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Comparative Analysis between Effect of Shoulder Strength and Core Endurance on Bowling Speed in Pace Bowlers

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Abstract

Background: Cricket has received considerable research attention due to popularity. Ability of bowlers to bowl with high-speed plays a major role in success. Earlier studies have suggested that shoulder and core play a crucial role in kinetic chain which results in improved bowling speed. **Objective:** The objective of this study was to study relative efficacies of shoulder strength and core endurance on bowling speed in pace bowlers. **Methods:** Forty male pace bowlers having age (20.10 ± 3.71) in years from Punjab participated in the study. Bowling speed was measured with Radar Gun. Shoulder strength measured with Biodex dynamometer. Core endurance was measured by McGill protocol. Statistical analysis of was carried out using SPSS version 23. **Results:** Bowling speed was recorded as mean ± SD 91.00 ± 10.10 km/h. Significant fair positive relationship found between bowling speed and external rotators at angular velocity of 90°/s and (r = 0.386) and shoulder flexors at 60°/s (r = 0.408), 90°/s (r = 0.383), and 120°/s (r =0.448). Trunk extension shows fair positive significant relationship (r =0.327) with bowling speed. **Conclusion:** The present study contributes toward pace bowlers' training and focus on necessity of further research considering limitations of COVID-19 pandemic.

Keywords: Bowling speed, Isokinetic dynamometer, McGill protocol, Radar gun

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Introduction

Cricket is a popular sport, and by increasing large number of spectators the playing teams always strive hard to win the game. The ability of bowlers to bowl with high-speed plays a major role in dismissing or reducing the score of the opposing batsmen by decreasing the time to perceive and execute appropriate motor response, therefore, contributes to victory. Thus, all teams right from the junior level endeavor to include fast bowlers in their team.[1,2] Strength and power characteristics are undoubtedly the important factors influencing ball-release speed.[3]

Rotator cuff muscles (i.e., supraspinatus, infraspinatus, teres minor, and subscapularis) are dynamic stabilizers as well as rotators of shoulder joint. Furthermore, deltoid muscle produces flexion (anterior fibers along with pectoralis major) and extension (posterior fibers along with latissimus dorsi).

During overhead action of shoulder, rotator cuff muscles play a key role and act in balanced and coordinated manner to maintain adequate glenohumeral joint congruency and stability.[4,5] Particularly, the external rotators develop an approximation force equal to body weight and control eccentrically on the upper arm to prevent joint distraction during overhead throwing motion.[6,7] Furthermore, the balance between external and internal rotation strength (muscle strength ratio) is important for normal shoulder joint function.[8,9] During overhead bowling, flexion-extension movement also plays an important role. Researchers suggest that during arm flexion and extension, the rotator cuff muscles are activated in a specific way to prevent potential anterior-posterior humeral head shifts.[10,11]

The term "core" includes the abdominals (rectus abdominus, transversus abdominis, and internal and external obliques), lumbar (multifidus, quadratus lumborum, erector spinae, intertransversarii, and inter-spinales), hip girdle musculature (Gluteus Maximus and Gluteus-Medius), and the thoracolumbar fascia.[12] During pre-delivery and delivery stride, rectus abdominis, obliques, and paraspinals facilitate bowling arm and trunk rotation that leads to rhythmic action.[13] The transversus abdominis has been found to be the first trunk muscle active with activity of the upper limb and results in trunk flexion.[14,15]

To transfer forces generated with the lower extremities, through the torso, and to the upper extremities during the bowling action; most desirable qualities required are core muscle strength and endurance.[16-19] Studies also stated that lumbar stability has an effect on an individual's bowling speed.[15,17]

A review of the literature on cricket concluded that much more research was required before a full understanding of the scientific aspects of the game could be made.[3,20] Several researchers have been previously working on determinants of bowling speed, which included individual effect of shoulder and core strength on bowling speed. The aim is to study the correlation between shoulder as well as core muscle strength on bowling speed in a single cross-sectional study design.

