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Cross-Sectional Study

Effect of neuromuscular training on functional throwing performance and speed in asymptomatic cricket players

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ABSTRACT

Objective: To determine the effect of neuromuscular training on functional throwing performance and speed among asymptomatic cricket players.
Design: Single-subject A-B-A design.
Method: Forty-three male asymptomatic sub-elite cricket players were recruited from Karnataka Institute of Cricket, Bangalore, India, with a mean age of 20.4 ± 2.03 years. Throwing accuracy and throwing speed were measured using Functional Throwing Performance Index (FTPI) and radar gun respectively, at zero, 12, 24 and 30 weeks in accordance with the A-B-A single-subject design. The neuromuscular training of the throwing arm was performed for 12 weeks, two days a week of supervised training including rhythmic stabilization drills were performed. A non-supervised training session including shoulder strengthening programme was conducted three days a week.
Result: Participants demonstrated significant improvement in throwing accuracy ($p < 0.001$) and speed ($p < 0.001$) after 12 weeks of neuromuscular training. Six weeks post-withdrawal of the neuromuscular training on throwing accuracy was not significant ($p = 0.117$), However, speed was sustained ($p = 0.013$).
Conclusion: Neuromuscular training showed an improved efficiency in throwing performance following 12 weeks of training in sub-elite cricket players. The sustained effect was not observed following 6 weeks of withdrawal of training.

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1. Introduction

Neuromuscular training has been considered an elemental therapeutic strategy to enhance the neurophysiological entity of the joints for coordinated functioning (Zech et al., 2009; Hubscher et al., 2010; Devis and Dickoff-Hoffman, 1993). Neuromuscular training is responsible for the dynamic joint stability which is defined as training enhancing unconscious motor responses by stimulating both afferent signals and central mechanisms (Zech et al., 2009). This training showed improvement in dynamic joint stability and fine motor control by increasing the synchrony and synergy of the muscle firing pattern (Lephart and Henry, 1996; Myers and Lephart, 2000; Guido and Stemm, 2007).

The neuromuscular control provides reflexive activation of dynamic restraints by several mechanisms including co-activation of shoulder girdle muscles and its muscular stiffness, activation and reflex stabilization (Myers and Lephart, 2000). Neuromuscular control is the response from the efferent motor system which ensues sensory information in the form of complex or simple, volitional or reflex stimuli (Guido and Stemm, 2007). Enhanced neuromuscular control through neuromuscular training has been thought to be advantageous to the throwing athlete (Freeston et al., 2015).

Throwing is an act which involves dissipation of force from static and dynamic restraints of the shoulder (Seroyer et al., 2009, 2010). It has been recorded that maximal humeral internal rotation velocity can reach up to 7500–7700°/second during a throw (Seroyer et al., 2009, 2010; Lephart and Henry, 1996). An intrinsic integration between static and dynamic structures of the shoulder is vital to maintaining shoulder stability and functional performance at this violent phase of the pitching motion. Muscular strength and endurance, flexibility and neuromuscular control are essential to balance the intricate unification between restraints for effective shoulder function during the throwing act (Lephart and Henry, 1996).

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Currently, there is an increase in emphasis on skillful fielding predominantly efficient throwing in the game of cricket for successful performance (McDonald et al., 2013; Freeston and Rooney, 2014). Throwing is a vital aspect in fielding where the fielders must throw the ball with great speed and accuracy from any part of the field to dismiss a batsman and prevent the opposition from scoring runs for having a successful game (McDonald et al., 2013; Freeston and Rooney, 2014; Hussain and Bari, 2011; Freeston et al., 2007, 2016).

Previous studies on neuromuscular training advocated as a preventive and rehabilitative strategy in knee and ankle injuries (Zech et al., 2009; Hubscher et al., 2010). However, there is a dearth of the literature on examining the effectiveness of neuromuscular training on throwing performance which is an imperative part of cricket. Hence, the purpose of current study was to determine the effect of neuromuscular training on functional throwing performance and throwing speed in asymptomatic cricket players.

