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Effect of Kinetic Chain Training on Movement Quality and Power in Recreational Overhead Athletes: A Pragmatic Randomised Controlled Trial

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Article

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Abstract

Purpose

The kinetic chain is a series of interconnected joints and segments that operate together to stabilize the body and facilitate the efficient transfer of energy across various regions. Although its importance in movement and performance is widely recognised, there remains a lack of empirical evidence to fully comprehend the effectiveness of kinetic chain training. This study investigated the effect of kinetic chain training on movement quality and power in recreational overhead athletes.

Method

A total of 28 individuals were recruited and randomised into two groups. The intervention group received a supervised kinetic chain training program for four weeks (3 sessions/week), while the control group continued their usual sports training. Measurements of movement quality, power, shoulder rotational range of motion, and myofascial stiffness were taken at baseline and post-training.

Results

A General Linear Model (GLM) showed a significant improvement in movement quality ($p < 0.001$, effect size = 0.270) and upper body power in the intervention group when compared with the control group. Moreover, the intervention group exhibited a clinically significant improvement of 8° in the dominant shoulder's internal rotation range of motion.

Conclusion

Kinetic chain training has the potential to enhance movement quality and shoulder internal rotational range of motion. Consequently, integrating this training into overhead athletes may significantly improve athletic performance.

Trial registration

This study was approved by the Kasturba Medical College Ethics Committee (IEC1304/2024) and registered in the Clinical Trials Registry India (CTRI/2024/10/074552) on 01/10/2024.

Introduction

Movement quality refers to the ability to execute movements while maintaining a balance between stability and mobility and is referred to as the thrower's paradox [1, 2]. Achieving this balance is vital for

enhancing overall performance and mitigating the risk of injuries [2]. Additionally, the ability to generate and transfer power is crucial to accomplish a sports-specific task [3]. Both attributes are essential in sports and are interdependent. Optimal movement patterns, combined with effective force generation and transfer, significantly enhance performance in overhead athletes, such as those in volleyball, badminton, swimming, and basketball [4].

Overhead athletes depend significantly on movement quality and power due to the demands of their sport-specific actions, such as throwing, spiking, serving, and smashing, which require both high speed and high force [4–6]. Repetitive movement patterns exert considerable stress on the lower extremities, spine, and shoulder complex. It is essential for these anatomical regions to function in a coordinated manner to minimise the risk of injury and to optimise performance outcomes.

Poor movement quality in overhead athletes is often linked to compensatory patterns, which can lead to muscular imbalances, joint overload, diminished performance, and an increased risk of injury [7]. Overhead athletes are particularly susceptible to shoulder injuries and scapular dyskinesis, with a prevalence of 61% compared to their non-overhead counterparts [8]. Scapular dyskinesis is considered to arise from inadequate movement quality and improper muscle activation patterns, a consequence of the repetitive nature of overhead activities [9, 10]. Functional movement screening (FMS) is a commonly utilised tool for assessing movement quality in athletes, and an FMS score below 14 is associated with a 51% likelihood of sustaining injuries [11, 12].

Deficiencies in power generation and transfer may impair the athlete’s capacity to execute movements effectively and heighten the risk of overuse injuries [13]. Muscle imbalances significantly contribute to shoulder injuries in athletes, often resulting from poor movement quality and power deficiencies [14].

Current strategies to improve movement quality and power in overhead athletes include traditional resistance training [15], core stability training [16–18], plyometric training [15, 19] and functional training [20]. New training methods are being developed as research reveals links between movement patterns and power, thereby improving performance and helping prevent injuries. While these methods provide certain advantages, they frequently neglect the interconnected nature of the kinetic chain, the sequential and coordinated movement of the body's segments, essential for effective force generation and transfer [13, 21, 22]. Traditional methods may inadequately address the complex and dynamic demands of overhead sports, resulting in less effective performance enhancement and reduced injury-prevention capabilities.

The kinetic chain functions through various myofascial chains that significantly stabilise and facilitate energy transfer between body parts, given their interconnected nature. A well-functioning kinetic chain is crucial for ensuring optimal movement quality and effective power transfer [22, 23]. The spiral line is particularly important in overhead sports and must be adequately trained to generate and transfer energy efficiently [24, 25]. This force generated from the lower extremities is transferred via the trunk to the sporting implement, such as a ball, shuttle, javelin, or shot put, to achieve the desired outcome [6, 26–28]. A weakness in any segment of a kinetic chain may lead to increased stress in the other segment

to complete the sports-specific task efficiently and effectively [29]. Dysfunction within this system not only impairs performance but also predisposes individuals to injury [21, 29, 30].

