strength-may better reflect the demands of overhead and throwing motions. More recently, mixed ratio models, involving different speeds and contraction types, have been proposed to capture the complexity of shoulder function during real-life movement patterns.[2,4-6]

Despite their widespread use, the clinical implications of these isokinetic ratios remain partially understood. While some studies have associated lower ER/IR ratios with

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shoulder dysfunction or increased injury risk, there is limited consensus on which ratios best reflect different clinical domains such as dynamic stabilization capacity or segmental power output.[7,8] Clinical functional tests such as the closed kinetic chain upper extremity stability test (CKCUEST) and the unilateral seated shot put test (USSPT) have been developed to measure these domains in a more task-specific and field-applicable manner. Still, their relationship with isokinetic ratios has not been clearly defined in asymptomatic young adults.[9,10]

This knowledge gap highlights the need to explore how specific isokinetic strength ratios correlate with clinical tests of stabilization and power, particularly in populations with no evident shoulder pathology. Such information could improve screening practices, inform rehabilitation programs, and provide normative data for performance optimization in overhead athletes and general populations.[7,11,12]

Therefore, this preliminary study aimed to investigate the relationships between selected isokinetic shoulder strength ratios-namely, conventional, functional, and mixed ratios-and two clinically relevant functional outcomes: CKCUEST and USSPT. We hypothesized that specific isokinetic ratios would demonstrate significant correlations with these performance measures, reflecting their potential as biomechanical markers for shoulder function assessment.

METHODS

Study Design and Participants

To maintain consistency in assessment, only the dominant upper limb of each participant was evaluated. Dominance was determined based on the arm preferred for writing and throwing tasks. The principles of the Declaration of Helsinki were followed in this study. Ethical approval was obtained from the Gazi University Ethics Committee (Date: 24.05.2022, Decision No: 2022-933) before data collection, and all participants provided written informed consent.

This preliminary observational study included data from 32 asymptomatic adults aged 18 to 40. All participants were free of upper extremity injury, surgery, or pain within the past six months and had not participated in structured shoulder rehabilitation or overhead throwing programs. Participants were required to be physically able to complete high-demand upper extremity tasks.

Isokinetic Testing and Strength Ratio Calculations

Isokinetic strength testing used an isokinetic dynamometer (Cybex NORM®, Humac, CA, USA). Participants were positioned supine with the shoulder in the frontal plane at 90° abduction and the elbow at 90° flexion. The range of motion was set from 50° internal to 40° external rotation.[5,8,13,14]

Each participant completed isokinetic testing for concentric contractions at 60°/s, 120°/s, and 240°/s, and eccentric contractions at 60°/s only. Each contraction type was performed for five repetitions at 60°/s and 120°/s, and 20 repetitions at 240°/s, as per the standard testing protocol. Peak torque values (Nm) were recorded for each test condition.

Based on these values, seven isokinetic strength ratios were calculated:

- Concentric external rotation/concentric internal rotation at 60 degrees per second (CVRC_60)
- Concentric external rotation/concentric internal rotation at 120 degrees per second (CVRC_120)
- Concentric external rotation/concentric internal rotation at 240 degrees per second (CVRC_240)
- Eccentric external rotation/eccentric internal rotation at 60 degrees per second (CVRE_60)
- Eccentric external rotation/concentric internal rotation at 60 degrees per second (FDR_60)
- Eccentric external rotation at 60 degrees per second/ concentric internal rotation at 240 degrees per second (MR)
- Eccentric internal rotation at 60 degrees per second/ concentric external rotation at 240 degrees per second (MR_cross)

All ratio calculations were performed after screening for outliers and missing values.

Clinical Performance Tests

CKCUEST: Participants were positioned in a modified push-up stance with hands placed 36 inches (91.4 cm) apart. They were instructed to alternately touch the opposite hand as many times as possible within 15 seconds. The total number of touches was recorded and used as the stability score.

By standard sex-specific procedures, the test was performed in a modified push-up position (knees on the ground) for female participants, and in a standard push-up position for male participants.[15-17]

One-arm seated medicine ball throw test (USSPT): Participants were seated with their backs supported and instructed to throw a 3-kg medicine ball using a single arm, in a forward direction, with maximal effort. Each participant completed three trials, and the farthest distance (in centimeters) was used as the final score. This test served as a measure of unilateral upper extremity segmental power.[18,19]

Statistical Analysis

All data analyses were performed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test, skewness–kurtosis values, and visual inspection of histograms and Q-Q plots.

USSPT scores were found to be non-normally distributed. All isokinetic strength ratios and CKCUEST scores followed normal distribution.

As a result:

- Pearson correlation was used to explore the relationship between strength ratios and CKCUEST scores.
- Spearman correlation was applied to compare the involvement of USSPT.

Statistical significance was set at $p<0.05$ for all analyses.

RESULTS

Descriptive Statistics and Normality Testing

The sample included 32 asymptomatic adults (16 females and 16 males; mean age: 24.9±3.5 years). All assessments were conducted on the dominant side, determined by self-reported writing and throwing preference.

Normality testing was performed for each variable using a combination of the Shapiro-Wilk test, skewness-kurtosis indices, histogram distributions, and Q-Q plots. The USSPT was found to be non-normally distributed ($p=0.000$), while CKCUEST scores and all isokinetic strength ratios exhibited normal distribution characteristics ($p>0.05$).

Correlational Analysis: CKCUEST and Isokinetic Ratios

Given the normal distribution of CKCUEST scores, Pearson's correlation analysis was conducted between CKCUEST and the isokinetic strength ratios, as shown in Table 1.

Table 1. Pearson's correlation analysis results between CKCUEST and isokinetic strength ratios

Isokinetic ratio	r (Pearson)	p-value	Interpretation
CVRC_60	-0.254	0.161	No significant correlation
CVRC_120	-0.284	0.115	No significant correlation
CVRC_240	-0.190	0.299	No significant correlation
CVRE_60	-0.149	0.416	No significant correlation
FDR_60	-0.233	0.200	No significant correlation
MR	-0.109	0.553	No significant correlation
MR_cross	0.134	0.465	No significant correlation

CVRC_60: Concentric external rotation/concentric internal rotation at 60 degrees per second, CVRC_120: Concentric external rotation/concentric internal rotation at 120 degrees per second, CVRC_240: Concentric external rotation/concentric internal rotation at 240 degrees per second, CVRE_60: Eccentric external rotation/eccentric internal rotation at 60 degrees per second, FDR_60: Eccentric external rotation/concentric internal rotation at 60 degrees per second, MR: Eccentric external rotation at 60 degrees per second/concentric internal rotation at 240 degrees per second, MR_cross: Eccentric internal rotation at 60 degrees per second/concentric external rotation at 240 degrees per second

These results indicate that none of the isokinetic ratios were significantly associated with shoulder stabilization performance as measured by the CKCUEST.

Correlational Analysis: USSPT and Isokinetic Ratios

Due to the non-normal distribution of USSPT data, Spearman's rho correlation analysis was used. The results are presented in Table 2.