2. Materials and methods

2.1. Participants

Forty-three healthy male sub-elite cricket players (age: 20.4 ± 2.03 years; BMI: 21.4 ± 2.6 kg/m^2; years of experience: 2.19 ± 1.11 years) at Karnataka Institute of Cricket, Bangalore, India, volunteered to participate in the study. Each participant completed a health history and sports participation questionnaire regarding demographics, years of experience, position played and history of shoulder or neck disorders and pain. We used this screening questionnaire to exclude volunteers who reported shoulder or neck disorder and pain within six months before testing. All eligible participants were provided informed consent prior to the commencement of the study and the study was approved by the institutional review board of School of Allied Health and Sciences, Manipal University, Manipal, India.

2.2. Design and procedure

A single subject A-B-A design was conducted (see Table 1). During the study, phase A functioned as the baseline period lasting for 12 weeks prior to the initiation of the neuromuscular training. Baseline outcomes were collected on throwing accuracy and speed before and at the end of phase A. The participants were allowed to practice regular training provided at the cricket club headed by an athletic trainer.

Following phase A (baseline), the phase B (neuromuscular training) for a period of 12 weeks with 4 sub-phases was conducted. These sub-phases included supervised and non-supervised training under the guidance of a physical therapist and athletic trainer respectively. During these sub-phases, sub-phase 1 was a non-supervised programme performed for 5 days a week for 2 weeks. The sub-phase 2, continued for 2 weeks with supervised training twice a week and non-supervised training thrice a week. The participants underwent 4 weeks of supervised (2 days a week) and non-supervised (3 days a week) in each of the sub-phases 3 and 4. Throughout the study, a log book was recorded to track the supervised and non-supervised training programmes.

Warm up preceded the commencement of the neuromuscular training regime. This included participants performing mild-intensity running, followed by major muscle group stretching for 5–10 min. After each session of neuromuscular training drills, participants performed cool down exercises.

The sub-phase 1 (0–2 weeks) was a non-supervised training phase for 5 days a week. This phase included the rotator cuff strengthening, scapular strengthening exercises and upper limb PNF D2 flexion and extension exercises. The club athletic trainer was asked to supervise the programme according to the manual guide provided and exercise adherence was recorded using the log book. The training volume ranged from 10 repetitions in each set for three sets followed by a 30-s rest period after each set.

Following this, sub-phase 2 (2–4 weeks) was initiated for two weeks which marked the beginning of supervised neuromuscular training drill programme. Supervised neuromuscular training programme consisted of rhythmic stabilization drills for the throwing arm (Freeston et al., 2015). The intervention includes side lying external rotation with rhythmic stabilization and scapular neuromuscular control drills. The training volume comprised of 10 s of rhythmic stabilization of 10 repetitions per 3 sets followed by 30 s rest period after each set, which was performed 2 days a week for 2 weeks. Non-supervised training was continued 3 days a week with progression to prone rowing with external rotation and inclined push-up.

The sub-phase 3 (5–8 weeks) exercise regime includes progression of the dynamic rhythmic stabilization drills from side lying to kneeling and external rotation at 90° of shoulder abduction. Further, the addition of PNF D2 flexion and extension with rhythmic stabilization, and wall dribble with rhythmic stabilization in 90°/90° position were performed for 2 days a week. Non-supervised training (3 days per week) includes endurance drills like wall dribble and ball flips in both side lying and prone lying positions with the continuation of strengthening programme. Training volume of the exercises remained the same and resistance was progressed from the green to the blue theraband®.

Subsequently, sub-phase 4 (9–12 weeks) began with

Table 1
Study design.