Kinetic chain training can be an optimal approach because it emphasises the integrated function of the body's segments. This training method focuses on coordinated, multi-joint movements that closely mimic the demands of specific sports. Despite our knowledge of this interconnectedness, we lack sufficient evidence to understand the effectiveness of kinetic chain training. Thus, this study aims to investigate the effects of kinetic chain training on movement quality (primary objective) and on power, shoulder range of motion, and myofascial stiffness (secondary objectives) in recreational overhead athletes.

Methods

Study design and approvals:

The study is designed as a pragmatic randomized controlled trial with triple blinding (participant, principal investigator, and outcome assessor) and an allocation ratio of 1:1. This study received approval from the Kasturba Medical College and Kasturba Hospital Institutional Ethics Committee (reference no. IEC1:304/2024) and was prospectively registered in Clinical Trials Registry - India (ICMR-NIMS) on 01/10/2024, under the registration number CTRI/2024/10/074552. The study procedure follows the Consolidated Standards of Reporting Trials (CONSORT) and the principles stated in the Declaration of Helsinki.

Study setting:

Marena Sports Complex, MAHE, and Centre for Sport Science, Medicine and Research.

Eligibility Criteria

Recreational overhead athletes between 18 and 35 years, comprising both male and female athletes who have consistently engaged in their sport for at least 2 to 4 hours per week over the past six months, were included. On the other hand, individuals with a history of musculoskeletal injuries within the past six months and participants who have undergone any spine or extremities surgery within the past year were excluded. Those with a known history of cardiovascular or respiratory diseases were also excluded from the study.

Participants:

Recreational overhead athletes were recruited to understand the effects of kinetic chain training. The sample size was calculated using GPower v3.1 software based on the FMS data from Sajad Bagherian et

al. (2019) [18]. With an effect size of 0.67, a power of 0.8, and an anticipated dropout rate of 30%, the final sample size was determined to be 28 participants, with 14 per group. All participants were evaluated for eligibility and provided with the participant information sheet (PIS) and written informed consent (IC) before being recruited into the study

Allocation process:

A total of 28 participants were recruited. The random allocation sequence was generated by an independent researcher not involved in recruitment or assessment, using a block-randomisation method with sealed envelopes (7 blocks × 4 participants): 2 in the intervention group and 2 in the control group. Allocation concealment was ensured using sequentially numbered, sealed opaque envelopes containing the group assignments. Eligible participants were enrolled by the primary investigator, and the envelopes were opened only after baseline assessment to assign participants to either the intervention or control group. All baseline and post-intervention outcome assessments were conducted by an assessor who was blinded to participant group allocation. Participants were instructed not to disclose their assigned intervention during the assessment sessions to maintain assessor blinding.

Procedure:

The study flow is illustrated in Fig. 1. Initially, participants were recruited and screened for eligibility according to the predefined inclusion and exclusion criteria. Eligible participants who agreed to participate provided written informed consent prior to enrolment. Baseline assessments were then conducted to evaluate movement quality, upper body power, shoulder rotational range of motion, and myofascial stiffness.

Following baseline testing, participants were randomly assigned to either the intervention or control group.

Participants in the intervention group received structured kinetic chain training in addition to their standard sports-specific training regimen. The training program comprised six exercises: deadbugs, prone plank with rotation, side plank with rotation, Pallof press, chop and lift, and landmine rotation. These exercises were selected to facilitate the coordinated activation of the trunk, pelvis, and both upper and lower extremities through multiplanar movements and anti-rotational control.

All exercises were performed under the supervision of the Physiotherapist with two years of experience in prescribing kinetic chain training to ensure proper technique and adherence to the protocol. Participants initially performed 1–2 sets of each exercise during the early phase of the intervention to facilitate familiarisation and neuromuscular adaptation. The training volume was progressively increased to 3–4 sets during the final two weeks of the intervention in accordance with the principle of progressive overload. Each set consisted of 8–10 repetitions, with adequate rest provided between sets and exercises to minimise fatigue and maintain exercise quality. The exercises were performed in a

controlled manner with emphasis on maintaining neutral spinal alignment, trunk stability, and coordinated movement execution throughout the training sessions.

