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BIOMECHANICAL ANALYSIS OF THROWING TECHNIQUES FOR VELOCITY AND ACCURACY

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ABSTRACT

The purpose of the study was the biomechanical analysis of throwing techniques for velocity and accuracy. To facilitate the study a total of six right-handed non-athletes were selected. It was assured that all selected subjects do not have any anatomical deformity and they were free from any orthopaedic or neurological disorders. Further, analysis of angular (joints angle in degree) and linear kinematic (velocity of release of the ball in m/s), SEMG signals (muscles activity in µv) were examined during different phases (winding, acceleration and follow through phase) of throwing techniques. Contribution was determined through descriptive statistics. The values obtained indicated the contribution of anterior deltoid (21%), right pectoralis major (18%), posterior deltoid (18%) and right posterior deltoid (14%) during underarm throwing technique. The results also showed the contribution of right middle deltoid (36%), right supraspinatus (16%) and right posterior deltoid (11%) during sidearm throwing technique. Similarly, right middle deltoid (36%), right supraspinatus (14%) and right posterior deltoid (12%). Pearson's product moment correlation was employed to examine the relationship of SEMG signal at selected muscle with velocity of release of ball. The level of significance was set at 0.05.
Keyword: *SEMG, throwing, angular, kinematics, kinetic.*

1. INTRODUCTION

Human movement performance can be enhanced in many ways. Effective movement involves anatomical factors, neuromuscular skills, physiological capacities, and psychological/cognitive abilities (Alexander, 1991). Most kinesiology professionals prescribe technique changes and give instructions that allow a person to improve performance. The phase when researcher was reviewing the literature and consulting various sources such as experts, books, research papers etc. developed the basic understanding of the biomechanical and physiological aspects of throwing techniques for velocity and accuracy (Escamilla et al., 2000; Hussainet et al., 2011). But still, they did not find themselves in a state from where they could clearly explain the causes and factors, which play vital role for the ideal throwing. It was evident from review of existing literature that biomechanical analysis is essential to understand the basics of movements such as physiological and biomechanical aspects during any activity (Chapman, 2008). The researcher also realized that it was important to understand the vital factor associated with velocity and accuracy in throwing.

With the evolution of highly precised technology such as SEMG used by researcher, now it is possible to have deeper insight in the issue with greater objectivity and accuracy (Hore et al., 1996). For improvement in techniques in any sport it should be mastered. For analyzing the technique, it is very important to know, what those variables of the techniques are, which must be given attention for its improvement. The researcher undertook the study with the intention to critically examine the throwing techniques for velocity and accuracy in order to have a deeper insight into the area.

2. METHODS AND MATERIALS

2.1 Participants

Six college going male non-athlete with an age range from 19 to 24 years were selected purposively as subjects of the study. Subjects were right handed without any anatomical deformity; and free from any orthopaedic or neurological disorders on the day of data collection.

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2.2 Variables of the Study

2.2.1 The study was confined to the activity in the muscles of Right biceps brachii, Right triceps brachii, Right deltoid (anterior), Right deltoid (middle), Right deltoid (posterior), Right pectoralis major, Right trapezieus, and Right supraspinatus.

2.2.2 Angular Variables
2.2.2.1 Right shoulder joint
2.2.2.2 Right elbow joint
2.2.2.3 Right wrist joint

2.2.3 Linear Variable
Velocity of release of the ball

2.3 Criterion Measures

2.3.1 RMS value was used of the signal to measure the root mean square amplitude and frequency (Hz) of the voluntarily elicited SEMG signal of selected muscles.
2.3.2 Angle of joint was measured in degrees.
2.3.3 Velocity of release of the ball was measured in meter/second.

2.4 Instrumentation

For analyzing the muscle activities apparatus used for surface EMG recording was Gunjan Human Karigar Nexus-10 channel Physiological Monitoring and Feedback system, India. Following settings were used bandwidth= 20-500 Hz, input impedance >100mΩ, Common Mode Rejection Ratio > 80 dB, maximum input voltage = ±5V, sampling rate =2048 sample per second.