Phase	Duration (weeks)	Outcome collection points	Total duration (weeks)		Intervention
Phase A (Baseline phase)	0–12	0th week (*Baseline*)	12		Routine training
Phase B (Intervention phase)	12–24	12th week (*Pre-intervention*)	12	00-02 (2)	**Sub-phase-1** NT: 5 days a week for 2 weeks (10 sessions)
				03-04 (2)	**Sub-phase-2** ST- 2 days/week (4 sessions) NT- 3 days/week (6 sessions)
		24th week (*Post-intervention*)		05-08 (4)	**Sub-phase-3** ST- 2 days/week (8 sessions) NT- 3 days/week (12 sessions)
				09-12 (4)	**Sub-phase-4** ST- 2 days/week (8 sessions) NT- 3 days/week (12 sessions)
Phase A (Withdrawal phase)	24–30	30th week (*Withdrawal*)	06		Routine training

ST- Supervised training and NT- Non-supervised training.

progressive dynamic rhythmic stabilization drills from kneeling to standing. Training volume and intensity of supervised training and non-supervised training were carried out for 2 days a week and 3 days a week respectively for 4 weeks. This marked the end of intervention phase (Phase B). Outcomes were recorded on throwing accuracy and speed at the same time of the day as the previous time of data collection.

Participants entered the second A phase (withdrawal phase) for the duration of 6 weeks. During this phase, neuromuscular training was withdrawn and participants continued with their regular training provided at the club. The athletic trainer was contacted on a regular basis to make sure that neuromuscular training was not continued by the participants. At the end of the 6th week, outcomes were collected on throwing accuracy and speed at the same time of the day as the previous time of data collection.

2.3. Outcome measures

Throwing accuracy and speed were measured using Functional Throwing Performance Index (FTPI) and speed measuring radar gun respectively. Outcomes were measured at the beginning of each phase and at the end of withdrawal phase comprising of four data collection points.

2.4. Functional Throwing Performance Index (FTPI)

The accuracy of the throw was recorded using the FTPI. A target of 30.48 × 30.48-cm square was marked on a wall at a height of 1.22 m from the floor and the participant threw the ball towards the target, standing at a distance of 4.57 m (See Fig. 1). The participant had to throw the ball (50.8-cm circumference) into the target for 30 s as many times as possible for three trials. A familiarisation session of 8 throws was completed by the participants before starting the test, following which participants performed the test. FTPI was calculated as the number of throws within the target divided by the total number of balls thrown (Mornieux et al., 2017; Wassinger et al., 2007, 2012; Devis and Dickoff-Hoffman, 1993). FTPI was shown to be a reliable tool (ICC = 0.81) (Hussain and Bari, 2011).

2.5. Speed measuring radar gun (Pocket Radar)

Throwing speed was measured at the cricket academy with a pitch replicating the virtual cricketing environment. Participants were asked to perform maximal throws from a distance of 20.14 m from the target (See Fig. 2). This distance was selected as it replicates the standard cricketing pitch. A standard four-piece leather ball of 156 g was thrown at a stump. A cordless speed radar gun (model # PR1000-BC, Pocket Radar, Inc. Santa Rosa, California, and U.S.A) is shown to measure maximum speed of 209 km/h with an accuracy of ±2 km/h. The radar gun was positioned over the delivery arm of the thrower. General warm-up routine consisting of mild-intensity running, followed by major muscle group stretching for 5–10 min was performed by the participants. Light intensity throwing for 5–10 min was then progressed to high-intensity throwing at completion. The participants threw the ball as hard as possible towards one stump. They were required to throw three times and a 2–3 min rest time was given between each throw. Participants were instructed to take one stride forward with the front leg while maintaining the front foot behind the marked line until ball delivery. Maximum throwing speed was recorded and the mean maximal throwing speed was calculated as the average of three throws in meters/second (Freeston et al., 2007).

