Chapter - II

REVIEW OF RELATED LITERATURE

Research scholar made an attempt to locate literature related to the study. The relevant studies pertaining to the Javelin Throw of specific importance are given below:

Paish¹ conducted a study on aimed at the technique employed by World-class performers. Much of the information here has been obtained from questionnaires sent out to leading Javelin throwers in Great Britain and Germany. Careful analysis of loop films seem to indicate that none of the top javelin throwers make use of principles related to a rigid lever and the human body in the live state is far from rigid. Analysis showed that in straight leg technique there was a tremendous loss of forward momentum which could more profitably be used for accelerating the spear is wasted by lifting the body over this long lever. In this method the release is high over his long lever and in bent leg technique advantage is less slowing of forward speed, and provided the straightening of left leg is timed correctly there could be a valuable increase in the range of movements. Such timings are extremely intricate and will occur quite in frequently. It must therefore be accepted that throwers going for the big

¹ Wilf Paish, "Technique of World Class Performers," Track Technique 24 (June 1966): 747-749.
one will produce in consistent result a factor already well established by
class throwers and the important thing about the arm action is that the pull
must be long, fast and straight. Any eccentric pull on the javelin will cause
movement about it flight path, often shown as tail quiver, which result in
decreased range

Witchey² used cinematographic techniques in conjunction with the
BMDO 2 R- stepwise regression computer programme to determine the
relationship between the mean horizontal distance attained in the javelin
throw and the degree of body lean at the start of power phase, the angle
of the left knee joint at the moment of release and the angle of elbow joint
of the throwing arm at the start of the power phase. Thirty-two subjects
participated in the 1971 California Collegiate Athletic Association (CCAA)
National Collegiate Athletic Association (NCAA) college division and
NCAA University Division Track and Field Championships. Investigator
assumed that an increase in the angle of body lean would demonstrate a
possible increase in the horizontal distance of the throw. It appeared that
there might have been an inverse relationship at time, which may indicate
that individual factor of each thrower such as strength and coordination
may have determining effect on how much lean an individual should have
in order to attain the best possible distance. Other finding appeared to

² Ronald L. Witchey, “Factors Influencing Javelin Performance”; *Track Technique* 52
(June 1973): 1666-1667.
support the importance of complete extension of the left knee joint at the moment of release of the javelin. It was interesting to note that thrower over 198 ft. demonstrated a negative relationship which may indicate that the subject who had throw better than 190 ft. started their delivery prior to the right foot contact with the ground.

Witchey\textsuperscript{3} conducted a study in which cinematographic techniques were used in conjunction with the BMDO -2 R stepwise regression computer programme to determine the relationship between horizontal distance attained in the javelin throws and certain movement factors. Subject (N=32) were participants in the 1971 California CCAA, NCAA College Division and NCAA University Division Track and Field Championship. Horizontal velocity of the right iliac crest during the power phase was related positively to the more advanced throwers. When considering intermediate and beginning throwers. Improvement in horizontal distance depends on extension of the left knee joint at the exact moment of release. The horizontal velocity of the right iliac crest during the power phase was considered the most important factor influencing the horizontal distance.

Hay\(^4\) in his study mentioned that in the better throws the inclination approaches 111-113 degrees. It increases the distance through which force may be exerted on the javelin and the hips are now 'square' to the front driven in that direction by the extension of right leg and by the resistance provided later by the left leg. The trunk is also 'square' to the front, chest will be forward and back arched slightly; and the throwing arm is being whipped forward with the shoulder leading the elbow high and the hand trailing. In the release the left leg has been extended to increase the height of release 1.68-2.01 m. for top the class throwers and by contributing primarily to the vertical component of the velocity to increase both the speed and the angle of release. The extension of the elbow is all but complete and the javelin is about to be released, spinning about its long axis from the fingers. This athlete takes a 1.5 -2.0 m. long recovery step to dissipate the momentum left over from the preceding movements.

Webb and Bobsing presented an article in 1988 at University of Oregon Clinic held in conjunction with the NCAA Division Track and Field Championship. He suggested the following key points:

\(^5\) Bill Webb and Bobsing, "Javelin Throw Principles" *Track and Field Quarterly Review* 89:3 (1989): 21
1. Accelerate (drive/jump) into the throw.
   a) Full extension of the left leg when driving into the throw.
   b) Aggressive forward/upward right knee drive into the throw.
   c) Forward, rather than upward, trajectory of the hips (center of gravity) into the throw.