Table 2. Spearman's rho correlation analysis results between USSPT and isokinetic strength ratios

Isokinetic ratio	ρ (Spearman)	p-value	Interpretation
CVRC_60	-0.378	0.033	Significant, moderate negative
CVRC_120	-0.422	0.016	Significant, moderate negative
CVRC_240	-0.585	0.000	Significant, strong negative
CVRE_60	-0.276	0.127	No significant correlation
FDR_60	-0.316	0.078	No significant correlation
MR	-0.255	0.158	No significant correlation
MR_cross	0.467	0.007	Significant, moderate positive

CVRC_60: Concentric external rotation/concentric internal rotation at 60 degrees per second, CVRC_120: Concentric external rotation/concentric internal rotation at 120 degrees per second, CVRC_240: Concentric external rotation/concentric internal rotation at 240 degrees per second, CVRE_60: Eccentric external rotation/concentric internal rotation at 60 degrees per second, FDR_60: Eccentric external rotation/concentric internal rotation at 60 degrees per second, MR: Eccentric external rotation at 60 degrees per second/concentric internal rotation at 240 degrees per second, MR_cross: Eccentric internal rotation at 60 degrees per second/concentric external rotation at 240 degrees per second

The strongest correlation was observed between USSPT scores and the CVRC_240 ratio ($\rho=-0.585$, $p<0.001$), followed by MR_cross ($\rho=0.467$, $p=0.007$). CVRC_60 and CVRC_120 also demonstrated moderate negative correlations with segmental power output.

Interpretation of Results

The findings revealed that concentric strength imbalances, particularly at high angular velocities (240°/s), were significantly associated with segmental power output, while eccentric and mixed ratios showed weaker or no associations. No meaningful relationships were observed between stabilization performance and any of the isokinetic ratios. These results suggest that isokinetic strength ratios may provide greater insight into segmental power capacity than dynamic stabilization ability in asymptomatic populations.

DISCUSSION

This preliminary investigation aimed to explore the relationship between various isokinetic shoulder strength ratios-including conventional (CVRC_60, CVRC_120, CVRC_240), eccentric (CVRE_60), functional deceleration (FDR_60), and mixed ratios (MR, MR_cross)-and clinical measures of shoulder stabilization and segmental power as assessed by CKCUEST and USSPT, respectively.

The most notable finding was the significant moderate negative correlation between CVRC_240 and USSPT ($r_s=-0.460$, $p<0.01$), suggesting that increased strength imbalance at higher angular velocities may negatively influence segmental power output. This observation aligns with prior evidence indicating that muscle imbalances at high velocities could compromise performance in explosive tasks requiring rapid force production and neuromuscular efficiency.[20,21]

Additionally, MR_cross, which involves cross-mode and cross-velocity comparison (eccentric IR at 60°/s over concentric ER at 240°/s), showed a moderate positive correlation with USSPT ($r_s=0.404$, $p<0.05$). This highlights the potential relevance of eccentric IR capacity in conjunction with high-speed concentric ER during ballistic throwing-like movements. Similar mixed-mode models have been proposed in the literature to better approximate functional joint demands.[5,22,23]

Contrary to expectations, none of the strength ratios correlated significantly with the CKCUEST performance. While previous research has demonstrated moderate associations between rotator cuff strength and closed-chain functional stability tests,[24,25] the absence of correlation in the present study may be explained by the broader involvement of trunk and scapular musculature in CKCUEST, reducing its sensitivity to isolated glenohumeral rotation strength. Moreover, the push-up-based task may rely more heavily on stabilization and endurance of proximal stabilizers than segmental torque ratios.[26,27]

Regarding the functional deceleration ratio (FDR_60), no significant association was observed with either USSPT or CKCUEST. While functional ratios are conceptually meaningful, their applicability may depend on the task's movement specificity and angular velocity demands.[5,28,29] The FDR_60 calculation-based on eccentric ER and concentric IR at 60°/-may not adequately reflect the dynamic shoulder control mechanisms required in the tests used.

Interestingly, both CVRC_60 and CVRC_120 failed to demonstrate significant relationships with either performance test, suggesting that conventional strength ratios at lower speeds may have limited predictive utility for functional capacity in healthy young adults. This aligns with prior findings emphasizing the contextual relevance of strength assessment protocols, particularly in asymptomatic populations.[30,31]

The results suggest that high-velocity and mixed-mode strength ratios, particularly CVRC_240 and MR_cross, may offer greater functional relevance in predicting segmental power outcomes, as measured by unilateral medicine ball throwing. However, their lack of association with stabilization performance indicates that different neuromechanical properties underlie these constructs.

Limitations

This preliminary study has several limitations that should be considered when interpreting the findings. First, the sample size was relatively small and limited to asymptomatic young adults, which may restrict the generalizability of the results to clinical populations. Second, only the dominant shoulder of each participant was assessed, preventing bilateral comparisons. Third, the analysis was cross-sectional, based solely on pretest isokinetic strength data, and therefore does not reflect longitudinal adaptations. Moreover, the study included only two clinical performance tests (CKCUEST and USSPT), which may not capture the full spectrum of shoulder function, particularly proprioceptive or scapular control components. Future studies with larger and more diverse samples, as well as additional functional assessments, are recommended.

CONCLUSION

This preliminary study demonstrated that among various isokinetic shoulder strength ratios, the high-velocity concentric conventional ratio (CVRC_240) and the cross-mode mixed ratio (MR_cross) were moderately associated with segmental upper extremity power, as assessed by the USSPT. These findings suggest that strength asymmetries may influence dynamic force output during functional unilateral tasks, particularly at higher speeds and across contraction types. In contrast, no meaningful associations were observed between the ratios and stabilization performance measured by CKCUEST, indicating a potential divergence between torque production and closed-chain stability capacity. These results highlight the selective predictive value of specific isokinetic ratios in assessing shoulder performance in asymptomatic young adults. Future studies involving symptomatic populations and task-specific strength assessments may further clarify the clinical utility of such indices in performance monitoring and rehabilitation planning.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Gazi University Ethics Committee (Date: 24.05.2022, Decision No: 2022-933).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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REFERENCES