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Methods

Participants

Forty male pace bowlers (36 right and 4 left arm) having age (20.10 ± 3.71) in years; body mass (65.11 ± 11.51) in kg; height (1.71 ± 0.06) in meters, and BMI (22.10 ± 3.06) kg/m^2 from various academies of Amritsar, Punjab, India volunteered to participate in the study. Sample size was calculated by G-power software (version 3.1). ([$Z\alpha$ =1.28, $Z\beta$=0.84]).

Participants included were asymptomatic and had no injuries 3 months before the testing.[5] Twenty eight out of 40 bowlers were associated with professional state level teams, rest of them had represented local cricket association within their respective age groups.

Testing Procedure

The study was duly approved by the Institutional Ethical Committee of Guru Nanak Dev University, Amritsar. Physical profile evaluation including body mass and stature, shoulder strength analysis, and core muscle endurance tests was performed at Strength Analysis Laboratory, Department of Sports Sciences and Medicine, Guru Nanak Dev University, Amritsar.

Bowling Speed Assessment

Participant's bowling speed was assessed using SRA 3000 Tracer Precision Radar gun (Homosassa, Florida, United States) with range up to 60 feet and measuring speed of 10–199 mph.[21] At bowling end, the gun was placed 5 m behind the bowling crease, pointing down at the middle stump at the bowler's end.[5] Set up of the radar gun is shown in Figure 1. Timing of 7 to 10 am of morning, session was selected to avoid exertion due to extremely hot weather. On a standard length of 20.12 m bowling facilities, good length (3.8 to 5.8 m) from keeper's end was marked with bowling cones at the edges. Two new SG Club four-piece cricket leather ball (weight–156 g) (Sanspareils Greenlands cricket) were used for standardization and to avoid effect of wearing and tearing.[22]

Participants were instructed to perform running, stretching, and shadow deliveries as a part of their warm up for 15 mins.[2,3,5] Participants were asked to bowl three good length deliveries targeting stumps as fast as they can using their full run-ups with rest of 40–60 s and average of three was calculated.[3,5,23] To minimize effect of fatigue, analysis was scheduled minimum 24 h after a training/match.[21] To exclude "no-ball" deliveries, front foot placement was monitored by assessor as per the cricket bowling rules.[2]

Shoulder Strength Analysis

Shoulder strength analysis of shoulder flexors, extensors, and external and internal rotators of bowling arm of player was measured using the Biodex System 4 Pro dynamometer (Biodex Medical Systems Inc., Shirley, NY, USA)[9,24,25] Parameters included were peak muscle torque and Agonist-antagonist muscle ratio. Biodex system provided data of peak torque in Ft-Lbs and ratio in percentage.

Dynamometer was calibrated before the testing session. Each participant was placed in the Biodex chair and stabilized by straps across the chest. The lower limbs were flexed in hip and knee joints and the hand of the non-testing side was laid on lap or on a lever.[11,25]

For shoulder rotator muscles, the tested limb was placed on the lever arm with the elbow joint flexed to 90° and the hand holding the handle (i.e., modified neutral position).[9,24] The dynamometer was adjusted to 20° of rotation and a 50° tilt. Elbow/shoulder attachment was aligned with olecranon and it was locked with a knob (Figure 2a and 2b).

For shoulder flexors and extensors, the test was performed with elbow in extension and forearm in mid-prone position. The dynamometer was set in neutral position with height of the dynamometer adjusted according to subject and the shoulder attachment was aligned with the lateral aspect of the acromion.[26] (Figure 2c and 2d).

The participants were asked to perform 15 mins of warm up and stretching exercises of upper limb and core muscles along with three submaximal repetition for familiarization at each speed. The test was performed in CON/CON mode for three repetitions with maximal effort throughout range at three different angular velocities 60°/s, 90°/s, and 120°/s. Rest period was given for 1 min within each set and for 5 min after rotator testing.[26] Consistent verbal encouragement and visual biofeedback was provided to all participants.