2.5 Description of Throws and Phases

2.5.1 Underarm Throw: The releasing point of the ball was in between 45 degree from the vertical line pointing through axis of the shoulder joint in the frontal plane, below the axis of shoulder joint.
2.5.2 Sidearm Throw: The releasing point of the ball was in between 45 degree from the horizontal line pointing through axis of the shoulder joint in the frontal plane either above or below the horizontal line.
2.5.3 Overarm throw: The releasing point of the ball was in between 45 degrees from the vertical line pointing through the axis of the shoulder joint in the frontal plane, above the axis of the shoulder joint.

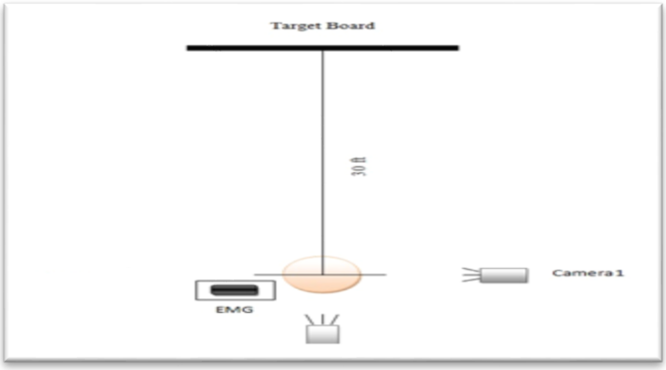
These throwing techniques were divided into the following three phases as mentioned below:

2.5.4 Winding up phase: For the purpose of the study, this phase defined as the throwing hand contact with the ball to the point of maximum shoulder extension at ball contact.
2.5.4 Acceleration phase: For the purpose of the study, this phase defined as maximum shoulder abduction to the point of releasing of the ball.
2.5.5 Follow through phase: During all the throws, the subject was sitting on stool with adjustable height, such that the axis of the shoulder joint lied at the same height (105 cm) as that of the center of the accuracy board. Throwing distance was fixed at 30 feet from the board.

2.6 Video Graphic Equipment and Location

The subject's throwing motion was recorded using Nikon L video camera in laboratory setting operating at a nominal frame rate and with a shutter speed of 1/2000 s at 50fps Camera was placed 5 m away from the subject and height of lens was set at 105 cm from the saggital plane on the right hand side to record the various stages of throwing, Camera was set-up on a rigid tripod and secured to the floor in the location. The camera was positioned perpendicular to the saggital plane and parallel to the medio-lateral axis (camera optical axes perpendicular on the saggital plane) as their subject's arm giving approximately 90^0 (degree) between their respective optical axes. The best trail was analyzed by silicon coach Pro-7 software. Only selected frames were obtained and developed the stick figures from which various kinematic variables were obtained. The stick figures were developed by using standard method, in which the body projections at the joint facing the camera were considered for the study (Figure1).

Figure 1: Illustration of the field layout for data collection



2.7 Administration of Tests and Collection of Data

Subjects were asked to do warm up and briefed about all three types of throws (i.e. underarm, sidearm and over arm throws) and appropriate visual (accuracy board) was shown to them prior to the commencement of trails. Subjects were asked to sit on the stool with adjustable height at a distance of 30 feet from the accuracy board. Then the height of the subject's frontal axis through the shoulder joint was adjusted (105 cm) to the height of the center of the accuracy Board. A white target board (Kolakowski & Malina's test of throwing accuracy board 1974) was placed vertically with two concentric circles of 6-inch radius and 30-inch radius marked black. The smaller circle was filled with color Red. Standard Nivia lightweight tennis ball was used for measuring throwing accuracy. Ball was made wet in red color. The surface electrodes were placed on the selected muscle with adhesive tape. The camera was placed perpendicular to the saggital plane on the right hand side to record the various stages of throwing and velocity of release of the ball. The data were collected simultaneously using a video camera (Nikon L 120) which was connected to a SEMG system synchronize with SEMG data during different stages throwing techniques. An identification number was placed at the back of the subject. The subjects were asked to undergo five underarm, sidearm and over arm throws respectively. The most accurate throw of each type of technique was considered for the purpose of analysis.

2.8 Data Reduction

After video recording sessions, recorded videos were uploaded into computer for trail identification. The identified trails were played with the help of Silicon Coach Pro-7 software to separate the clips of each throwing technique (Hussain, Khan, & Mohammad, 2012). The separate clips were opened on to the Silicon Coach Pro-7 software. The selected parameters were (velocity of release of the ball and angles in different phases of throws).