The deadbug exercise was used to improve lumbopelvic stability and coordinated activation of the anterior core musculature. The prone plank with rotation and side plank with rotation were included to enhance dynamic trunk stabilisation, anti-rotational control, and transverse-plane movement competency. The Pallof press was performed to develop anti-rotational core strength and postural control during resisted upper-extremity movement. The chop and lift exercise targeted integrated rotational movement patterns involving the upper body, trunk, and lower extremities, thereby promoting efficient force transmission across the kinetic chain. The landmine rotation exercise was incorporated to improve rotational power, trunk coordination, and multiplanar movement control relevant to athletic activities. Details of the intervention protocol are provided in the supplementary file.

Meanwhile, participants in the control group continued their usual training routine throughout the study period and did not receive the additional kinetic chain training intervention. Their routine training consisted of their regular sport-specific conditioning and practice activities as prescribed by their coaches.

Recruitment and Follow-up:

Participants were recruited between October 2024 and January 2025, and follow-up outcome assessments were completed by February 2025. Adverse events were monitored throughout the study period, and no intervention-related harm was reported.

Outcome measures:

Baseline measures of all the outcomes, including Functional Movement Screening (FMS), Medicine ball put test (MBPT), Shoulder rotational range of motion (SRROM), and Myofascial stiffness, were taken, and follow-up measurements were taken after the four-week intervention.

Functional Movement Screening (FMS)

Our primary outcome was to evaluate athletes' movement quality. We used FMS (for 21 points) to understand the movement quality, which consists of 7 different movements (Deep Squat, Hurdle Step, In-line Lunge, Shoulder Mobility, Active Straight-leg Raise, Trunk Stability Push-up, and Rotary Stability). The FMS has an intraclass correlation coefficient (ICC) of 0.81 for intra-rater and inter-rater reliability[31]. It is also valid for understanding injury risk (with a score < 14) and identifying poor movement patterns[32]. The minimum clinically important difference (MCID) for FMS is found to be 1.25 [33]. The minimum detectable change (MDC) was 2.1 to 2.5 points on the 21-point scale in athletes or healthy individuals [34].

Medicine ball put test (MBPT):

The medicine ball put test (MBPT) was used to measure upper-body power, and the distance thrown serves as an indicator of the athlete's explosive power. Participants performed the test while seated on a 45 ° incline bench, which helps isolate upper-body movement. Male participants used a 9 kg medicine ball, while females used a 6 kg ball. A measuring tape was used to record the distance. This test is recognised for its high validity and reliability in evaluating explosive upper-body power. Previous research has demonstrated excellent test-retest reliability, with a correlation coefficient of 0.996, indicating consistent and accurate results [35–38].

Shoulder rotational range of motion (SRROM)

A universal goniometer was utilized to measure the shoulder rotational range of motion (SRROM). The participant was positioned on their side with the shoulder and elbow flexed at 90 degrees. The rotational ROM was then measured using the goniometer. The goniometer has an intra-class correlation (ICC) value for interrater reliability ranging from 0.84 to 0.90 and is also valid for measuring the SRROM [39, 40].

Myofascial stiffness: Myoton Pro was utilised to measure myofascial stiffness (N/m) in the following muscles: sternocleidomastoid, deltoid, trapezius, supraspinatus, infraspinatus, rhomboids, and pectoralis major. The device operates by inducing oscillation on the skin's surface, which helps determine myofascial stiffness [41, 42]. The Myoton Pro has an ICC value for interrater reliability ranging from 0.92 to 0.98 and interrater reliability ranging from 0.91 to 0.97 and is also valid for measuring the SRROM [41].

Statistical Methods

The General Linear Model (GLM) was used to analyse all continuous primary and secondary outcome variables. All statistical tests were performed at a 5% significance level (two-sided) using Jamovi version 2.5.3. Mean scores for all outcomes measured before and after the intervention are reported. The differences in outcomes between the intervention and control groups are presented. Regardless of protocol adherence, all significant analyses were conducted using intention-to-treat (ITT) methods, which included all individuals who were randomly assigned to participate in the study.