Core Endurance Analysis

The four tests of McGill protocol were scored as individual held isometric postures for time. A 5 min rest was given between tests.[18]

Trunk flexion Test

The starting position of the athlete was sit-up position with hip and knees 90° flexed, arms across the chest and back rested on a wooden plank angled at 60° (Figure 3a). Then, the plank was pulled 10 cm backward and the athlete was asked to hold this unsupported position isometrically (Figure 3b). Timer was stopped when trunk was deviated anteriorly or posteriorly from 60°.[16,18,19]

Biering–Sorenson Trunk Extension Test

The test started in the "Biering–Sorensen position"[27] as the athlete was lying in prone position with anterior superior iliac spine aligned with the edge of the couch and their hands on the seat of a chair placed in front of them at the edge of the table (Figure 3c). To secure the participant's, lower body assistant held the strap above and below their knees. Timer was started when the participant maintained a horizontal position of the body and clear from the chair with the arms across the chesttill when the subject was unable to maintain the position.[18,28]

Right and Left flexion Tests

The test for lateral musculature started with the side-bridge position. The participant's knees were fully extended and the subjects had to place their top foot in front of the lower foot in order to increase their base of support placing their arm perpendicular to the floor, elbow resting on the mat, with the opposite arm across the chest resting on the testing shoulder (Figure 3c and 3d). The test started when participants lifted their hips off the mat, and a straight line was created with their body and terminated when the subject was unable to maintain the straight-line position and the hips lowered toward the turf.[18]

Statistical Analysis

All data are reported as means ± standard deviations. To determine, correlations Pearson's product-moment correlation coefficients (two-tailed) were used. Statistical significance was set at $P \leq 0.05$. In an attempt to generate a multivariate predictive model of ball release speed, a step-wise multiple regression was used. Statistical analysis was conducted using SPSS statistics version 23 (IBM, Chicago, IL, USA)

Results

Ball Release Speed

A histogram of the distribution of average ball release speeds (mean 91.00 ± 10.10 km/h) of the participants is shown in Graph I. The range of ball release speeds was 74.33–123.00 km/h and, according to Abernethy, 1981,[29] it is classified as slow (below 96 km/h), medium (96–119 km/h), and medium-fast (120–129 km/h) pace bowlers.

Isokinetic Shoulder Strength and Core Endurance Analysis

The mean isokinetic concentric peak torque (Ft-LBS) and concentric agonist antagonist ratio (in %) of the current participants' bowling arm (dominant) shoulder flexion, extension, and internal and external rotation are summarized in Table 1. Participant's core endurance test data (in sec) is presented in Table 2.

Table 1: Isokinetic data for shoulder movements at different angular velocities

Parameters n=40	*Shoulder flexion PT*	*Shoulder extension PT*	*Flex/Ext ratio*
Concentric action at 60°/s	30.19±10.58	42.81±14.74	79.86±81.61
Concentric action at 90°/s	29.06±10.51	41.68±15.51	71.93±33.24
Concentric action at 120°/s	30.30±11.18	43.51±15.07	72.31±32.19
	Shoulder IR PT	*Shoulder ER PT*	*ER/IR ratio*
Concentric action at 60°/s	34.98±13.90	18.15±5.35	74.78±89.37
Concentric action at 90°/s	36.51±14.60	17.00±5.60	59.82±5.87
Concentric action at 120°/s	36.90±14.07	17.22±5.78	56.34±51.42

Table 2: Core endurance score in sec

Parameters n=40	*Reading 1*	*Reading 2*	*Average*
Trunk flexion	285.91±142.53	279.41±135.88	282.66±138.66
Trunk extension	94.90±42.96	88.45±41.89	91.67±41.97
Right side plank	76.30±16.49	68.10±13.54	72.20±14.33
Left side plank	78.30±19.81	69.75±16.79	74.03±17.58

Relationship between Ball Release Speed and Shoulder Strength and Core Variables

The relationships between the ball release speed and shoulder strength and core variables are presented in Table 3. Significant fair positive results were found for the relationship between peak torque during concentric external rotation at angular velocity of 90°/s (Graph II), shoulder flexion peak torque at all the three angular velocities (i.e., 60°/s, 90°/s, and 120°/s) (Graphs III, IV, V), and average ball release speed.