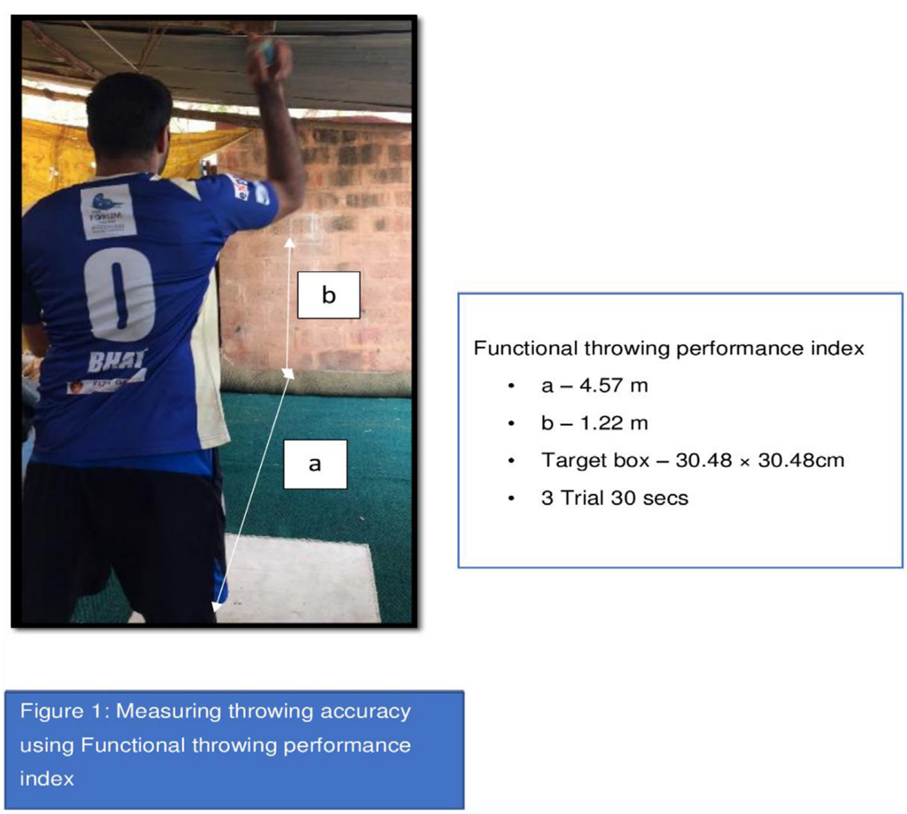

Fig. 1. Functional throwing performance index.

Fig. 2. Measuring throwing speed with speed-measuring radar gun.

2.6. *Statistical analysis*

Data were analyzed using R software version 3.2.2. Continuous variables were presented as a mean and standard deviation and categorical variables were presented as count and percent. Shapiro Wilk test was done for all continuous variables and found to be normally distributed. To compare means of accuracy and speed at various time points, one-way repeated measures ANOVA was used. Post hoc Tukey test was done to find out the significant difference between time points. The p-value < 0.05 was considered statistically significant.

3. Result

Fifty-five cricketers from Karnataka Institute of Cricket, Bangalore, India, volunteered to be part of the study. Forty-five players who met the inclusion criteria were included in the study and baseline outcome measure of FTPI and throwing speed was taken. Forty-three players completed the study, two participants withdrew from the study due to personal reasons.

Descriptive values of the means across three phases were calculated. Mean throwing accuracy was 0.62 (SD $\pm$ 0.134) at pre-intervention and at post-intervention, it was 0.68 (SD $\pm$ 0.122). The mean throwing speed at pre-intervention was 29.02 m/s (SD $\pm$ 9.36) and post-intervention was 29.61 m/s (SD $\pm$ 9.36). These mean values reveal improvement in the throwing performance across all the phases.

One-way analysis of variance for repeated measures on throwing accuracy and speed was found to be statistically significant. It was followed by the post hoc Tukey test which demonstrated that throwing speed was statistically significant across the three phases (baseline, intervention phase, and withdrawal) ($p < 0.001$). Throwing accuracy was found to be significantly improved between the baseline and intervention phase ($p < 0.001$). The improvement was maintained but was insignificant between interventions to withdrawal phase ($p < 0.117$). (See Tables 2 and 3).