1. Ager AL, Borms D, Bernaert M, et al. Can a conservative rehabilitation strategy improve shoulder proprioception? A systematic review. *J Sport Rehabil*. 2020;30(1):136-151. doi:10.1123/jsr.2019-0400
2. Noffal GJ. Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and nonthrowers. *Am J Sports Med*. 2003;31(4):537-541. doi:10.1177/03635465030310041001
3. Tooth C, Gofflot A, Schwartz C, et al. Risk factors of overuse shoulder injuries in overhead athletes: a systematic review. *Sports Health*. 2020; 12(5):478-487. doi:10.1177/1941738120931764
4. Berckmans K, Maenhout AG, Matthijs L, Pieters L, Castelein B, Cools AM. The isokinetic rotator cuff strength ratios in overhead athletes: assessment and exercise effect. *Phys Ther Sport*. 2017;27:65-75. doi:10.1016/j.ptsp.2017.03.001
5. Yildiz Y, Aydin T, Sekir U, Kiralp MZ, Hazneci B, Kalyon TA. Shoulder terminal range eccentric antagonist/concentric agonist strength ratios in overhead athletes. *Scand J Med Sci Sports*. 2006;16(3):174-180. doi:10.1111/j.1600-0838.2005.00471.x
6. Wilkinson MS, Guy JH, Obst SJ. Isokinetic shoulder strength and its associations to ınjury in tactical populations: a critical review. *Int J Exerc Sci*. 2024;17(3):235-251. doi:10.70252/TDKV8862
7. Barbosa GM, Calixtre LB, Fonseca Fialho HR, Locks F, Kamonseki DH. Measurement properties of upper extremity physical performance tests in athletes: a systematic review. *Braz J Phys Ther*. 2024;28(1):100575. doi:10.1016/j.bjpt.2023.100575
8. Leahy I, Florkiewicz E, Shotwell MP. Isokinetic dynamometry for external and internal rotation shoulder strength in youth athletes: a scoping review. *Int J Sports Phys Ther*. 2024;19(12):1521-1531. doi:10.26603/001c.125765
9. Declève P. Analytical and Functional Assessment of the Athlete's Shoulder Ghent University; 2021. Accessed 27.07.2025. https://www.epauleautop.com/wp-content/uploads/2020/10/24082021_These-P.-Decleve.pdf
10. Secchi LLB, Kamonseki DH, Camargo PR, Mendonça LM. Is the isometric strength of the shoulder associated with functional performance tests in overhead athletes?. *Phys Ther Sport*. 2022;55:131-138. doi:10.1016/j.ptsp.2022.03.007
11. Waldhelm A, Aida J, Boyd J, et al. Relationship between shoulder rotation strength and upper extremity functional assessments in collegiate baseball players. *J Funct Morphol Kinesiol*. 2025;10(2):120. doi:10.3390/jfmk10020120
12. Lobo JD, Motimath B, Chivate D. Correlation between shoulder external-internal rotation strength ratio and throwing accuracy in cricketers: an observational study. *Age (yrs)*. 2025;20(2):77.
13. Habets B, Staal JB, Tijssen M, van Cingel R. Intrarater reliability of the Humac NORM isokinetic dynamometer for strength measurements of the knee and shoulder muscles. *BMC Res Notes*. 2018;11(1):15. doi:10.1186/s13104-018-3128-9
14. Saccol MF, Gracitelli GC, da Silva RT, et al. Shoulder functional ratio in elite junior tennis players. *Phys Ther Sport*. 2010;11(1):8-11. doi:10.1016/j.ptsp.2009.11.002
15. Tucci HT, Martins J, Sposito Gde C, Camarini PM, de Oliveira AS. Closed kinetic chain upper extremity stability test (CKCUES test): a reliability study in persons with and without shoulder impingement syndrome. *BMC Musculoskelet Disord*. 2014;15:1. doi:10.1186/1471-2474-15-1
16. Torabi TP, Bencke J, van den Tillaar R. The closed kinetic chain upper extremity stability test (CKCUEST) performance in elite team handball players playing with shoulder pain, previous pain, or no pain. *Int J Sports Phys Ther*. 2024;19(2):189-198. doi:10.26603/001c.92014

17. Heick JD, Haggerty J, Manske RC. A Comparison of resting scapular posture and the davies closed kinetic chain upper extremity stability test. *Int J Sports Phys Ther*. 2021;16(3):835-843. doi:10.26603/001c.23425
18. Linkovski M, Lewis J, Sarig Bahat H. Validity and feasibility of the seated medicine ball throw and unilateral shot-put tests in assessing upper extremity function in rotator-cuff-related shoulder pain. *Appl Sci*. 2024;14(24):12038. doi:10.3390/app142412038
19. Chmielewski TL, Martin C, Lentz TA, et al. Normalization considerations for using the unilateral seated shot put test in rehabilitation. *J Orthop Sports Phys Ther*. 2014;44(7):518-524. doi:10.2519/jospt.2014.5004
20. Hadjisavvas S, Efstathiou MA, Themistocleous IC, et al. Can resistance training improve throwing performance in handball players? A systematic review and meta-analysis. *BMC Sports Sci Med Rehabil*. 2024;16(1):85. doi:10.1186/s13102-024-00872-y
21. Roach NT, Lieberman DE. Upper body contributions to power generation during rapid, overhand throwing in humans. *J Exp Biol*. 2014;217(Pt 12):2139-2149. doi:10.1242/jeb.103275
22. Agrebi B, Dhahbi W, Abidi H, et al. Isokinetic peak torque improvement and shoulder muscle ratios ımbalance correction after specific strength training on a new ballistic throwing device: a randomized controlled trial. *J Sport Rehabil*. 2024;33(6):423-436. doi:10.1123/jsr.2023-0253
23. Forthomme B, Crielaard JM, Forthomme L, Croisier JL. Field performance of javelin throwers: relationship with isokinetic findings. *Isokinet Exercis Sci*. 2007;15(3):195-202. doi:10.3233/IES-2007-0273
24. Schilling DT, Elazzazi AM. Shoulder strength and closed kinetic chain upper extremity stability test performance in division III collegiate baseball and softball players. *Int J Sports Phys Ther*. 2021;16(3):844-853. doi:10.26603/001c.24244
25. Decleve P, Van Cant J, De Buck E, Van Doren J, Verkouille J, Cools AM. The self-assessment corner for shoulder strength: reliability, validity, and correlations with upper extremity physical performance tests. *J Athl Train*. 2020;55(4):350-358. doi:10.4085/1062-6050-471-18
26. Palmer TG. Effects of proximal stability training on sport performance and proximal stability measures. 2012.
27. Arghadeh R, Alizadeh MH, Minoonejad H, Sheikhhoseini R, Asgari M, Jaitner T. Electromyography of scapular stabilizers in people without scapular dyskinesis during push-ups: a systematic review and meta-analysis. *Front Physiol*. 2023;14:1296279. doi:10.3389/fphys.2023.1296279
28. Vargas VZ, Motta C, Vancini RL, Barbosa de Lira CA, Andrade MS. Shoulder isokinetic strength balance ratio in overhead athletes: a cross-sectional study. *Int J Sports Phys Ther*. 2021;16(3):827-834. doi:10.26603/001c.22162
29. Mayer F, Baur H, Hirschmüller A, Heitkamp H, Horstmann T, Dickhuth H. The quantification of reciprocal shoulder strength relation in various working modes at different movement velocities. *Isokinet Exercis Sci*. 2001;9(2-3):73-77. doi:10.3233/IES-2001-0068
30. Land H, Gordon S. What is normal isokinetic shoulder strength or strength ratios? A systematic review. *Isokinet Exercis Sci*. 2011;19(4):231-241. doi:10.3233/IES-2011-0427
31. Mak N, Howe S, Monkman E, Pemberton M, Whiffin E, Samuel D. The relationship between muscle strength, balance and functional ability in recreationally active young adults. *Physiotherapy*. 2024;123:e78-e79.

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Original Article

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Acute effects of rigid shoulder taping in patients with cervical disc herniation

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ABSTRACT

Aims: This study aimed to investigate the acute effects of non-elastic taping applied to the shoulder on the painful side in individuals with cervical disc herniation, focusing on pain and range of motion (ROM).

Methods: Forty participants were randomly assigned to two groups; study group (n=20) and control group (n=20). Both groups received a conventional physiotherapy program including TENS, vacuum interferential current, hot pack, and ultrasound. The control group received no additional intervention. The study group received one session of non-elastic taping applied to the painful side shoulder in addition to conventional physiotherapy. Pain was assessed using the Visual Analog Scale (VAS), and cervical ROM was measured with a universal goniometer before and after the intervention.

Results: Within-group comparisons revealed statistically significant improvements in pain and ROM in both groups ($p<0.01$). Although pain reduction was observed in both groups, no statistically significant difference was found between them ($p>0.05$). Similarly, no significant differences were observed between groups in any cervical ROM measurements before and after the intervention ($p>0.05$).

Conclusion: The findings showed that pain was reduced and ROM was increased in both groups, but there was no significant difference between them. Further studies with larger sample sizes and long-term follow-ups are recommended to evaluate the effects of non-elastic taping.