All the core variables were found non-significantly related to the ball release speed except for trunk extension as fair positive significant relationship was noticed (Graph VI).

Attempts to Generate a Multivariate Prediction Model of Ball Release Speed

A multiple step-wise regression modeling method was used to determine how well the parameters predicted the ball release speed. The independent variables (Age, BMI, shoulder ER PT at 90°, shoulder flexion PT at 60°, shoulder flexion PT at 90°, shoulder flexion PT at 120°, and trunk extension score) included in the model were selected due to their significant ability to predict ball release speed. No significant multivariate model could be established for ball release speed as no model was more predictive than shoulder flexion PT at 120° at ball release alone.

Discussion

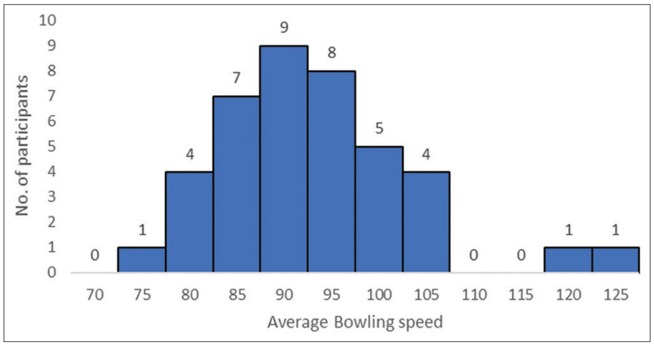
The ability of bowlers to bowl with high-speed plays a major role in dismissing or reducing the score of the opposing batsmen; consequently, it helps in securing victory of the team.[30] The range of bowling speed in this study was 74.33–123.00 km/h, which may be due to lower mean age and lack of basic strength training and conditioning due to COVID-19 pandemic.

The present study shows significant fair positive relationship between shoulder external rotators and flexors strength and bowling speed. Some studies suggested that during delivery phase of bowling, anterior deltoid, biceps and infraspinatus rotates the arm through flexion and adduction. In addition, Pooja *et al*., 2017, found significant positive relation between bowling speed and shoulder external rotation and flexion.[31] In contrast, November R. V., 2019, suggested statistically insignificant relationship between concentric external rotation and maximal throwing velocity.[5]

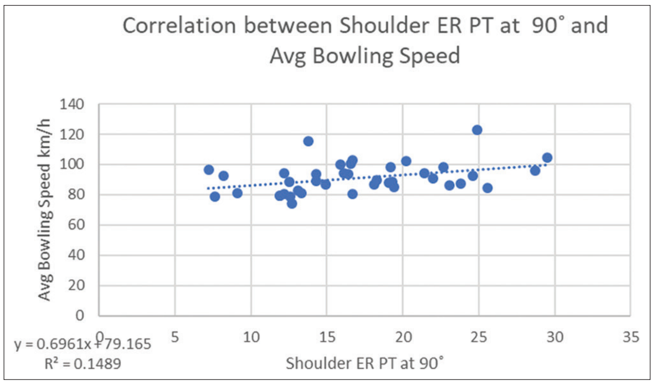
The present study showed mild non-significant positive correlation between shoulder internal rotators and bowling speed, shoulder extensors, and bowling speed. Similar to these