2. Keep trunk/head erect and in balance up through the release.

3. Complete the delivery one javelin length from the scratch line.

4. At the instant of touch down, with the right foot in the throwing stride, a position of readiness should be assumed.
   a) Weight should be over or behind the flexed right leg.
   b) Throwing hand should be approximately at the middle of the back and should not slide out as the left foot is regrounded maintain, "maximum controlled the torque/wrap."

5. The left arm and right leg initiate the throw.

6. The left side block and the release is completed in a full frontal position.

7. All things being the same, an improvement in general over all athletic ability will improve One's ability to create greater forces during the throw. Thus allowing one to increase is her or his distance.
Mero and others\textsuperscript{6} investigated body segment contribution to javelin throwing during last thrust Phase. A 3 D analysis was performed on the male and female javelin throwers during the final of the 1992 Olympic games in Barcelona. The subjects were videotaped from the right side of the throwing area by two NAC high-speed cameras operating at 100 frame per second. The subjects were male (N=11) and female (N=11) javelin finalists. The means, S.D. and ranges for height, mass and one throw were analysed for each subject. For data analysis direct linear transformation method was used in calculating 3-D coordinates of the digitized body and the javelin parts.

They used linear correlation technique to quantify relationship between the various parameters and throwing distance. The significance level for statistical analysis was set at $P< .05$. Greater release speeds longer last step and pull distance and higher grip position at release were measured in males when compared to females ($P< .05 - .001$). Altitude angle was greater ($P< .01$) in females (40 ± 5 degree) than in the males (31 ± 6 degree). No significant differences either in angular velocities or in any timing parameter were observed between the two groups. There was only one degree of decrease in his knee joint during the first half of the contact and then 8° of increase towards the javelin release. The height of

body CG decreased at the beginning of the final contacts phase. After a period of 56.63 ms. from the beginning it started to increase simultaneously with this increase (78-79 ms.) potentiation through stretch-shortening cycles may have occurred and peak joint center speeds occurred in sequence from proximal to distal segment and finally to javelin at release.

Atwater\(^7\) conducted a study to investigate selected spatial and temporal aspects of the over arm throw as measured from films of men and women performers at three distinctly different level of throwing skills 15 right handed throwers were filmed performing three trails of a maximum velocity over arm throw. The technique of graphical differentiation was used to obtain instantaneous directional velocities from the displacement curves, and from these velocities, the resultant velocity of the ball in the hand was calculated for all skilled men and one skilled women, an early increase followed by a noticeable decrease in resultant velocity occurred just prior to final acceleration of the ball towards release. Other skilled and average women decelerated the ball slightly or maintained a relatively slow constant velocity before final acceleration rate measured from the resultant velocity curves during the final .05 sec before release were on the order of 1500-2000 ft. / sec\(^2\) for skilled men, 1000 ft/sec\(^2\) for skilled

women. The second objective of the study was to describe the joint actions and changes in body position associated with the measured displacement and resultant velocity of the ball. Final acceleration of the ball commenced as the abducted and laterally rotated arm was carried to the right by on going but decelerating forward trunk rotation, and continued until release as right elbow extension, shoulder medial rotation and forearm pronation occurred. Average women subjects were limited in both the range and speed of motion and were characterised by elbow extension in the sagittal plane at release. Rather than by the more horizontal arm action used by the skilled men and women.

Stevenson⁸ conducted a study to determine through the use of three dimensional cinematographical analysis, the effect of lacrosse stick shaft length of 29, 39, 49, and 59 inches on the performance of a maximal velocity lacrosse throw with respect to selected kinematic variables. Subjects for the study was 11 lacrosse players from Johns Hopkins university. Subjects were filmed in two orthogonal planes using two high speed 16 mm cameras in order to provide “x” and “y” coordinate data in two dimensions. Each subject performed one trial each using an overhead and side arm throwing style and also four throwing trails with

each experimental shaft length. The data were then analyzed using appropriate statistical procedures in order to determine:

1. The reliability of the throwing arcs
2. The difference in ball release velocity between the overhead and sidearm throwing styles
3. The difference in ball release velocity among the selected shaft lengths and
4. Relationship among the selected variables among the subjects.