Keywords: Pain, taping, range of motion, cervical disc herniation

INTRODUCTION

Intervertebral discs are cartilaginous structures located between adjacent vertebrae that function as shock absorbers, supporting the spine against axial loading.[1] Anatomically, they consist of three components: the centrally located nucleus pulposus, the outer annulus fibrosus, and the endplates that anchor the disc to the adjacent vertebral bodies.[2] Disc herniation is a pathological condition characterized by the partial or complete protrusion of the nucleus pulposus through the annulus fibrosus. This condition may manifest either acutely often due to trauma or chronically, typically resulting from degenerative changes such as reduced proteoglycan content and loss of hydration, leading to weakening of the nucleus pulposus. Acute herniations tend to produce more severe and sudden symptoms compared to chronic cases, due to extrusion of the nucleus through a defect in the annular ring. Cervical disc herniation can result in significant functional impairments. It most frequently occurs at the C5-C6 and C6-C7 intervertebral levels, thereby producing symptoms corresponding to the C6 and C7 nerve roots, respectively. Patients with cervical disc herniation often experience neck pain, reduced cervical range of motion (ROM), and functional limitations.[2]

The most common subjective complaints include ipsilateral arm pain or paresthesia along the corresponding dermatome. A comprehensive neurological examination is required to assess sensory deficits, motor weakness, and abnormalities in deep tendon reflexes.[3] Although surgical interventions are available, numerous conservative treatment options are commonly employed.[4] Conservative treatment remains the first-line approach, with non-surgical methods such as oral neuropathic pain medications, physical therapy, and epidural steroid injections forming the basis of symptom management. In addition, clinicians often incorporate taping techniques to manage pain and edema and to provide functional support.[5] Taping is a widely utilized method in clinical settings for both injury prevention and rehabilitation.[6] It restricts unwanted joint movements while allowing or facilitating desired ones. Another proposed mechanism is the enhancement of proprioceptive feedback through increased sensory input.[7] Two primary types of tape are used in clinical practice for

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biomechanical support: rigid (non-elastic) adhesive tape[6] and elastic therapeutic tape.[8] Rigid tape provides superior support and joint positioning compared to elastic tape, as it aims to maintain the joint in a defined position while still allowing functional movement.[5]

Therapeutic taping has demonstrated short-term clinical efficacy in managing certain musculoskeletal disorders, including pain reduction,[9,10] improvement in ROM,[11] and gait enhancement.[12] However, the exact mechanisms underlying its therapeutic effects are still not fully understood.[10,12] Neuroplastic changes have been observed in individuals with musculoskeletal pathologies,[13] though the extent to which such changes influence regional kinematics and neuromuscular control remains unclear. These mechanisms are thought to involve neuromuscular or non-cortical neurological pathways rather than alterations in corticospinal excitability.[11]

The aim of this study was to investigate the acute effects of non-elastic taping applied to the painful-side shoulder in individuals with cervical disc herniation, focusing on its impact on pain intensity and cervical ROM. We hypothesized that maintaining the shoulder in a passively elevated position with rigid tape would reduce neural tension caused by the disc pathology, thereby alleviating pain and improving range of motion.

METHODS

Ethical Considerations

The study was approved by the Üsküdar University Non-interventional Researches Ethics Committee (Date: 23.02.2023, Decision No: 61351342/2023-51) and conducted in the Physical Therapy and Rehabilitation Department of Kadıköy Medicana Hospital between March and August 2023. The study adhered to the principles of the Declaration of Helsinki.

Informed Consent

This study was conducted in accordance with ethical principles, and written and verbal informed consent was obtained from all participants prior to their inclusion. Participants were informed about the study's purpose, procedures, potential risks, and benefits. They were assured that participation was voluntary and that they could withdraw at any time.

Study Design

This study was designed as a prospective, randomized controlled trial.

Participants

The study included 40 volunteers who met the inclusion criteria. Participants were required to be between the ages of 18 and 60 and have a confirmed diagnosis of cervical disc herniation. Individuals with coexisting cervical pathologies, cognitive or visual impairments, or skin hypersensitivity were excluded from the study.

Prior to randomization, all participants received baseline assessments. A blinded independent researcher randomly allocated participants into either the study or control group using a computer-generated simple randomization list.

Data Collection Tools and Procedures

Intervention program: Both groups received a conventional physiotherapy program consisting of transcutaneous electrical nerve stimulation (TENS, 20 min), vacuum interferential current therapy (20 min), hot pack application (20 min), and therapeutic ultrasound (5 min). No additional intervention was administered to the control group.

The study group received one additional session of non-elastic taping applied to the shoulder on the painful side following the physiotherapy session. The tape was kept in place for 30 minutes while participants remained seated without performing any physical activity. Post-intervention measurements were taken immediately after the tape was removed.

Pain levels were evaluated using the Visual Analog Scale (VAS), and cervical ROM was assessed using a universal goniometer, both before and after the intervention.

Taping procedure: Taping was performed in a seated position after the completion of physiotherapy. Two types of tape were used; Rollfix (hypoallergenic, applied underneath) and Rollipek (rigid, applied on top). The tape was initially applied over the middle deltoid muscle, and while passively elevating the patient's arm, it was extended and fixed over the cervicothoracic junction region while maintaining tension (**Figure**). VAS and goniometric assessments were repeated after the taping. No allergic reactions were observed in any participants during the procedure.

Figure. Application of non-elastic taping to the shoulder region

Socio-Demographic and Clinical Information Form: This form collected socio-demographic and clinical data from all participants, including age, height, weight, body-mass index (BMI), educational level, alcohol and tobacco use, duration of complaints, side of pain, and medical history. Comorbidities were also evaluated to ensure eligibility.

Visual Analog Scale (VAS): Pain intensity before and after the intervention was assessed using the Visual Analog Scale. The VAS consists of a horizontal line anchored by two verbal descriptors at each end, where participants mark a point that best represents their current level of perceived pain.[14]

Range of motion (ROM) measurement: Cervical ROM measurements were taken before and after the intervention using a universal goniometer. ROM assessment is a widely used musculoskeletal evaluation method employed by physiotherapists to objectively assess joint function, asymmetry, and treatment effectiveness.[15] Due to its ease of use, low cost, and established reliability and validity in numerous studies, the universal goniometer remains a preferred tool in clinical settings for ROM evaluation.[16]

Statistical Analysis

All data analyses were performed using SPSS version 25.0 for Windows (SPSS Inc., IBM Corp., Armonk, NY). Descriptive statistics were calculated using means and standard deviations (SD) for continuous variables, and frequency analyses were used for nominal and binary data. The normality of the data distribution was assessed with the one-sample Kolmogorov-Smirnov test and histogram inspection. The Wilcoxon signed-rank test was used for within-group comparisons before and after taping. Independent samples T tests were used for between-group comparisons. Statistical significance was set at $p<0.05$.

RESULTS

The socio-demographic characteristics of the participants are presented in Table 1. There were no statistically significant differences between the study and control groups in terms of age, height, or weight ($p>0.05$).