Table 3: Correlation of bowling speed with different shoulder and core variables

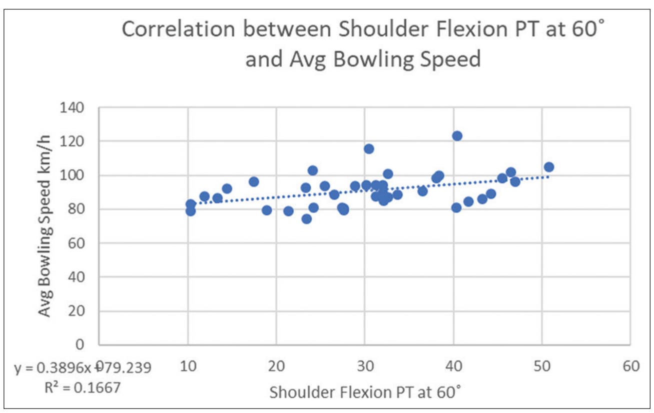
Variables	*At 60°/s*		*At 90°/s*		*At 120°*	
	r value	*P-value*	*r value*	*P-value*	*r value*	*P-value*
Shoulder IR PT	0.193	0.232	0.253	0.116	0.126	0.181
Shoulder ER PT	0.303	0.058	0.386*	0.014*	0.280	0.080
ER/IR ratio	−0.113	0.489	0.010	0.953	−0.022	0.893
Shoulder flexion PT	0.408*	0.009*	0.383*	0.015*	0.448*	0.004*
Shoulder extension PT	0.187	0.247	0.217	0.179	0.281	0.080
Flexion/extension ratio	0.107	0.510	0.130	0.424	0.136	0.402
	Reading 1		*Reading 2*		*Average*	
Trunk flexion	0.062	0.702	0.084	0.607	0.073	0.654
Trunk extension	0.246	0.127	0.327*	0.040*	0.289	0.071
Right plank	0.263	0.101	0.183	0.259	0.238	0.140
Left plank	0.165	0.310	0.146	0.369	0.162	0.317



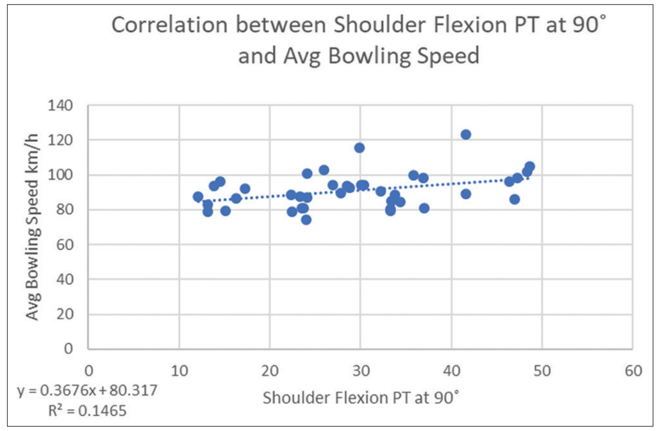
Graph I: Histogram of average bowling speed



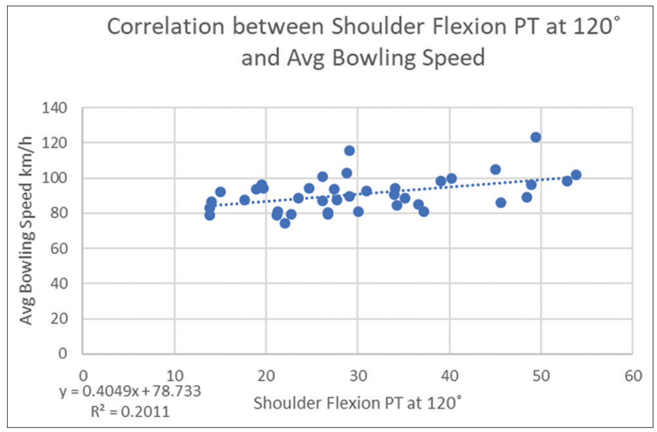
Graph II: Correlation between shoulder strength and bowling speed