From the results of this study it was concluded that neither throwing style or stick shaft length do not effect the velocity of the bat at release during a maximal velocity lacrosse throw and in addition, any kinematics differences which exist in the performance of maximal velocity throwing in lacrosse are due to factor other than throwing style and shaft length.

Duthie conducted study in 1971, 1975 and 1979, 50 institutionalized individuals with Down's syndrome, 23 females and 27 males were filmed performing the horizontal jump. From the film 18 anatomical landmarks were digitized in five significant frames and the orthogonal coordinates were recorded. The data were then reduced to

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orthogonal coordinates for the total body center of gravity angles at three joints, and the angles of inclination of the trunk and shank, linear and angular displacement, velocities and linear momentum were calculated. The subjects were grouped by the sex and were further subdivided into five age group means and total population means for four demographic and 30 kinetic and kinematics factors were discussed and compared. An analysis of covariance and a Duncan's multiple range test were used to test five kinematics and one kinetic variable for differences among the age groups and differences among the trails with all jumps pooled, each factor was correlated with every other factor. The males with Down's syndrome performed better than their female counterparts but neither performed as well as normal individuals. These Down's syndrome individuals did not follow the normal development curve, but rather all groups, regardless of age, showed a decline in performance between 1975 and 1979. Trunk action contributed to the propulsive force in a higher ratio to leg action than is found in the normal population. There was more variability among a subject performance and among subjects than there was across age groups.
Raach,\textsuperscript{10} carried out a study to determine whether the performance characteristics of the overhead throwing pattern could be duplicated using a modified isokinetic dynamometer as a prototype. Ten experienced male baseball players were filmed performing the overhand throw at three different speeds of isokinetic contraction (i.e., 360, 480, and 600 degrees/sec) as well as executing an actual throwing motion. The kinematics analyzed consisted of the horizontal velocity and displacement of the total body's center of gravity, the joint angles and angular shoulder positioning of the hip, and elbow, and the horizontal and angular velocity of the arm trunk, upper and lower arm. Statistical treatment of the data consisted of a within subjects ANOVA for repeated measures where there was only one dependent variable and a within subjects MANOVA for repeated measures where there were two or more related variables. Results of the statistical analyses revealed that:

a) an exact replication of the skill did not occur when executed using the machine.

b) consistent pattern of movement can be obtained at different speeds of isokinetic contraction but this may not be the same as the actual throwing pattern.

Gorton,\textsuperscript{11} conducted a biomechanical investigation of the technique used and of the primary factors involved in a one-handed jump shot as performed by highly skilled men and women basketball players of various ability levels. An attempt was made to record and quantify selected kinematic and kinetic factors involved in the basketball jump shot.

Eight basketball players, four men and four women, selected from Indiana University, during the 1975–1976 agreed to participate as subjects. Each athlete completed three shooting trials. Force plate recording and 16 mm filmed records were obtained simultaneously for all shooting trials performed. Two LOCAM 16 mm cameras running at 200 frames per second were placed perpendicularly at the front of the motion and at the side of the motion. One force platform was used to record kinetic measures for the final step to take—off. Significant findings of the study were reported in two sections i.e. kinematic parameters and kinetic parameters, kinematic parameters are as follows:

1. The time for the execution for the whole motion averaged 0.656 seconds.

2. There were some temporal differences between the men and women within the three phases of motion.

3. The men released the ball after the peak of their Jump, while the women released it prior to the peak.

4. The mean angle of take-off was 78.89 degrees. The men averaged 80.08 degrees and the women averaged 77.70 degrees.

5. For the women, the mean angle of the trajectory of the ball was 48.94 degrees and for the men the average was 39.05 degrees.

6. The average height of release for the women was 13.31 feet and 14.74 feet for the men.

7. The men showed a greater horizontal velocity of the ball at release while the women showed a greater vertical velocity of the ball at release.

And kinetic parameters are as follows:

1) The vertical impulse per unit of mass averaged 187.50 for the men and 162.48 for the women.

2) The greatest peak vertical force reached almost 5g's compared with the lowest peak vertical forces of almost 3g's.
3) All subjects recorded a greater horizontal thrusting impulse than a horizontal braking impulse.

4) The better jumpers recorded a greater total vertical impulse and horizontal thrusting impulse than did the poorer jumpers.

It is possible through the use of forces platform cinematographic equipment to identify selected kinetic and kinematic parameters that are important in highly skilled basketball shooting. Development of shooting ability is dependent upon the mechanical efficiency of these parameters. The men were more efficient shooters than the women in this study.