2.9 Statistical Analysis

In order to analyze the data statistically, the mean, standard deviation and Pearson's product moment correlation were calculated. For testing the hypothesis, the level of significance was set at 0.05. The statistical techniques were performed by use of SPSS v.19.

3. RESULTS

Table 1: Descriptive statistics of underarm, sidearm and overarm throw SEMG signals at muscle in microvolts

S.N.	Muscles	Underarm		Sidearm		Overarm	
		Mean	SD	Mean	SD	Mean	SD
1	Right triceps brachii	21.8	2.73	13.13	1.33	15.9	1.25
2	Right anterior deltoid	42.9	1.84	13.02	1.84	13.3	1.49
3	Right biceps brachii	27.74	3.26	17.32	2.29	16.1	2.58
4	Right pectoralis major	35.6	2.36	14.92	2.38	12.1	2.33
5	Right middle deltoid	25.43	0.74	60.02	3.59	61	2.13
6	Right posterior deltoid	28.16	1.91	18.33	1.64	21.3	1.49
7	Right supraspinatus	18.35	1.45	27.23	2.5	23.8	1.4
8	Right trapezieus	10.73	1.13	9.2	3.12	9.6	1.45

Table 2: Coefficients of correlation between SEMG signals of selected muscle and underarm velocity of release of the ball (N=6)

S.N.	Muscles	Underarm velocity of release of the ball	
		r-value	*p*-value
1	Right triceps brachii	0.262	0.616
2	Right anterior deltoid	.949*	0.004
3	Right biceps brachii	-0.526	0.284
4	Right pectoralis major	.968*	0.002
5	Right middle deltoid	-0.336	0.515
6	Right posterior deltoid	.941*	0.005
7	Right supraspinatus	0.168	0.751
8	Right trapezieus	-0.526	0.284

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

It reveals the statistical significance of the coefficient of correlation of SEMG signals of selected muscle during underarm throwing technique and underarm velocity of release of ball. The coefficient of correlation required to be significant for 4 degree of freedom at 0.01 level is (0.917). It is clearly evident from the above table that the coefficient of correlation for right anterior deltoid (0.949), right pectoralis major (0.968) and right posterior deltoid (0.941) were found significantly correlated with underarm velocity of release of the ball as the values obtained were greater than the tabulated value. Whereas, the obtained coefficient of correlation for right triceps brachii (0.262), right biceps brachii (-0.526), right middle deltoid (-0.336), right supraspinatus (0.168) and right trapezieus (-0.526) were found insignificant as the obtained values were lesser than the required tabulated value.

Table 3: Coefficients of correlation between SEMG signals of selected muscle and sidearm velocity of release of the ball

S.N.	Muscles	Sidearm velocity of release of the ball	
		r-value	p-value
1	Right triceps brachii	-0.451	0.369
2	Right anterior deltoid	.949**	0.004
3	Right biceps brachii	.972**	0.001
4	Right pectoralis major	.985**	0.0
5	Right middle deltoid	.982**	0.001
6	Right posterior deltoid	-0.105	0.843
7	Right supraspinatus	.951**	0.004
8	Right trapezieus	0.809	0.051

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

The coefficient of correlation required to be significant for 4 degree of freedom at 0.01 level is (0.917). Table 3 clearly indicates that right anterior deltoid (0.949), right biceps brachii (0.972), right pectoralis major (0.985), right middle deltoid (0.982) and right supraspinatus (0.951) were significantly correlated with sidearm velocity of release of the ball as the values obtained were greater than the tabulated value. Whereas, the obtained coefficients of correlation for right triceps brachii (-0.451), right posterior deltoid (-0.105) and right trapezieus (0.809) were found insignificant as the obtained values were lesser than the required tabulated value.

Table 4: Coefficients of correlation between SEMG signals of selected muscle and velocity of release of the ball during overarm throw

S. N.	Muscles	Overarm velocity of release of the ball	
		r-value	*p*-value
1	Right triceps brachii	.916*	0.01
2	Right anterior deltoid	.974**	0.001
3	Right biceps brachii	.999**	0
4	Right pectoralis major	-0.514	0.297
5	Right middle deltoid	-0.094	0.859
6	Right posterior deltoid	0.074	0.889
7	Right supraspinatus	0.011	0.984
8	Right trapezieus	0.027	0.959