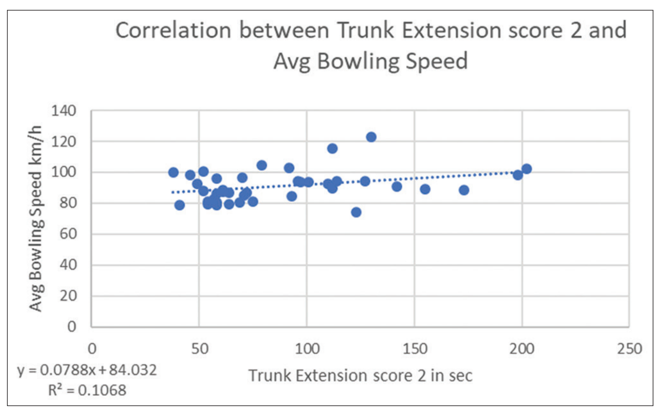
Graph III: Correlation between shoulder strength and bowling speed



Graph IV: Correlation between shoulder strength and bowling speed



Graph V: Correlation between shoulder strength and bowling speed



Graph VI: Correlation between core endurance and bowling speed

findings, Bayios *et al*., 2001, showed that the peak torques of the internal and external rotators of the shoulder were not related to ball velocity.[32] In contrast, a significant positive correlation was observed between relative concentric shoulder extension strength at 60°/s and ball release speed.[2] The strength ratio of internal and external rotators at all three angular velocity showed mild negative non-significant correlation with bowling speed.

In cricket players, the kinetic chain along with core as center of it of body involved in bowling and the energy is transferred from one link to the next. Stability of this trunk region is proposed to be a requisite for optimal bowling performance as the force is been generated from the lower extremity.[33]

Unique to this study, the core extension endurance showed significant fair positive correlation with bowling speed. It has been suggested that extension takes place at back foot strike, may serve the purpose of increasing ball acceleration,[20] and that the transversus abdominis muscle also contributes to this action.[14] In contrast, the study by Okada *et al*., 2011, also revealed significant correlations between core stability and performance tests, but showed no significant correlation with trunk extension.[34]

The present study reported non-significant mild to fair correlation between the right and left plank score and bowling speed. A study by Ruma *et al*., 2018, reported that all computed values of coefficient of correlations between performance and

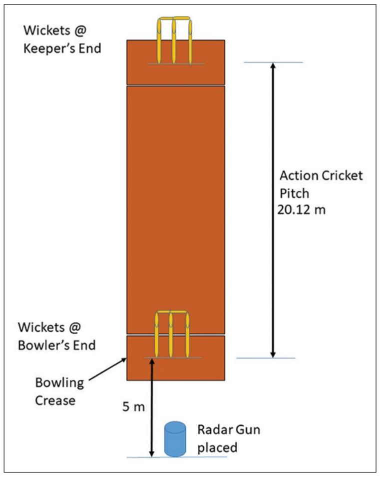


Figure 1: Set-up of the tracer precision radar gun

Figure 2: Shoulder isokinetic strength analysis by Biodex system 4 pro. (a): Shoulder Internal external rotation starting position, (b): Shoulder internal and external rotation movement, (c): Shoulder flexion extension starting position, and (d): Shoulder flexion extension set-up with Biodex computer screen

core abilities were statistically insignificant both for bowlers and batsman.[35] Opposite result was reported by Pooja *et al*., 2017, revealed a significant strong positive correlation between core stability (prone plank, left and right plank) and bowling speed.[36]

In multiple regression, no significant multivariate model could be established for ball release speed as no model was more predictive than shoulder flexion PT at 120° at ball release alone.

Conclusion

In conclusion, the cross-sectional analysis identified many variables that are significantly associated with ball release speed and some variables that are not. The study will be helpful to physical therapists and strength and conditioning professionals in the development of pace bowling specific training programs, which includes shoulder and core muscle training. While the present study identified a significant relationship, there is a strong need of intervention study for further investigation.

Figure 3: Core endurance McGill protocol, (a): Trunk flexion test starting position, (b): Trunk flexion testing position, (c): A modified Biering–Sorensen trunk extension test, (d): Left flexion test, and (e): Right flexion test

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