Henry\textsuperscript{12} said the purpose of this study was to examine and quantify the developmental sequence of kicking in children using direct and angled approaches to the ball. Twenty children, ranging from three to eight years of age participated in the study. Using the aerial performance analysis system (APAS) the subjects were video taped while kicking a standard youth size three soccer ball and the newly developed lightweight micro-soccer ball. Angular displacement, velocities and acceleration of the kicking limb were calculated for data analyses.

\textsuperscript{12} Alfred Henry \textit{A Kinematic Analyses of the Developmental Sequence of Kicking Using a Direct and Angled Approach, Dissertation Abstracts International}, Vol. 59 No. 7 (January, 1999) p. 2416
Predicted trends were established for both approach types. Few of the predicted characteristics were found for the direct approach, whereas, most of the predicted characteristics were found for the angled approach. One major finding was knee flexion at contact for all four stages with both ball types during both approaches.

Significant differences were found in the angular velocity of the shank and angular acceleration of the thigh between stages three and four at contact. Significant differences were also found in the angular velocity of the shank and angular acceleration of the thigh at maximum forward movement of the kicking limb between stages three and four. Although few significant differences were found in the angular velocities and accelerations of the thigh, as well as the shank between stages three and four, observable differences were evident in the graphs of the kicking sequences for selected stage three and four subjects.

Difference between the direct and angled approaches were minimal only the angular acceleration of the shank, at contact, was found to be significantly different between stages three and four. This finding was likely due to the increased difficulty of the angled approach, as the angular acceleration of the shank was lower for the angled approach.
The Micro—soccer ball was found to be significantly different in release than that of the standard youth size three soccer ball. No significant differences were found between the two approaches. If kicking performance is measured by ball velocity, the Micro—soccer ball did positively improve kicking performance.

Williams and other, a study to investigate the effectiveness of a multimedia performance principle training protocol on subjects' ability to analyze and diagnose throw-like sport skill movement. This study also examined the extent to which subjects' analytic and diagnostic skills generalized to untrained throw-like movements.

The design used for this study was a multiple probe baseline design across four performance principles; magnitude of force, point of application of force, horizontal direction of force, and vertical direction force. Subject included six undergraduate volunteers who had an interest in physical education, sport studies, and/or coaching.

The study was conducted over a six-week period. Performance principle interventions were administered in the order listed above. Subjects completed training in pairs. At the end of each instructional module a mastery test score of 80% or higher allowed subjects to exit the

program, otherwise subjects were forced to review certain components of the instruction and re-take the mastery test Probes asked subjects to –

1) Discriminate between correct and incorrect performance,

2) Select which performance principal was most deficient, and

3) To indicate which sequential phase of the throwing movement first exhibited performance deficiencies.

Data was visually analyzed. Results indicated that prior to intervention baseline measures for correct discrimination of performance were moderately high, however appropriate performance principle and throwing sequence identification were low. Following intervention, subjects correct and incorrect performance principle discrimination scores improved from an already high level. Immediately following interventional proficiency levels improved for performance identification, however the degree to which subjects maintained proficiency level varied across subject and across performance principles. Proficiency levels for identification of throwing phase errors was moderate at best and varied across subjects and phases. Training for diagnosis was not as effective as discrimination and analysis training, with the instructional format employed. Discrimination analytic, and diagnostic skill acquired through intervention generalized to untrained throw like movements.
The main problem of the study was to compare the validity of kinematic data from high-speed super 8 motion picture film with like data from 16 mm. films. A sub-problem was to test the reliability of similar kinematical data between two independent 16 mm films. Each experiment was simultaneously filmed by three cameras, two 16 mm. and one super 8 under nine filming conditions produced by the combination of three film emulsions kodak Tri-x, 4-x, and Ektachrome EF, and three camera speed 50, 100 and 200 fps. The mean displacement form three observations per filming condition served as data for analysis in each experiment. The data were statistically analyzed by two planned comparison among camera means and a three factor analysis of variance with repeated measures on one factor (cameras). The running data were analysed twice, once with super 8 data from an image that was relative size to 16 mm. and again with super 8 data from an image the same size as 16 mm. in findings.