Results

Participant characteristics:

A total of 28 participants were included in the study, with baseline characteristics that were comparable across groups. In the intervention group, two participants did not receive the intervention due to personal issues, and one participant in the control group was unable to attend the post-assessment. The demographic characteristics of the participants are presented in Table 1.

Table 1
Participants' demographic characteristics

Characteristics	Group		Mean ± SD
Age	Control	N = 14	22.9 ± 2.81
	Intervention	N = 14	23.0 ± 3.37
Gender: n (%)	Control	Male	10 (35.71)
		Female	4 (14.28)
	Intervention	Male	10 (35.71)
		Female	4 (14.28)
Dominance: n (%)	Control	Right	14 (100)
		Left	0 (0)
	Intervention	Right	14 (100)
		Left	0 (0)

N – Number of participants, SD – Standard deviation.

In the overall sample, the population was predominantly male, comprising 71.42% of participants. The average age in the control group was 22.9 ± 2.81 years, while the intervention group had an average age of 23.0 ± 3.37 years.

Difference in the means of pre- and post-measurements:

To analyse the differences in outcomes between the control and intervention groups during pre- and post-measurements, a general linear model was employed. The mean and standard deviation for all variables is presented in Table 2.

Table 2
Data (Mean ± SD) of outcomes from pre- and post-measurements.

Timeline	Group	FMS (Mean ± SD)	MBPT (Mean ± SD)	IRROM (Mean ± SD)		ERROM (Mean ± SD)	
				Left	Right	Left	Right
Pre	CG	15.14 ± 1.460	2.63 ± 0.466	80.71 ± 10.351	77.50 ± 9.354	97.50 ± 5.095	100.36 ± 10.089
	IG	15.93 ± 1.730	2.64 ± 0.451	77.14 ± 9.945	76.79 ± 10.304	96.43 ± 6.022	98.93 ± 5.942
Post	CG	15.15 ± 1.625	2.64 ± 0.467	78.46 ± 10.485	78.85 ± 8.697	97.69 ± 5.250	101.54 ± 9.439
	IG	19.50 ± 1.168	2.91 ± 0.354	82.92 ± 7.217	85.42 ± 8.382	96.25 ± 3.769	95.83 ± 3.589

IRROM-Internal rotation range of motion, ERROM-External rotation range of motion, FMS-Functional movement screening, MBPT-Medicine ball put test.

Table 3
Changes in outcome measures over time across different groups.

Outcomes		**F-value**	**p-value**	**partial eta squared (η^2p)**
Movement quality (FMS)		18.1	< 0.001	0.270
Power (MBPT)		1.18	0.282	0.024
IRROM	Left	2.2786	0.138	0.044
	Right	2.04	0.159	0.040
ERROM	Left	0.0172	0.896	0.000
	Right	0.988	0.325	0.020

IRROM-Internal rotation range of motion, ERROM-External rotation range of motion, FMS-Functional movement screening, MBPT-Medicine ball put test

The primary outcome, movement quality assessed using the FMS, demonstrated a statistically significant difference between groups across time points and significant improvements over time within groups. This finding was indicated by a mean score that improved from 15.93 ± 1.730 to 19.50 ± 1.168, with a p-value of < 0.001 and an η2p of 0.270. In contrast, the control group showed similar scores: pre-intervention 15.14 ± 1.460 and post-intervention 15.15 ± 1.625 as shown in Table 3.

Other outcome measures did not show statistically significant differences between the groups, across timelines, or overtime within groups. However, upper-body power increased moderately in the

intervention group, from pre-intervention scores of 2.64 ± 0.451 to post-intervention scores of 2.91 ± 0.354. Meanwhile, upper-body power in the control group remained unchanged.

A clinically significant difference was observed in the internal rotation ROM of the dominant shoulder across different timelines ($p = 0.05$). An increase of 8° was recorded in the dominant shoulder's internal rotation, with pre-intervention scores of 76.79 ± 10.304 and post-intervention scores of 85.42 ± 8.38. This improvement enhances the rotational arc and lowers the risk of developing a glenohumeral internal rotation deficit. The MCID for SRROM is reported to be between 2° and 10° [43, 44]. Therefore, the observed difference is considered clinically significant.