4. Discussion

To our knowledge, this is the first study to investigate the effect of a neuromuscular training programme on throwing accuracy and speed in cricket. Neuromuscular training resulted in beneficial improvement in both accuracies of throwing and speed of the throw in asymptomatic cricket players.

The throwing accuracy measured using functional throwing performance index (FTPI) demonstrated significant improvement of 10.2%. These findings are consistent with the previous study, where the authors found 10% improvement on FTPI after 5 weeks of PNF training, comparing open kinetic chain and closed kinetic chain exercises of the shoulder joint in normative population (Padua et al., 2004). The observed improvement was not sustained during the withdrawal phase. Our study showed a modest improvement on FTPI in comparison with the study where the authors found an improvement of 18.87%–22% for the OKC/CKC/CS and OKC/CKC groups, respectively after 6 weeks of intervention among baseball players (Lust et al., 2009).

To our knowledge, this is the first study to prospectively examine the neuromuscular training of shoulder joint in cricket population. Our results revealed that 12 weeks of neuromuscular training had a positive effect in improving throwing accuracy. Although this could be an effective training tool in improving throwing accuracy, we were unable to find published literature to either support or refute this theory.

The biomechanical reasoning for the improvement in throwing accuracy could be attributed to physiological changes observed as an effect of neuromuscular training drills employed (Myers and Lephart, 2000; Guido and Stemm, 2007; Devis and Dickoff-Hoffman, 1993; Reinold et al., 2010). Use of specific drills such as rhythmic stabilization of the throwing arm has been advocated to enhance neuromuscular control of the overhead throwing athlete. These drills facilitate co-contraction of anterior and posterior rotator cuff musculature which influences the balance between force couple formed by deltoid and rotator cuff muscles of the glenohumeral joint. This, in turn, exaggerates the humeral head compression thereby improving the dynamic joint stability and throwing performance. Also, these drills may enhance synchronous firing pattern of the stabilizing musculature and could escalate the kinesthetic awareness of the shoulder joint required during the game situations (Wilk et al., 2002; Reinold and Gill, 2010).

Further, enhancing neuromuscular control of scapulothoracic joint was influenced by scapular neuromuscular control drills. Neuromuscular training drills of the scapulothoracic joint have been shown to selectively activate scapular retractors, protractors, elevators and depressors. Rhythmic stabilization drills at scapulothoracic joint might challenge the force couple formed by upper and lower trapezius and serratus anterior increasing the scapular stability. Thus, enhancing proprioceptive and kinesthetic

Table 2
Mean and standard deviation of accuracy across the phases.

Outcome Collection Points	weeks	n	Mean ± SD	Mean difference	p-value
Baseline	0	45	64.2 ± 14.1		
Pre-Intervention	12	43	61.6 ± 13.4	2.61	0.787
Post-intervention	24	43	67.9 ± 12.2	6.3	<0.001
Withdrawal	30	43	62.5 ± 21.5	5.98	0.117

Significance level set at 0.05.

Table 3
Mean and Standard deviation of Speed (m/s) across the phases.

Outcome Collection Points	Weeks	n	Mean ± SD	Mean Difference	p-value
Baseline	0	45	28.5 ± 8.94		
Pre-intervention	12	43	29.0 ± 9.36	1.6	0.022
Post-Intervention	24	43	29.6 ± 9.36	2.1	<0.001
Withdrawal	30	43	29.2 ± 9.74	1.3	0.013

Significance level set at 0.05.

awareness of the scapula could have improved the function of shoulder joint resulting in increased throwing accuracy (Wilk et al., 2002; Reinold and Gill, 2010).

We administered an exercise regime which consisted of rhythmic stabilization drills provided at end range of motion in various sports-specific positions. These sports-specific exercises included in our study were progressed from side lying external rotation and internal rotation at 0° of abduction to kneeling external and internal rotation in 90°/90° position. Further, rhythmic stabilization was given to the player in standing 90°/90° position. To increase the difficulty level, shoulder external rotation and internal rotation were performed with external tubing and rhythmic stabilization drills were performed in various positions at end range (Reinold et al., 2010; Wilk et al., 2002; Borsa et al., 1994).