No significant differences were found in the mean angular displacement of the rotating device between the 16 mm. cameras or between the super 8 and the mean of the 16mm. cameras. For relative size data, the mean horizontal displacement of the total body center of

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gravity did not differ significantly between the 16 mm cameras, but the mean of the super 8 cameras was significantly different from both the individual and the combined mean of the 16 mm cameras. With like size data, no significant differences were found in the mean horizontal displacement of the total body center of gravity between the 16 mm cameras between the super 8 and the mean of 16mm cameras. Film emulsion and frame rate were found to have inconsistent effects on measured displacement values and on the performance of individual cameras. In conclusion.

The super 8 camera is a viable alternative to the 16 mm camera to record data for movement analysis or biomechanics research, provided the super 8 image is magnified to a size similar to the 16 mm to enhance validity. Reliable kinematical data of the same event can be obtained from the film of independent 16 mm cameras.

Gustavson A computer simulation of the soccer instep drive penalty kick was developed using engineering simulation software. The simulation allowed for changes to be made in foot-to-ball contact angles and initial (immediately after being kicked) soccer ball velocities.

Knowledge revolution, Inc, Working model version 2.0 was used to create

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a hominoid which kicked a simulated soccer ball at a target. The target location was 1.5 ft inside the goal post of a simulated soccer goal. Official FIFA rules and regulations were applied to all simulation objects including balls, goal, and field dimensions. The ball was propelled from a spot 36 ft from the center of the goal equidistant from both goal posts. Ball trajectories were calculated and displayed on a gateway 2000 p-5 Pentium microprocessor, 75 MHz computer and a 15 gateway 2000 Vitron color monitor. Hard copies of the simulations were printed using a Hewlett Packard laser jet 4 printer. Trajectories studied were the result of numerous trials in which initial soccer ball velocities were \( \geq 50 \text{mp hand foot-to-ball contact angle were set at } 0^\circ, 5^\circ, 10^\circ, 15^\circ, 20^\circ. \) All simulations that did not result in a goal in \(<0.7 \text{ s were considered unsuccessful. Final ball positions (ball completely over the goal line and under the crossbar) }<3 \text{ ft were considered minimally successful. Kicks which resulted in initial ball velocities } \geq 56 \text{ mph at } 10^\circ \text{ contact angle produced minimally successful penalty kicks. Initial ball velocities } \geq 57 \text{ mph at a } 15^\circ \text{ foot-to-ball contact angle produced successful penalty kick. A contact angle of } 20^\circ \text{ had a limited initial velocity range of } 58 \text{ mph to } 66 \text{ mph that produced successful penalty kicks.}
Sung prepared a computer program to visualize human motion utilizing computer graphic from digitized data obtained from high speed film was developed. A three - dimensional graphic model was created consisting of 14 rigid - linked segments with cylinders, ellipses, and cones to represent the human body.

There are several options in this program:

(1) Calibration factor
(2) Frame selection
(3) isolating the segment
(4) transformation of the coordinates.

An application of this development was made to the soccer thrown - in as a means of analyzing difference between the skilled and unskilled players . Male college players (n=12) and unskilled players (n=11) were asked to throw the soccer ball with the throw - in rule. Their performance was recorded by a 16 mm high - speed camera at 150 fps. A second - order Butter worth filter was used with the cutoff frequency at 12.5 Hz to smooth the raw data . The skilled player demonstrates a greater stride length , approach with greater velocity , decreases the upper extremity

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radius of gyration to increase angular velocity and utilizes trunk angular velocity to impart force to the ball. The unskilled player tended to be less stable, to initiate the final ball acceleration from a backward leaning position (cocked position) and did not complete the momentum transfer from the whole body to the distal part (the hand). These results were verified by comparing the computer display of two groups. Using only the computer display without any numerical results. The two groups are easily compared and analysed.

Kugler\textsuperscript{17} said that backward travel is a significant component in the repertoire of human locomotion. Backward walking is used as a therapeutic gait alternative in cases of cerebral vascular disorders and ankle, knee, and hip rehabilitation. Backward running is used as an adjunct to fitness enhancement and sport-specific training. The duration of foot segment pressures, the peak pressures at each foot segment and the percentage of stance phase at which the pressures peak were studied in order to compare the mechanics of backward and forward Walking and Jogging.