Table 1. Socio-demographic characteristics of the participants

		Study group (n=20)	Control group (n=20)	
		n (%)	n (%)	
Sex	Female	13 (65)	10 (50)	
	Male	7 (35)	10 (50)	
Education level	High school	4 (20)	3 (15)	
	University	16 (80)	17 (85)	
Alcohol use	Yes	8 (40)	7 (35)	
	No	12 (60)	13 (65)	
Smoking	Yes	13 (65)	13 (65)	
	No	7 (35)	7 (35)	
Painful side	Right	12 (60)	13 (65)	
	Left	8 (40)	7 (35)	
Complaint duration	1 week	2 (10)	4 (20)	
	2 weeks	8 (40)	3 (15)	
	3 weeks	5 (25)	7 (35)	
	4 weeks	5 (25)	6 (30)	
		Mean±SD	Mean±SD	p
Age (years)		37.75±8.45	39.35±11.13	0.081
Height (cm)		148.15±57.22	133.40±69.27	0.128
Weight (kg)		71.35±11.32	72.20±12.46	0.694

SD: Standard deviation

In group and inter-group comparisons for pain severity and cervical ROM are presented in Table 2. A statistically significant improvement was observed in pain and ROM within both groups following treatment ($p<0.01$). While both groups experienced a reduction in pain severity, no statistically significant difference was found between the groups ($p>0.05$). Similarly, no statistically significant inter-group differences were observed in any of the cervical ROM measurements before and after treatment ($p>0.05$).

Table 2. Within-group and between-group comparisons of pain and ROM

Variable		Study group (n=20) Mean±SD	Study group p	Control group (n=15) Mean±SD	Control group p	p
VAS	Pre-treatment	5.35±2.10	<0.01	5.15±2.53	<0.01	0.783
	Post-treatment	2.35±1.56		3.30±2.05		0.118
Flexion (°)	Pre-treatment	38.60±7.40	<0.01	39.70±7.48	<0.01	0.606
	Post-treatment	43.25±5.89		43.65±5.10		0.989
Extension (°)	Pre-treatment	37.35±7.76	<0.01	38.20±6.44	<0.01	0.786
	Post-treatment	41.65±6.86		41.45±5.23		0.644
Lateral flexion (right) (°)	Pre-treatment	35.10±5.49	<0.01	34.35±5.73	<0.01	0.663
	Post-treatment	39.05±6.21		36.70±4.13		0.186
Lateral flexion (left) (°)	Pre-treatment	35.40±5.73	<0.01	34.20±6.24	<0.01	0.549
	Post-treatment	39.25±3.62		38.20±5.43		0.565
Rotation (right) (°)	Pre-treatment	71.65±8.52	<0.01	72.30±9.13	<0.01	0.806
	Post-treatment	75.60±7.52		75.80±7.00		0.946
Rotation (left) (°)	Pre-treatment	71.30±9.35	<0.01	73.05±8.30	<0.01	0.567
	Post-treatment	75.85±7.46		76.85±7.11		0.595

ROM: Range of motion, VAS: Visual Analog Scale, SD: Standard deviation

DISCUSSION

This study aimed to evaluate the acute effects of non-elastic taping applied to the shoulder on the painful side in individuals with cervical disc herniation, specifically regarding pain intensity and cervical ROM. The results demonstrated a significant reduction in pain and improvement in ROM within both the intervention and control groups; however, no statistically significant differences were found between the two groups.

Neck pain is recognized as a major global public health concern,[17,18] with the cervical intervertebral disc considered a common source of neck pain,[19,20] In cases of cervical disc herniation-with or without radiculopathy-conservative treatment is typically the first-line approach. Various non-surgical treatment modalities are available, supported by varying levels of scientific evidence. These include oral medications, injections, physiotherapy, cervical collars, manual therapy, and acupuncture. Despite the lack of strong consensus regarding specific exercise combinations, physiotherapy remains a primary treatment method for patients presenting with neck pain and/or radicular symptoms not requiring surgical intervention.[21] For this reason, pain was selected as the primary outcome in the current study.

Among conservative treatment options, taping is a therapeutic method commonly used by physiotherapists for the prevention and management of musculoskeletal conditions, including spinal pain.[22,23] Although taping techniques are widely used in clinical practice, their efficacy remains under investigation due to inconsistent evidence.[24] One study examined the effects of both elastic and non-elastic taping on spinal pain and disability, aiming to determine their effectiveness relative to other interventions. Elastic taping was shown to have low-level evidence when compared to placebo and moderate-level evidence compared to no treatment in patients with neck pain. In contrast, non-elastic taping demonstrated only a small effect on pain and was supported by low-level evidence when compared to no treatment.[24]

In a study investigating kinesio taping in patients with cervical radiculopathy, the addition of kinesio taping to conventional treatment was associated with reduced neck pain, decreased disability, and improved upper extremity function.[25] Another study involving patients with non-specific neck pain showed that kinesio taping led to significant improvements in pain and disability; however, no statistically significant differences were observed in cervical ROM when compared to an exercise-only group.[26] Current literature suggests that kinesio taping is primarily used to alleviate pain, reduce swelling and disability, and improve circulation. Non-elastic taping, on the other hand, stands out due to its supportive and positional correction properties. McConnell, for example, utilized non-elastic taping to support the patella and maintain it in the proper position in patients with patellofemoral pain syndrome.[27] This method has also been applied to the shoulder and hip joints.[5] One study reported an acute increase in shoulder flexion and abduction ROM following McConnell taping,[11] although the effect was not sustained at 24-hour follow-up, suggesting a primarily mechanical effect. In contrast, our study may have provided not only mechanical support but also a reduction in neural tension at the nerve root, thus offering a neurophysiological benefit as well. In a study investigating patients with shoulder pain and limited ROM, mobilization techniques with and without taping were compared. Both groups demonstrated significant acute improvements; however, improvements were more persistent in the taping group during a one-week follow-up.[28] Similarly, in a study involving stroke patients, modified Mulligan techniques with and without taping were compared, showing significant improvements in both active and passive ROM in both groups.[29]

The limited number of studies focusing specifically on non-elastic taping is noteworthy. This study may contribute to the literature by addressing this gap. Non-elastic taping is one of the earliest taping methods and is still used as an adjunct in the management of musculoskeletal injuries. Its mechanism of action is thought to involve increased proprioception and mechanical support for joint protection.[24] Given the rationale for using non-elastic taping by McConnell and Mulligan, this method could be explored in greater detail as a potential intervention for cervical disc herniation. Patients with cervical disc herniation are often evaluated using inhibition tests, one of which is the shoulder abduction test. This test reduces tension on the nerve root and can alleviate pain, particularly in cases involving lower cervical radiculopathy. In such cases, lifting the arm often results in symptom relief. According to a case report, the shoulder abduction test can serve not only as a diagnostic tool but also as a conservative intervention strategy for patients with cervical radiculopathy involving the lower cervical nerve roots.[30]

Limitations

One of the main limitations of this study was the inability to use gold-standard objective measurement tools for the evaluated parameters-namely, pain and ROM. Due to financial constraints and practical considerations, pain was assessed using the VAS, and ROM was measured using a traditional universal goniometer. For future research, the use of more sensitive and advanced tools such as three-dimensional motion analysis systems is recommended. These technologies may enhance the reliability of the findings and provide more clinically applicable insights.

CONCLUSION

In the intervention group of our study, non-elastic taping was applied in a manner consistent with the shoulder abduction relief test. The painful-side shoulder was passively elevated to reduce tension on the nerve roots, and this position was maintained using non-elastic tape. Acute outcomes showed a reduction in pain and an increase in cervical ROM in the taped group. However, there were no statistically significant differences between the intervention and control groups, both of which received conventional physiotherapy. Non-elastic taping can be considered a simple, cost-effective, and easily applicable method that may serve as an adjunct to rehabilitation programs. In our study assessing the acute effects of non-elastic taping on pain and ROM, no superiority was found over standard conservative treatment alone. However, considering the mechanism of action-mechanical support and enhanced proprioception-non-elastic taping may offer improved clinical outcomes over the long term when integrated into conservative therapy programs. We believe that future studies with larger sample sizes and longer follow-up periods are necessary to further explore and support the clinical utility of non-elastic taping. It is also recommended that future research include functional outcome measures specific to the cervical region. A better understanding of the underlying kinematic and neuroplastic mechanisms involved in cervical taping may help refine intervention strategies using this method.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of the Üsküdar University Non-interventional Researches Ethics Committee (Date: 23.02.2023, Decision No: 61351342/2023-51).