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

The coefficient of correlation required to be significant for 4 degree of freedom at 0.05 is (0.811) and at 0.01 is (0.917). It was found in the table that right triceps brachii (0.916) was significantly correlated with side arm velocity of release of the ball, as the calculated value at 0.05 level was more than the tabulated value. Again right anterior deltoid (0.974) and right biceps brachii (0.999) were significantly correlated with sidearm velocity of release of the ball, as the calculated value at 0.01 level were more than the tabulated value at the same level. Whereas, the obtained correlation coefficient for right pectoralis major (-0.514), right middle deltoid (-0.094), right supraspinatus (0.011), right posterior deltoid (-0.074) and right trapezieus (0.027) were found insignificantly correlated as the obtained values were lesser than the required tabulated value (0.811).

Table 5: Descriptive statistics of underarm, sidearm and overarm kinematic angles during different phases of throwing winding; acceleration and follow through phase at selected joints

Kinematic Angles During Selected Phases	Underarm		Sidearm		Overarm	
	Mean	SD	Mean	SD	Mean	SD
WINDING PHASE						
Angle at shoulder joint	166.5	5.96	71.17	4.02	132.67	4.8
Angle at elbow joint	181.5	7.82	26.83	3.06	57.33	6.47
Angle at wrist joint	130.33	4.93	122.17	6.34	109.67	8.64
ACCELERATION PHASE						
Angle at shoulder joint	44.5	6.41	72.5	5.61	109	12.41
Angle at elbow joint	156.17	9.28	52.83	4.67	81.33	6.12
Angle at wrist joint	155.67	5.39	127.67	6.28	137.33	6.77
FOLLOW THROUGH						
Angle at shoulder joint	54.83	2.86	75	4.9	96.67	7.15
Angle at elbow joint	135.5	4.32	103.5	7.06	107.17	7.19
Angle at wrist joint	184.67	2.66	159.83	5.23	180.83	5.04

Table 6: Coefficients of correlation between underarm kinematic angles during different phases of throwing i.e. winding, acceleration and follow through phase at selected joints and underarm score of accuracy in throwing

Kinematic Angles During Selected Phases	Underarm scores of accuracy in throwing	
	r-value	*p*-value
WINDING PHASE		
Under-arm kinematic angle at shoulder joint	-0.248	0.636
Under-arm kinematic angle at elbow joint	0.346	0.502
Under-arm kinematic angle at wrist joint	-0.592	0.215
ACCELERATION PHASE		
Under-arm kinematic angle at shoulder joint	.906*	0.013
Under-arm kinematic angle at elbow joint	-0.07	0.895
Under-arm kinematic angle at wrist joint	0.338	0.512
FOLLOW THROUGH PHASE		
Under-arm kinematic angle at shoulder joint	.967**	0.002
Under-arm kinematic angle at elbow joint	-0.234	0.655
Under-arm kinematic angle at shoulder joint	.876*	0.022

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

Since, the coefficients of correlation required to be significant for 4 degree of freedom at 0.05 level is (0.811) and at 0.01 level is (0.917). It clearly indicates that Kinematic angles during acceleration phase at shoulder joint (0.906) and follow through at wrist joint (0.876) were significantly correlated with underarm scores of accuracy in throwing at 0.05 level as the calculated values obtained were greater than the tabulated value at the same level. Again kinematic angles during follow through phase at shoulder joint (0.967) was significantly correlated with underarm scores of accuracy in throwing at 0.01 level as the values obtained were greater than the tabulated value at the same level. Whereas, the obtained coefficient of correlation for kinematic angles during winding at shoulder joint (-0.248), elbow joint (0.346), and wrist joint (-0.592), acceleration phase at elbow joint (-0.070), wrist joint (0.338) and follow through at elbow joint (-0.234) were found insignificant as the obtained values were lesser than the required tabulated value.