Also, Proprioceptive Neuromuscular Facilitation (PNF) diagonal pattern for the shoulder along with rhythmic stabilization was incorporated in the current study as these patterns mimic overhead throwing activities. In overhead athletes, during the wind-up and cocking phases of throwing motion, shoulder undergoes flexion, abduction and external rotation. Progressing to acceleration, deceleration and follow-through phases of throwing, shoulder moves into extension, adduction and internal rotation. These similarities within throwing motion and PNF diagonal pattern have been found to influence the synergistic and antagonistic co-activation of the involved muscles in throwing motion more efficiently (Padua et al., 2004). EMG studies on PNF diagonal pattern of shoulder joint have been reported to activate upper trapezius, middle trapezius, lower trapezius, serratus anterior and anterior deltoid (Ann et al., 2015; Youdas et al., 2012; Witt et al., 2011; Sullivan and Portney, 1980). The cumulative effect would have resulted in scapular upward rotation, abduction and posterior tilting hereby influencing the improvement in throwing accuracy in the present study.

Measurement of throwing speed was done using Radar Gun (model # PR1000-BC, Pocket Radar, Inc. Santa Rosa, California, U.S.A). The results showed an increase of 2% after 12 weeks of neuromuscular training. The observed improvement is modest and statistically significant compared to a previous study where authors found an increase of 6.6% after 8 weeks of progressive velocity training (Freeston and Rooney, 2008).

The possible biomedical mechanism of improvement observed in throwing speed could be ascribed to activation of mechanoreceptors present in the inert structures as a consequence of neuromuscular training. These mechanoreceptors were stressed to extreme functional positions during rhythmic stabilization drills, thereby stimulating synchronous muscle firing pattern through muscle reflex arc (Reinold et al., 2010; Wilk et al., 2002; Borsa et al., 1994). Therefore, exaggeration of synchronous firing pattern of dynamic and static stabilizers might have yielded the gain in the throwing speed by optimizing kinaesthetic awareness (Devis & Dickoff-Hoffman, 1993). Also, neuromuscular control and proprioception could have improved as a result of neural adaptation and specific training principle administered in our study (Devis & Dickoff-Hoffman, 1993; Padua et al., 2004).

Neural adaptation is a common theory which suggests the selective recruitment of high-threshold motor units after a specific training regime. Improvement in throwing speed can be attributed to preferential recruitment of high-threshold motor unit due to neuromuscular training drills performed in functional positions. Therefore, when these high-threshold motor units are recruited, they are shown to produce maximal power as they innervate a relatively high number of force producing muscle fibers required during the ballistic throwing motion. This recruitment pattern was achieved by the specific training principle in the current study by mimicking the throwing motion (Cormie et al., 2011).

The improvement was maintained in the withdrawal phase. However, it was not found to be significant. According to the study design, this observation suggests that the resulted improvement in treatment phase was not by chance, but after 12 weeks of neuromuscular training.

Neuromuscular training for 12 weeks was found to enhance throwing performance amidst cricket players. The current study employed sports-specific exercise regimes, where the players underwent exercises in various functional positions. This type of training should be taken into consideration by coaching staff. However, there were some limitations in the current study. Throwing skills were measured by task-oriented activity which is an artificial environment which limited the players from experiencing real situations. Components influencing the throwing performance included a psychological component, proprioception, muscle recruitment and strength of the throwing arm which were not measured. The relationship between these factors should be explored in future studies. A single subject design was utilized in the current study to learn more about a clinical phenomenon. Further studies using a comparison group or a control group would give a better understanding of the neuromuscular training programme.

5. Conclusion

The neuromuscular training led to modest and beneficial improvement in throwing performance in terms of accuracy and speed in asymptomatic sub-elite cricket players.

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