Informed Consent

All patients signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Waxenbaum JA, Reddy V, Futterman B. Anatomy, back, intervertebral discs. 2017.
2. Caridi JM, Pumberger M, Hughes AP. Cervical radiculopathy: a review. *HSS J.* 2011;7(3):265-272. doi:10.1007/s11420-011-9218-z
3. Dydyk AM, Mesfin F. Disc herniation. 2017.
4. Ho A, Desai AM. Intervertebral Disc Degeneration. Nova Science Publishers, Incorporated; 2016.
5. Constantinou M, Brown M. Therapeutic taping for musculoskeletal conditions-E-Book. Elsevier Health Sciences; 2010.
6. Bahr R. Principles of injury prevention. Clinical Sports Medicine, 3rd ed Australia: McGraw-Hill. 2006;96
7. Matheus JP, Zille RR, Gomide Matheus LB, Lemos TV, Carregaro RL, Shimano AC. Comparison of the mechanical properties of therapeutic elastic tapes used in sports and clinical practice. *Phys Ther Sport.* 2017; 24:74-78. doi:10.1016/j.ptsp.2016.08.014
8. McNeill W, Pedersen C. Dynamic tape. Is it all about controlling load? *J Bodyw Mov Ther.* 2016;20(1):179-188. doi:10.1016/j.jbmt.2015.12.009
9. Kaya E, Zinnuroglu M, Tugcu I. Kinesio taping compared to physical therapy modalities for the treatment of shoulder impingement syndrome. *Clin Rheumatol.* 2011;30(2):201-207. doi:10.1007/s10067-010-1475-6
10. Miller P, Osmotherly P. Does scapula taping facilitate recovery for shoulder impingement symptoms? A pilot randomized controlled trial. *J Man Manip Ther.* 2009;17(1):E6-E13. doi:10.1179/jmt.2009.17.1.6E
11. Snodgrass SJ, Farrell SF, Tsao H, et al. Shoulder taping and neuromuscular control. *J Athl Train.* 2018;53(4):395-403. doi:10.4085/1062-6050-68-17
12. Kneeshaw D. Shoulder taping in the clinical setting. *J Bodywork Movement Ther.* 2002;6(1):2-8.
13. Ngomo S, Mercier C, Bouyer LJ, Savoie A, Roy JS. Alterations in central motor representation increase over time in individuals with rotator cuff tendinopathy. *Clin Neurophysiol.* 2015;126(2):365-371. doi:10.1016/j.clinph.2014.05.035
14. Wewers ME, Lowe NK. A critical review of visual analogue scales in the measurement of clinical phenomena. *Res Nurs Health.* 1990;13(4):227-236. doi:10.1002/nur.4770130405
15. Milanese S, Gordon S, Buettner P, et al. Reliability and concurrent validity of knee angle measurement: smart phone app versus universal goniometer used by experienced and novice clinicians. *Man Ther.* 2014; 19(6):569-574. doi:10.1016/j.math.2014.05.009
16. Brosseau L, Tousignant M, Budd J, et al. Intratester and intertester reliability and criterion validity of the parallelogram and universal goniometers for active knee flexion in healthy subjects. *Physiother Res Int.* 1997;2(3):150-166. doi:10.1002/pri.97
17. Fejer R, Kyvik KO, Hartvigsen J. The prevalence of neck pain in the world population: a systematic critical review of the literature. *Eur Spine J.* 2006;15(6):834-848. doi:10.1007/s00586-004-0864-4
18. Manchikanti L, Boswell MV, Singh V, et al. Comprehensive evidence-based guidelines for interventional techniques in the management of chronic spinal pain. *Pain Physician.* 2009;12(4):699-802.
19. Fujimoto K, Miyagi M, Ishikawa T, et al. Sensory and autonomic innervation of the cervical intervertebral disc in rats: the pathomechanics of chronic discogenic neck pain. *Spine (Phila Pa 1976).* 2012;37(16):1357-1362. doi:10.1097/BRS.0b013e31824ba710
20. Yang L, Yang C, Pang X, et al. Mechanoreceptors in diseased cervical intervertebral disc and vertigo. *Spine (Phila Pa 1976).* 2017;42(8):540-546. doi:10.1097/BRS.0000000000001801
21. Greis AC, Young GW, Usman-Oyowe I. Nonoperative management of cervical disc herniations: an evidence-based approach. *Semin Spine Surg.* 2016;28(2):68-74. doi:10.1053/j.semss.2015.11.008
22. Alexander CM, Stynes S, Thomas A, Lewis J, Harrison PJ. Does tape facilitate or inhibit the lower fibres of trapezius? *Man Ther.* 2003;8(1):37-41. doi:10.1054/math.2002.0485
23. Morris D, Jones D, Ryan H, Ryan CG. The clinical effects of Kinesio® tex taping: a systematic review. *Physiother Theory Pract.* 2013;29(4):259-270. doi:10.3109/09593985.2012.731675
24. Vanti C, Bertozzi L, Gardenghi I, Turoni F, Guccione AA, Pillastrini P. Effect of taping on spinal pain and disability: systematic review and meta-analysis of randomized trials. *Phys Ther.* 2015;95(4):493-506. doi:10.2522/ptj.20130619
25. Pajnee K, Kalra S, Yadav J. Effect of kinesio taping in patients with cervical radiculopathy: a longitudinal study. *J Clin Diagnost Res.* 2022; 16(3):KC01-KC04.
26. Ceylan CM, Korkmaz MD, Corum M, Kesiktas FN. Demonstration of kinesio taping effect by ultrasonography in neck pain. *Rev Assoc Med Bras (1992).* 2022;68(10):1452-1457. doi:10.1590/1806-9282.20220668
27. Campolo M, Babu J, Dmochowska K, Scariah S, Varughese J. A comparison of two taping techniques (kinesio and mcconnell) and their effect on anterior knee pain during functional activities. *Int J Sports Phys Ther.* 2013;8(2):105-110.
28. Teys P. Time course and the effects of taping of a mulligan's mobilization-with-movement manual therapy technique in pain limited shoulders. *Physiotherapy.* 2011;97:S1.
29. Kim TK, Shin SJ, Jeon YG. Effects of modified mulligan technique accompanied by taping on the scapular posture and shoulder range of motion of stroke patients. *J Korean Acad Orthoped Manual Physic Ther.* 2016;22(2):1-7.
30. Fast A, Parikh S, Marin EL. The shoulder abduction relief sign in cervical radiculopathy. *Arch Phys Med Rehabil.* 1989;70(5):402-403.

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Case Report

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Is there any clinical significance of biceps brachii being three-headed?