Table 7: Coefficients of correlation between sidearm kinematic angles during different phases of throwing i.e. winding, acceleration and follow through phase at selected joints and sidearm score of accuracy in throwing

Kinematic Angles During Selected Phases	Sidearm scores of accuracy in throwing	
	r-value	*p*-value
WINDING PHASE		
Side-arm kinematic angle at shoulder joint	-0.43	0.395
Side-arm kinematic angle at elbow joint	-0.26	0.619
Side-arm kinematic angle at wrist joint	-0.379	0.459
ACCELERATION PHASE	-0.697	0.124

Side-arm kinematic angle at shoulder joint		
Side-arm kinematic angle at elbow joint	0.248	0.635
Side-arm kinematic angle at wrist joint	-0.367	0.474
FOLLOW THROUGH PHASE		
Side-arm kinematic angle at shoulder joint	.935*	0.006
Side-arm kinematic angle at elbow joint	0.385	0.452
Side-arm kinematic angle at wrist joint	.952*	0.003

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

Since, the coefficients of correlation required to be significant for 4 degree of freedom at 0.01 level is (0.917). Clearly indicates that kinematic angles during follow through phase at shoulder joint (0.935) and wrist joint (0.952) were significantly correlated with sidearm scores of accuracy (cm) in throwing because the values obtained were greater than the tabulated value at the same level. Whereas, the obtained coefficient of correlation for kinematic angles during winding at shoulder joint (-0.43), elbow joint (-0.26), and wrist joint (-0.379), acceleration phase at shoulder joint (-0.679), elbow joint (-0.248), and wrist joint (-0.367) and follow through at elbow joint (0.385) were found insignificant as the obtained values were lesser than the required tabulated value.

Table 8: Coefficients of correlation between overarm kinematic angles during different phases of throwing i.e., winding, acceleration and follow through phase at selected joints and overarm score of accuracy in throwing

Kinematic Angles During Selected Phases	Overarm scores of accuracy in throwing	
	r-value	*p*-value
WINDING PHASE		
Over-arm kinematic angle at shoulder joint	0.726	0.103
Over-arm kinematic angle at elbow joint	-0.012	0.982
Over-arm kinematic angle at wrist joint	0.696	0.124
ACCELERATION PHASE		
Over-arm kinematic angle at shoulder joint	0.526	0.283
Over-arm kinematic angle at elbow joint	-0.241	0.645
Over-arm kinematic angle at wrist joint	-0.161	0.761
FOLLOW THROUGH PHASE		
Over-arm kinematic angle at shoulder joint	0.452	0.369
Over-arm kinematic angle at elbow joint	.986**	0
Over-arm kinematic angle at wrist joint	.979**	0.001

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

The coefficients of correlation required to be significant for 4 degree of freedom at 0.01 level is (0.917). The coefficients of correlation presented in table 12 clearly indicate that kinematic angles during follow through phase at elbow joint (0.986) and wrist joint (0.979) were found significantly correlated with over arm scores of accuracy in throwing because the values obtained were greater than the tabulated value at the same level. Whereas, the obtained coefficients of correlation for kinematic angles during winding at shoulder joint (0.726), elbow joint (-0.012), wrist joint (0.696), acceleration phase at shoulder joint (0.526), elbow joint (-0.241), wrist joint (-0.161) and follow through at shoulder joint (0.452) were found insignificant as the obtained values were less than the tabulated value.

Table 9: Descriptive statistics of scores of accuracy and velocity of release of the ball during underarm throwing

Variables	Mean	SD
Underarm score of accuracy in throwing	26.74	5.9
Underarm velocity of release of the ball	17.06	2.48

Table depicts that the mean and standard deviation of underarm scores of accuracy (cm) and underarm velocity of release of the ball (m/s). Which were (26.74±5.9), and (17.06±2.48) respectively.

Table 10: Coefficient of correlation between scores of accuracy and velocity of release of the ball during underarm throwing

Variable	Underarm velocity of release of the ball	
	r-value	*p*-value
Under arm score of accuracy in throwing	.964*	0.001

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

Since, the coefficient of correlation required to be significant for 4 degree of freedom at 0.01 level is (.917). Coefficient of correlation presented in table 14 clearly indicate that underarm score of accuracy was found significantly correlated with underarm velocity of release of the ball, as the calculated value was (.964), which was greater than the tabulated value (.917) at the same level.

Table 11: Descriptive statistics of score of accuracy and velocity of release of the ball during sidearm throwing

Variables	Mean	SD
Sidearm score of accuracy in throwing	21.28	3.48
Sidearm velocity of release of the ball	27.06	3.49

Table clearly represents the mean and standard deviation of sidearm score of accuracy (21.28±3.48) (cm) and sidearm velocity of release of the ball (m/s) (27.06±3.49).