Discussion

Movement quality is a crucial aspect of athletic performance, emphasising the balance between stability and mobility. If movement quality is compromised, it can lead to recurrent injuries that affect athletic capabilities [2]. An effective kinetic chain can play a vital role in attaining this balance between stability and mobility [45]. Our findings suggest that KCT significantly enhances movement quality, produces a moderate increase in upper-body power, and results in a clinically significant improvement in the dominant shoulder's internal rotation range. In contrast, myofascial stiffness did not show any statistically significant results.

Research indicates that the kinetic chain plays a crucial role in neuromuscular control, force transmission, and biomechanical efficiency [46]. The observed improvements in movement patterns suggest that kinetic chain training can enhance intersegmental coordination and reduce compensatory movement strategies, ultimately improving functional performance. This may be due to the likely biomechanical and neuromuscular adaptations resulting from kinetic chain training. Movement dysfunction or compromised movement quality is frequently due to deficits in proximal control, particularly in the lumbopelvic region. Such deficits can disrupt the kinematic sequence and negatively affect the performance of distal segments [47]. KCT focused on integrating proximal stability with distal mobility to optimise movement quality and performance through intersegmental coordination of lumbopelvic control.

Various training strategies have been established to enhance movement quality, including core stability training programs lasting 6 weeks [16] and 8 weeks [18]. A 6-week training program improved FMS scores by an average of 2.5 points, while an 8-week program yielded improvements of 2.4 to 4.4 points. Although the primary focus of these training sessions was to strengthen or enhance core stability in a single plane, it is also crucial to address other movement aspects across multiple planes. In this study, KCT demonstrated an average improvement of 3.5 points in just four weeks. Targeting the entire kinetic chain can yield more significant improvements in a shorter time frame.

Enhancing movement quality and intersegmental control can improve power production. Howenstein et al. (2019) demonstrated a strong correlation between efficient energy transfer from the trunk to the hand in baseball pitchers and pitch velocity [48]. This underscores the importance of a well-functioning kinetic

chain in facilitating effective energy transfer and enhancing overhead throwing power. Although the KCT exhibited a promising upward trend in power output, the results did not reach statistical significance.

Reduced internal rotation range is commonly observed in overhead athletes due to the demands of their sport [49–51].This can result from impaired scapular control[52] and muscle imbalances [53]. Numerous studies have indicated that incorporating a kinetic chain enhances the activation and recruitment of scapular muscles [54–56]. Kinetic chain training engages all body segments from proximal to distal, effectively addressing this concern [57]. The KCT also showed a notable increase in shoulder internal rotation range of motion, which may be due to improved scapular control and better coordination between segments along the myofascial lines.

Nevertheless, no statistically significant differences in myofascial stiffness were observed between the groups. The lack of significant changes following KCT may suggest the intricate nature of fascial adaptation mechanisms. The adaptation of fascial tissue involves complex biochemical signaling pathways that govern collagen turnover and cross-linking. These processes might require specific mechanical stimuli or an extended duration to produce measurable changes in tissue stiffness [58–60]. Furthermore, fascial tissues exhibit different responses to adaptation compared to muscle tissues. Changes in hydration levels and hyaluronan content often occur prior to any structural modifications in collagen networks [61]. It is possible that our assessment methods did not capture these subtle biochemical and hydration-related changes that could precede observable alterations in mechanical properties.

This study has some limitations, such as a small sample size and a brief intervention period, which might restrict the ability to observe long-term changes. Previous studies employing training durations of more than four weeks have reported statistically significant improvements in power [62, 63].

Furthermore, the findings may be generalisable mainly to recreational overhead athletes and may not directly apply to elite or non-overhead sporting populations. Nevertheless, the results indicate that kinetic chain training may be an effective adjunct intervention to improve movement quality, shoulder mobility, and functional performance in overhead athletes.

Conclusion

The findings suggest that kinetic chain training can positively influence movement quality and shoulder internal rotation range of motion. Incorporating this training approach in overhead athletes may enhance performance outcomes while simultaneously mitigating injury risk.

Declarations

Competing interests:

None of the authors reports any conflicts of interest with regard to this manuscript. The authors have no relevant financial or non-financial interests to disclose.

Ethics approval:

This study received approval from the Kasturba Medical College and Kasturba Hospital Institutional Ethics Committee (reference no. IEC1:304/2024). This trial was prospectively registered in Clinical Trials Registry - India (ICMR-NIMS) under the registration number CTRI/2024/10/074552 on 01/10/2024. The study procedure follows the Consolidated Standards of Reporting Trials (CONSORT) and the principles stated in the Declaration of Helsinki.