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ABSTRACT

The biceps brachii is an arm muscle which normally has two heads named as the long head and the short head. The incidence of an accessory head of biceps brachii was reported to be 8-20% in the literature. Variations in biceps brachii were found mostly in cadaver studies and also, they were rarely found incidentally in clinical practice. We report a 38 years-old man who presented with right shoulder pain during routine daily activities. Shoulder impingement syndrome and rotator cuff tear were suspected during physical examination. MRI incidentally revealed bifurcation of the long head of the biceps tendon. Biceps tendon has an important role in shoulder stability. Variations in long head of biceps brachii are reported to cause compression syndromes at upper extremity. Moreover, being aware of this variation may provide clinical benefit in diagnosis or arthroscopic surgery. It is also clinically important to plan a treatment or follow up for a patient presenting with shoulder-arm pain.

Keywords: Biceps brachii, anatomical variation, anatomy, shoulder

INTRODUCTION

Bicipital tendon originates from upper border of glenoid cavity, continues with glenoid labrum, and passes through bicipital groove. A few anatomical variations have been defined.[1] Variations in biceps brachii were found mostly in cadaver studies and also they were rarely found incidentally in clinical practice. Variations in biceps brachii are important in surgical interventions to the shoulder and they should be considered in compression syndromes of the upper extremity.

CASE

A 38 years old male presented with right shoulder pain from which he was suffering for 5 months. In his physical examination no swelling, erythema or muscle atrophy was revealed and Neer test, Yergason and speed test which suggest rotator cuff tear were positive and tenderness was present over right bicipital groove. However, her right subacromial bursa and acromioclavicular joint were tender. Degrees of flexion, abduction and external rotation were 90°, 70° and 30°, respectively, and internal rotation was through lumbosacral level. Progressive pain was denoted when flexion over 90°. The opposite shoulder was symptom free and normal on examination. There wasn't a comorbidity and laboratory tests were within normal limits. In radiological evaluation, osseous structures were normal in direct X-Ray films (**Figure 1**). In magnetic resonance imaging T2 axial, coronal and sagittal lipid suppression proton density sections showed duplication of tendon at the level of bicipital groove. Signal intensity of the tendon was normal and there was peripheral effusion (**Figure 2a-c**). After the first visit, 10 sessions of physical therapy modalities (TENS, US, Superficial heat) were done once every two days, each session for 45 minutes. Beside modality, 15 mg Meloxicam tablet was prescribed for the patient twice per day, which was taken for only the one first week by the patient. An exercise program began from the fifth session of physical therapy modalities. Exercise program was under the physician's supervision twice per week in the first month and trained exercises were performed daily at home. Patient's cooperation during 6 months of treatment was excellent and he performed taught exercises with high precision.

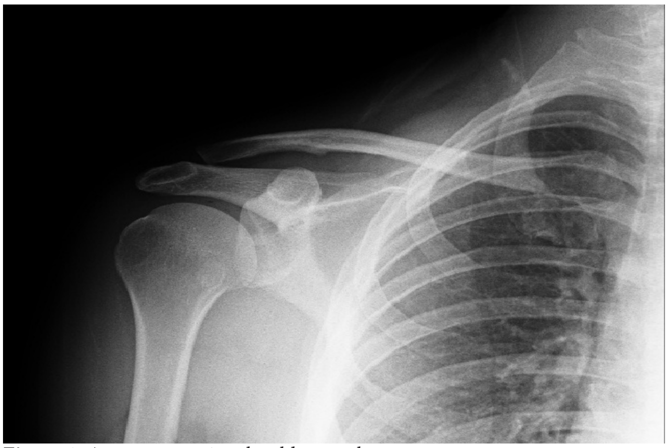

Figure 1. Antero-posterior shoulder graphy

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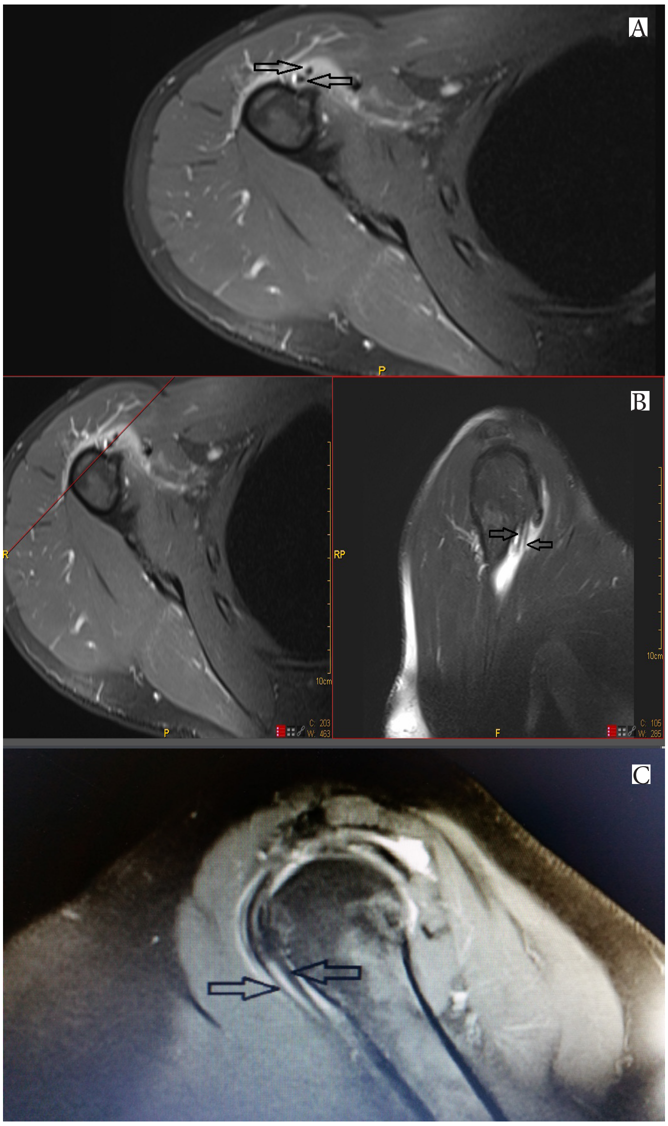

Figure 2. MRI shows duplication at the level of bicipital groove in T2 axial (a), coronal (b), and sagittal (c) sections

DISCUSSION

Biceps brachii is a long fusiform muscle at the anterior side of arm and it has two heads. Its short head originates from coracoid process, while its long head originates from supraglenoid tubercle at the upper border of glenoid cavity, continues with glenoid labrum, passes through bicipital groove, and terminates at radial tuberosity.[1]

Several variations of the long head of biceps brachii have been described. Some of these anomalies are believed to have roles in rotator cuff tendinopathy. The most common anomaly occurs at the body of the muscle. Variations of the long head are more common than short head although absence of the long or the short head is rare. With multiplication of the long head 3, 4, or 5 headed biceps brachii have been described. Variation rate in biceps brachii change between different populations and rates between 8-38% have been reported.[2,3]

Three headed biceps brachii is seen in 10% of the population. The third head extends at upper and medial side of the brachialis muscle and it may terminate at lacertus fibrosus or medial side of the brachialis tendon. Rarely a fourth head is present. It may originate from lateral side of humerus, bicipital groove or great tubercle. Kopuz et al.[3] studied shoulders of 160 cadevers and found 15% prevalence for three headed biceps brachii. In literature, during diagnostic shoulder arthroscopy, long head of the biceps was reported to have a bifurcated origin. In these cases, one of the long heads originates from supraglenoid tubercle and the other originates from posterosuperior capsulolabral tissue.[4,5] Posttraumatic tendon separation which may have a similar appearance can be differentiated with formation of a bony septum.[5]

Awareness of this anatomical variation may be helpful for clinical diagnosis and surgical intervention.[6] Appearance of this variation in the long head of biceps tendon may mimic a tear in tendon or superior labrum.[7,8]

In some cases brachial artery and median nerve may pass inside the variant biceps brachii muscle. In addition, aponeuroses of accessory heads may press on median nerve at arm or ankle and may produce clinical complaints. Signs of compression are especially prominent when forearm is supinated.[9,10] Variants of biceps brachii may cause clinical complaints mimicking radiculopathy or carpal tunnel syndrome.[11]

CONCLUSION

As a result, biceps tendon has an important role in shoulder stability. Variations in long head of biceps brachii are reported to cause compression syndromes at upper extremity. Moreover, being aware of this variation may provide clinical benefit in diagnosis or arthroscopic surgery. It is also clinically important to plan a treatment or follow up for a patient presenting with shoulder-arm pain.