Table 12: Coefficient of correlation between score of accuracy and velocity of release of the ball during sidearm throwing

Variable	sidearm velocity of release of the ball	
	***r*-value**	***p*-value**
Sidearm score of accuracy in throwing	.975*	0.001

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

The coefficient of correlation required to be significant for 4 degree of freedom at 0.01 level is (0.917). The coefficient of correlation presented in table 16 clearly indicate that sidearm score of accuracy was significantly correlated with sidearm velocity of release of the ball as the value obtained (0.975) was greater than the tabulated value (0.917) at the same level.

Table 13: Descriptive statistics of scores of accuracy and velocity of release of the ball during overarm throwing

Variables	Mean	Std. Deviation
Over arm score of accuracy in throwing	16.56	3.72
Over arm velocity of release of the ball	29.72	3.34

Above-mentioned table clearly presents the mean and standard deviation of over arm scores of accuracy (cm) (16.56±3.72) and over arm velocity of release of the ball (m/s) (29.72±3.34).

Table 14: Coefficient of correlation between score of accuracy and velocity of release of the ball during overarm throwing

Variable	Overarm velocity of release of the ball	
	***r*-value**	***p*-value**
Over arm score of accuracy in throwing	.988**	0

*Significant at the 0.01 level. $r_{.01}$ (4) =.917

The coefficient of correlation required to be significant for 4 degree of freedom at 0.01 level is (0.917). The coefficient of correlation presented in table 14 clearly indicates that over arm score of accuracy was significantly correlated with over arm velocity of release of the ball, as the values obtained (0.988) were greater than the tabulated value at the same level.

4. DISCUSSION

The first objective was to examine the significance of relationship between SEMG signals at various muscles with underarm velocity of release of the ball. The analysis of data revealed that a significant positive relationship existed between the underarm SEMG signals at right anterior deltoid (0.949), right pectoralis major (0.969), and right posterior deltoid (0.941) and underarm velocity of release of the ball. This significant value of correlation may be substantiated by many factors, such as the location of these muscles and plane of movement of arms during underarm throw. It is known that, the underarm throw takes place in saggital plane and the muscles, which are found to be significantly related with underarm velocity of release of the ball, are located at anterior and posterior sides of body (Hussain, Khan, & Mohammad, 2011). During any action, the muscles located in line of the plane of movement are primarily involved, as these are attached to bones in the same plane. The movement of arms during underarm throw is extension & flexion of shoulder joint. These findings are also supported by the conclusions made by Hamlyn, Behm, and Young (2007).

The analysis of data also revealed that insignificant relationship exist between SEMG signals of right triceps brachii (0.262), right biceps brachii (0-.526), right middle deltoid (0-.336), right supraspinatus (0.751) and right trapezieus (0-.526) with underarm velocity of release of the ball. This insignificant relationship could have been caused due to lack of involvement of these muscles in the technique of underarm throw as, these movements take place in saggital plane and these muscles are attached to the bones at planes of the body rather than saggital plane. It means during the movement of shoulder flexion and extension; these muscles participate to a minimal extent. The findings are also supported by Gowan, et al. (1987) who conducted a study on electromyography and motion analysis of the upper extremity in sports.

The analysis of data also revealed that there existed a significant relationship between the SEMG signals at right anterior deltoid (0.949), right biceps brachii (0.972), right pectoralis major (0.985), right middle deltoid (0.982) and right supraspinatus (0.951) with sidearm velocity of release of the ball. The primary reason behind this significant relationship may be the movements involved in the technique of sidearm throw and the role played by these muscles in movement in this plane. It may be considered that side arm throw includes horizontal adduction of the shoulder joint, which primarily involves muscles located at lateral aspect of bones and partially attached to the muscles at anterior aspect of body (Hussain, Mohammad, & Khan, 2012). In horizontal adduction, the arms come almost parallel to the ground and fetch horizontally closer to midline of the body. This movement also activates the right biceps muscle and right anterior deltoid to a significant level. During this movement, deltoid muscle, which is located at lateral side of the body also prominently contribute in this movement of the arm. Further, in the sidearm throw the middle deltoid is dominant. It participates in all arms elevation movements. They may act synergistically to add abductor force or assume primary responsibility for arms elevation in their direction (flexion and extension). Hence, the pattern of deltoid action various with the plane of motion used. In case of arm flexion, the anterior deltoid is the primary muscle it is assisted by the clavicular pectoralis major coroco-brachilies and biceps brachii as well as the middle deltoid. In case of supraspinatus this muscle is active in all pattern of arms elevation, it is a short leverage and modest to the limit to the torque that can be produced, however maximal effort could accomplish arm elevation to 30 degree but not higher.