Consent to participate:

All participants were evaluated for eligibility, provided with the participant information sheet (PIS), and given written informed consent (IC) before being recruited into the study.

Consent to publish:

The authors affirm that human research participants provided informed consent for publication of the data.

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Author Contribution

Study conception and design were done by SM and PRG. Intellectual inputs were provided by P.R.G Material preparation, data collection and intervention were provided by Srinivas M. Data analysis was done by S.M., P.R.G., P.R.G, and V.J. All authors read and approved the final manuscript.

Data Availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

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Figures

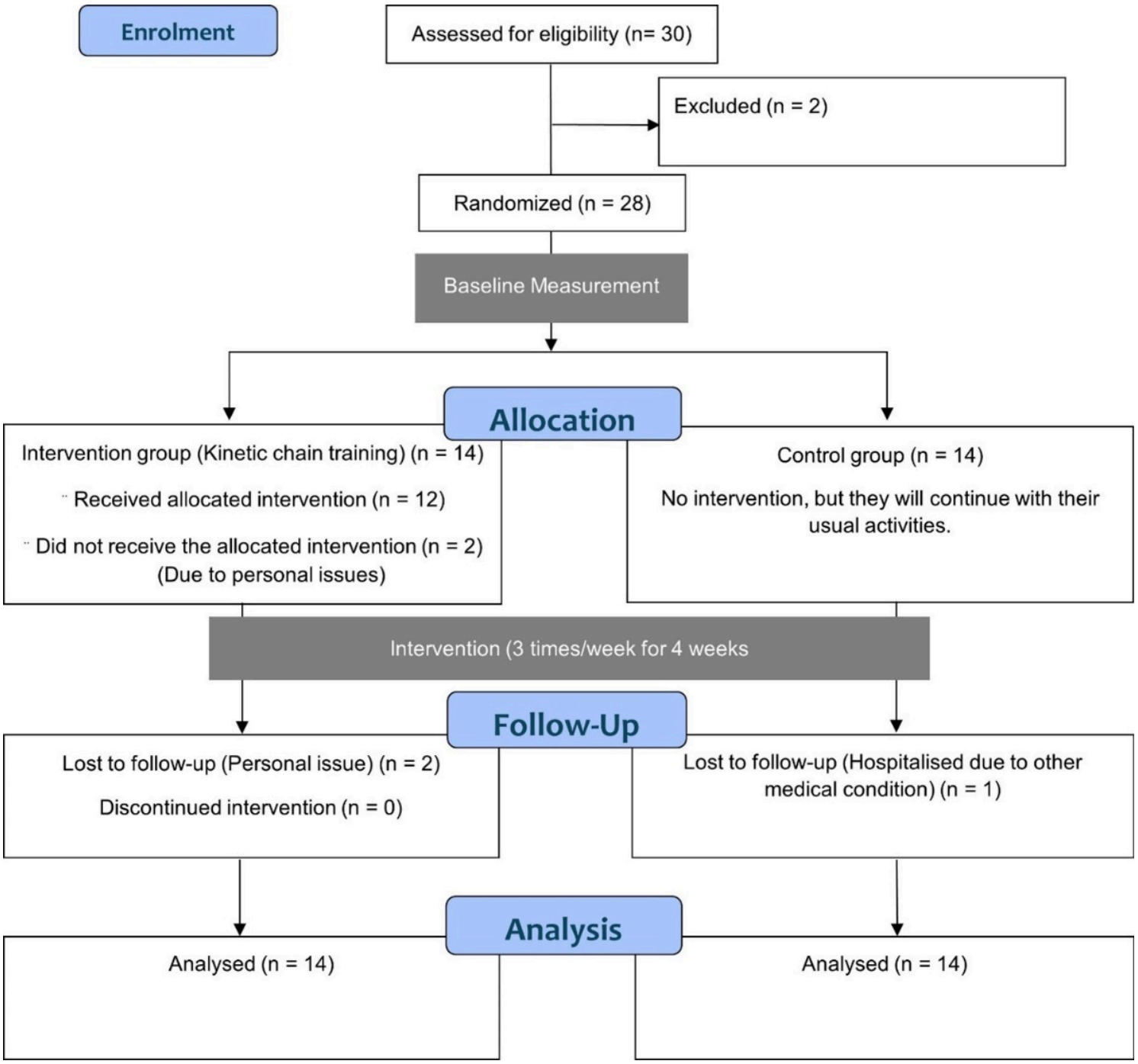


Figure 1

Consort flow diagram

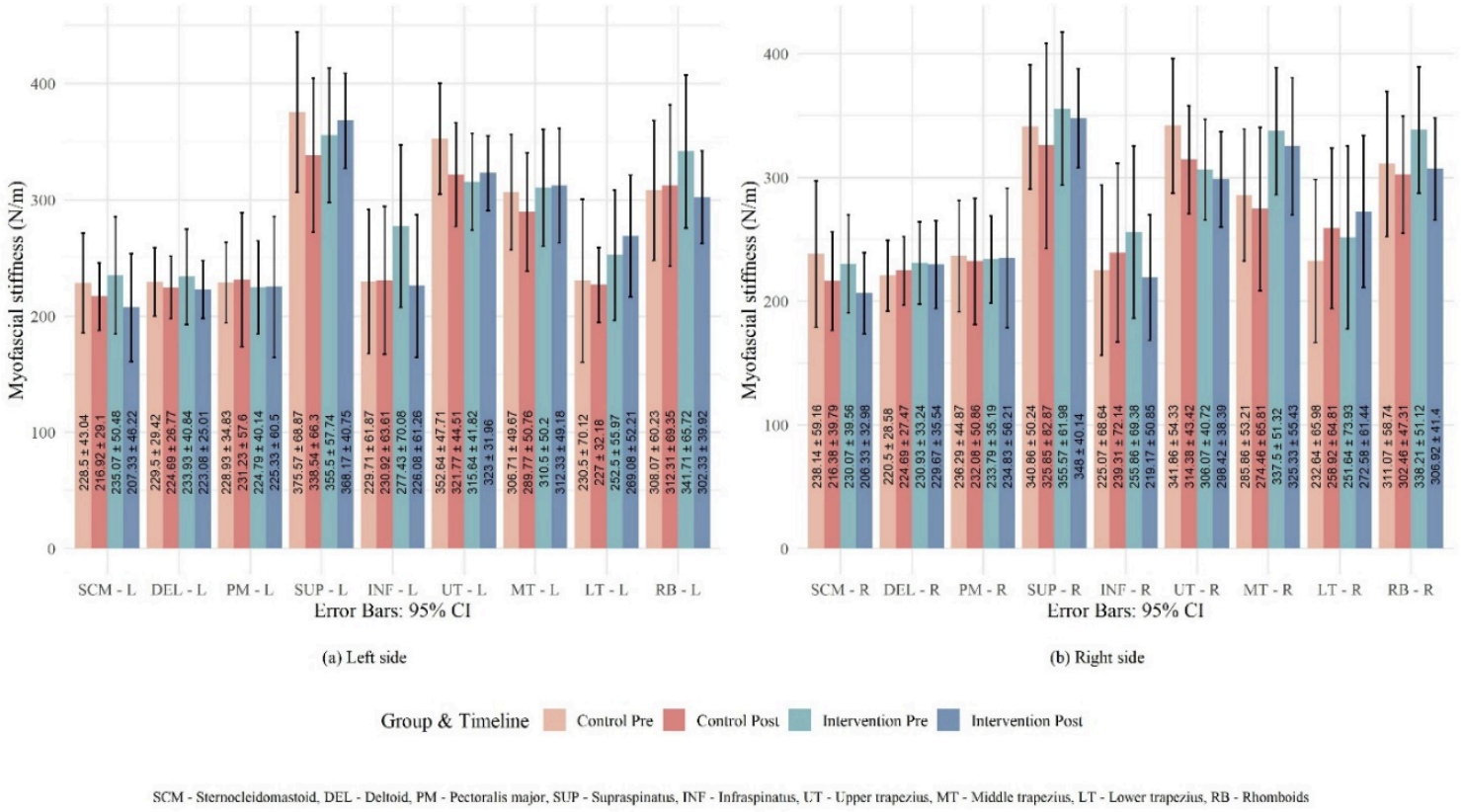


Figure 2

Pre- and post-comparison of myofascial stiffness

Supplementary Files

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- Interventionvideo.mp4