ETHICAL DECLARATIONS

Informed Consent

The patient signed and free and informed consent form.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Lee SE, Jung C, Ahn KY, Nam KI. Bilateral asymmetric supernumerary heads of biceps brachii. *Anat Cell Biol.* 2011;44(3):238-240. doi:10.5115/acb.2011.44.3.238
2. Rodríguez-Niedenführ M, Vázquez T, Choi D, Parkin I, Sañudo JR. Supernumerary humeral heads of the biceps brachii muscle revisited. *Clin Anat.* 2003;16(3):197-203. doi:10.1002/ca.10060
3. Kopuz C, Sancak B, Ozbenli S. On the incidence of third head of biceps brachii in Turkish neonates and adults. *Kaibogaku Zasshi.* 1999;74(3):301-305.
4. Enad JG. Bifurcate origin of the long head of the biceps tendon. *Arthroscopy.* 2004;20(10):1081-1083. doi:10.1016/j.arthro.2004.09.003
5. Vangsness CT Jr, Jorgenson SS, Watson T, Johnson DL. The origin of the long head of the biceps from the scapula and glenoid labrum. An anatomical study of 100 shoulders. *J Bone Joint Surg Br.* 1994;76(6):951-954.

6. Egea JM, Melguizo C, Prados J, Aránega A. Capsular origin of the long head of the biceps brachii tendon: a clinical case. *Rom J Morphol Embryol.* 2010;51(2):375-377.
7. Gaskin CM, Golish SR, Blount KJ, Diduch DR. Anomalies of the long head of the biceps brachii tendon: clinical significance, MR arthrographic findings, and arthroscopic correlation in two patients. *Skeletal Radiol.* 2007;36(8):785-789. doi:10.1007/s00256-007-0291-9
8. Audenaert EA, Barbaix EJ, Van Hoonacker P, Berghs BM. Extraarticular variants of the long head of the biceps brachii: a reminder of embryology. *J Shoulder Elbow Surg.* 2008;17(1 Suppl):114S-117S. doi:10.1016/j.jse.2007.06.014
9. Ozan H, Atasever A, Sinav A, Simsek C, Basar R. An unusual insertion of accessory biceps brachii muscle. *Kaibogaku Zasshi.* 1997;72(6):515-519.
10. Ongeti K, Pulei A, Ogeng'o J, Saidi H. Unusual formation of the median nerve associated with the third head of biceps brachii. *Clin Anat.* 2012;25(8):961-962.
11. Oztürk NC, Uzmansel D, Oztürk H. An unreported pattern of musculocutaneous and median nerve communication with multiple variations of biceps brachii: a case report. *Surg Radiol Anat.* 2010;32(9):887-890. doi:10.1007/s00276-009-0616-6

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Letter to the Editor

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Letter to the editor: comment on “Artificial Intelligence in fracture detection: is it time to redefine the role of the orthopedic surgeon?”

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Dear Editor,

The integration of Artificial Intelligence (AI) into musculoskeletal imaging has advanced rapidly in recent years. Among its most notable applications is the detection of bone fractures on plain radiographs and computed tomography (CT) scans. This technological shift invites a critical question; should the role of the orthopedic surgeon be redefined in the era of AI-supported diagnosis?

Recent studies confirm that deep learning algorithms can detect fractures with an accuracy comparable to human experts. A comprehensive meta-analysis by Kuo et al.[1] analyzed over 55,000 radiographic images and reported pooled sensitivities and specificities exceeding 90% for both AI models and human readers. Similarly, a systematic review evaluating commercial AI tools demonstrated high sensitivity across platforms, particularly when used in tandem with clinical oversight.[2]

AI’s added value becomes most apparent in challenging or subtle cases. For instance, Liu et al.[3] showed that an optimized AI system significantly outperformed radiologists in identifying subtle avulsion fractures on CT scans. This diagnostic enhancement is not limited to imaging experts. Meetschen et al.[4] demonstrated that AI assistance improved fracture detection sensitivity among radiology residents from 58% to 77%, without compromising specificity or increasing reading time. Likewise, Bachmann et al.[5] found that non-specialist readers benefited significantly from AI support, with notable reductions in both missed diagnoses and false positives.

Despite these advances, current evidence does not suggest that AI can or should replace orthopedic surgeons. The most consistent finding across multiple studies is that diagnostic performance is optimized when AI is used as a complement-not a substitute-for human expertise. While AI may flag fractures efficiently, clinical management requires the integration of imaging results with physical examination findings, patient history, and surgical acumen-areas in which AI still lacks capacity.

From an educational standpoint, AI also holds promise as a training tool for residents and junior clinicians, helping to calibrate diagnostic accuracy and confidence. However, over-reliance on algorithmic outputs without clinical correlation may pose new risks, particularly in ambiguous or atypical presentations.

In conclusion, AI has demonstrated remarkable accuracy in fracture detection and shows significant potential as an adjunctive tool in orthopedic practice. Yet, the human clinician remains central to the diagnostic and therapeutic pathway. Rather than redefine the surgeon’s role, the focus should be on strategic integration of AI to enhance, not diminish, clinical judgment. As evidence continues to accumulate, the orthopedic community must guide the ethical and practical deployment of AI to ensure patient-centered outcomes remain paramount.

Keywords: Artificial Intelligence, fracture detection, orthopedic surgery

ETHICAL DECLARATIONS

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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REFERENCES

1. Kuo RYL, Harrison C, Curran TA, et al. Artificial Intelligence in fracture detection: a systematic review and meta-analysis. *Radiology.* 2022;304(1):50-62. doi:10.1148/radiol.211785
2. Husarek J, Hess S, Razaeian S, et al. Artificial Intelligence in commercial fracture detection products: a systematic review and meta-analysis of diagnostic test accuracy. *Sci Rep.* 2024;14(1):23053. doi:10.1038/s41598-024-73058-8
3. Liu Y, Liu W, Chen H, et al. Artificial Intelligence versus radiologist in the accuracy of fracture detection based on computed tomography images: a multi-dimensional, multi-region analysis. *Quant Imaging Med Surg.* 2023;13(10):6424-6433. doi:10.21037/qims-23-428
4. Meetschen M, Salhöfer L, Beck N, et al. AI-assisted X-Ray fracture detection in residency training: evaluation in pediatric and adult trauma patients. *Diagnostics (Basel).* 2024;14(6):596. doi:10.3390/diagnostics14060596
5. Bachmann R, Gunes G, Hangaard S, et al. Improving traumatic fracture detection on radiographs with artificial intelligence support: a multi-reader study. *BJR Open.* 2024;6(1):tzae011. doi:10.1093/bjro/tzae011