It is also evident from the analysis of data that right posterior deltoid (-0.105) and right trapezieus (0.809) were insignificantly related to the sidearm velocity of release of the ball. The lack of significant relationship may be attributed to the fact that the right trapezieus muscle is not attached to the bones moving in this sidearm throwing techniques and lies well above the line of action of involved joints. The posterior deltoid also does not contract maximally during this movement Illyés and Kiss (2003) results were in agreement with the results.

Further analysis of data revealed that there is a significant relationship between the SEMG signals at right triceps brachii (0.916), right anterior deltoid (0.974) and right biceps brachii (0.999) and with over arm velocity of release of ball. This significance may be attributed to a variety of factors. In this case, right triceps brachii is the primary muscle, which activates force to overcome the weight of the ball and forearm during the extension of elbow (Narwaria, 2015). The results also revealed that the SEMG signals at right pectoralis major (-0.514), right middle (-0.094), right posterior deltoid (0.074), right supraspinatus (0.11) and right trapezieus (0.027) were insignificantly related to the over arm velocity of release of ball.

The data were further analyzed in order to accord with second objective i.e., to find the relationship if any between kinematic angles and throwing accuracy. The analysis of data revealed that significant relationship existed between kinematic angles during acceleration phase at shoulder joint (0.906), follow through at shoulder joint (0.967), and wrist joint (0.876) with underarm scores of accuracies. This relationship may be attributed to a number of factors contributing in the movement.

In acceleration phase, the biceps brachii muscles are a humeral head depressor. It demonstrated insignificant role in elevation and rotation of the shoulder. The shoulder is abducted and externally rotated. This is done in order to attain better control over the direction and releasing of the ball in underarm throwing. The other factors that may be possible reasons for the given relationship is that in over arm throw at final execution the area is closer to the proximity of eye and hence provide better control over the movement (van den Tillaar & Ettema, 2004). It also could be explained that to increase the velocity, the angles is increased as (V = ὼr) as seen in the graphs, it is evident that in majority of cases represent a decreased performance with increase in velocity. However, contradictions are also present. Therefore, it is suggested that is required optimum velocity in order to attain for better accuracy (van den Tillaar & Ettema, 2003). Although possibility may also be there that, a different picture might be highlighted if a similar study is conducted with larger sample size, as the coefficients of correlation did not indicated any cause and effect relationship, especially with lower sample size.

The analysis of data revealed that there was a significant relationship between coefficients of correlation of sidearm throw. Angle during follow through at shoulder joint (0.935) and wrist joint (0.952) with sidearm scores of accuracy were seen in throwing. The angles would have been significantly related due to the factors during sidearm throw. Enhancement the angles at follow through results in complete extension of elbow joint and hence increase angular space for the arm to strike the ball on the target. An increased angle at wrist joint increases the angular space and there is less scope for the target to be aimed linearly (Lagally et al., 2004). Analysis of data also made it evident that there is insignificant relationship between sidearm throws kinematic angles during winding at shoulder joint (-0.430), elbow joint (-0.260), wrist joint (-0.379), acceleration phase at shoulder joint (-0.697), elbow joint (0.635), wrist (-0.367), and follow through at elbow joint (0.385).

Lack of significant relationship of angles during winding phase at shoulder, elbow and wrist joint with sidearm scores of accuracy might have been due to the reason that the movement at the instant of the release mostly contributes the accuracy of the throw while winding phase occurs at the initial movement of the throwing. It is caused by the fact that there is a final transfer of momentum on the ball by wrist and adjoining joints at final instant of release, as the force is created at shoulder and elbow joint is finally transferred to the wrist joint. While lack of significant relationship between kinematic angles during acceleration phase at shoulder joint, elbow joint and wrist joint may be attributed to the lack of involvement of this phase in its contribution to the release accuracy.

The analysis of data further revealed that there was a significant relationship between over arm angles during follow through at elbow joint (0.986) and wrist joint (0.979) with over arm accuracy score in over arm throwing. This significant relationship may be attributed to the factors associated with the increased angle at elbow joint during follow through action, which might have contributed in increasing the scores of accuracy. The increased angles could result in the decreased distance between target and the ball at the moment of release. It may also support with optimum velocity required during over arm ball release for better accuracy. Results also were in agreement. It may also be argued that increase in elbow joint and wrist joint may lead momentum at follow through phase and at the same decreasing the instant of linearity during the throw (Kelly, Backus, Warren, & Williams, 2001).

The results also revealed that other factors were insignificantly related with over arm ball throw accuracy. This may be caused due to lack of involvement of muscular attachment to the moving bones and insignificant contribution of the joints at winding and acceleration phase in comparison to the follow through phase in determining score of accuracy.

The analysis of data showed a significant relationship between scores of accuracy and velocity of release of the ball (0.964) during underarm throwing. The significance of the relationship indicates that if there is an increase in the releasing velocity of the ball there is also an increase in throwing scores of accuracy. Hence, consequently indicating decrease in accuracy performance.

The underlying factors behind these results may be many. The releasing velocity of the ball may be more than optimum, which can lead to the inefficient control over the ball, at the time of the release. It may also be cited that to increase the velocity of release of the ball, the thrower will have to execute the movement of arms at greater speed. Hence, imparting less time in each phase, which could have caused inefficient adjustment of the point of the release of ball from the hand. The work of van den Tillaar and Ettema, (2006) also supports the obtained findings.

The analysis of data also showed that the sidearm scores of accuracy in throwing and sidearm velocity of releasing of the ball (0.975) was significantly correlated. This could be attributed to the reason that the acceleration phase at the wrist joint and horizontal adduction plays a vital role at the moment of release of the ball during sidearm throw.

In order to increase the velocity, the thrower needs to execute the movement of arms in a brisk manner resulting in decreased time for the adjustment of the wrist and forearm at the moment of release to the target. Hussain and Bari (2011) and Hussain, Mohammad and Khan (2011) findings also supported the results of the study.

The significant relationship might have caused due to the reason that the extension of elbow joint and wrist joint during the follow through phase is crucial factor for accuracy in an over arm throw. The proper extension of the elbow and wrist joint may also result into the external rotation of arms at the shoulder joint. However, if the velocity is exaggerated then there remains a scarcity of time for the thrower to execute the required movements at elbow and wrist joints. This lack of time may have caused insufficient adjustment and alignment of muscles and direction of throw to the target.

The analysis of data showed a significant relationship between scores of accuracy and velocity of release of the ball during over arm throw (.988). The positive relationship between the selected variables pointed towards a decline in the performance of accuracy of throwing with increasing the velocity of the ball. Hussain and Bari (2011) also concluded with a significant relationship between speed and accuracy throw in their study conducted to analyze the relationship between throwing speed and throwing accuracy.

Thus, the significance of relationship may be attributed to the reason that over arm throwing includes a complex mechanism during the throw, which includes adequate extension of elbow joint and optimum external rotation of the arm. However, if the velocity is more than required then their vital condition will not be fulfilled.

5. CONCLUSION

Based on the findings of the present study the following conclusions were drawn:

- During the underarm throw, muscles located at anterior and posterior sides of shoulder joint played prominent role during the throwing movement. Significant contributions were made by anterior deltoid, right pectoralis major and posterior deltoid played significant role.
- During sidearm throw, muscles located at lateral aspects of shoulder joint prominently contributed in the throwing movement. During sidearm throwing movement right middle deltoid, right supraspinatus, and posterior deltoid played the major contributing role.
- During over arm throw, also muscles located at lateral and posterior sides of the shoulder joint contributed significantly to the throwing movement.
- In the over arm throw, muscles which were found to have played significant role were right middle deltoid, right supraspinatus and right posterior deltoid played significant role in over arm throw.
- The over arm and sidearm throwing techniques are quiet similar in the nature in the terms of muscle electrical activity, as it was observed that mostly same group of muscles exhibit approximately equal contribution.
- The angles increase at different joints i.e., shoulder, elbow and wrist joint particularly during follow through phase, a decline was observed in accuracy performance.
- The over arm throw is most appropriate technique where the conditions of the greater velocity along with higher accuracy are required to be met.
- The underarm throwing technique was least efficient in terms of accuracy and velocity.
- The pattern of involvement of muscles during various phases of different throwing technique was approximately similar during over arm and sidearm throw.

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