Fourteen subjects were acclimated to and tested on a treadmill while walking (1.34 m/s) and jogging (2.01 m/s). The electodyogram\textsuperscript{TM}

\textsuperscript{17} Leek, M. Kugler A Comparative Analysis of the Kinematics and Kinetics of Forward and Backward Human Locomotion, \textit{Dissertation Abstracts International}, Vol. 49 No. 10 (April, 1989) P-2963
was used to measure the duration percent of stance, peak pressure and peaked at percent of stance for seven plantar segments on both feet. Eight trials for each locomotors mode were randomly performed: forward walk, backward walk, forward jog and backward jog.

The data were analysed using a repeated measures three-way ANOVA on the three dependent variables. The results indicated statistically significant (.01 level) main effects for speed (walking/jogging) and direction (forward/backward) but not for foot (left/ right). The interaction between speed and direction was statistically significant (.01 level). The data indicated that the mechanical function of the foot are pronouncedly different in backward locomotion when compared to forward locomotion. Backward walking results in long duration, moderately high rear foot pressures. Backward jogging evinced a dramatic forefoot pronation and very high metatarsal peak pressures. It is suggested that backward locomotion results in loading of the lower ineticchain in a unique and extreme manner. The clinical and sport implications of these results indicate judicious application of backward travel in therapeutic fitness and sports settings.
Finch\textsuperscript{18} studied the kinematics and kinetics of the arm swing and shoulder action during the bowling delivery. Twenty four college male students were selected as subjects for this study. The subjects were screened by arm length and met intermediate bowling average requirements of 135 plus 12 pins in order to control body parameters variability and provide more consistent deliveries. The ball velocities were determined using information provided by a pair of lesser timing gates. The average velocity of the five trails was used to categorize the subjects as high and slow speed bowlers. The bowlers average velocity served as his criterion, or target velocity to be approximated in the following trials. The bowlers rolled six trials for each of the three ball weight (13, 15, and 17 pounds). The subject trials to trails alteration in ball speed and the timing gates determined constant errors from their criterion velocity. Cinematography records were taken of the fourth, fifth and sixth trials but only trails with the smallest constant error were analyzed for each ball weight. Six data point making the shoulder joint, wrist joint, geometric center of the ball, and three reference markers were digitized using a numonics 1224 digitizer. The filmed horizontal and vertical coordinates of the data points were scaled to real distances and digital filtering was used to smooth the coordinates of the end point employing a four Hertz

\textsuperscript{18} Alfred Earl Finch, "A Biomechanical Analysis of the Arm swing and shoulder action when bowling with varied ball weight," \textit{Dissertation Abstracts International} 42:8 (February 1982) p. 3497
frequency cut off. Then linear and angular displacements velocities, and accelerations were calculated using the real distances. Also shoulder torques, shoulder impulses, and timing information were calculated for the three phases of the bowling delivery. A three dimensional factorial analysis with repeated measures on ball weight and trial factor was employed to analyse the alteration in the ball speed and constant errors from the criterion velocity. It was concluded that the position of the ball with respect to the shoulder influenced the shoulder height during the approach. High-speed bowlers developed greater horizontal ball velocity at release by walking faster during their approach. The bowler's horizontal ball velocity a release was significantly affected when the ball weight was varied more than two pounds. Non zero torques were applied at the shoulder during the arm swing which indicated that a free swinging delivery. Therefore, a muscually accelerated pendulum model should be developed to ensure a more valid teaching model for the arm action during the bowling delivery.

Hopkins\textsuperscript{19} filmed six member of the Springfield college varsity tennis team while serving the flat; slice and top spin tennis serves. Three trails were used for each type of serve. A cine eight model SP-1 camera with a 25 mm. lens was used to photograph the serves and Subsequent

ball flight: frame rate was 100 frames per second. Thirty-nine correlations were computed based upon film measurements. Only the correlation between ball velocity and recoiling distances on the slice serve (r = -.884) was found to be significant (p < .05).

Patrish\(^{20}\) examined the three dimensional resultant linear velocities of the ball, right elbow joint center and right shoulder joint center; the three dimensional components, velocities of the ball; three angular displacement and the velocity of the right elbow joint; and the body position at release, four adult female subjects, who were or had been college varsity softball players performed both overarm and sidearm soft ball throws. They were filmed using two high speed motion picture cameras aligned so their optical axes intersected at 90 degree. The film data were then reduced to three-dimensional coordinates by mean of the susanka vector approach. It was concluded that there were more similarities between the over arm and side arm throwing patterns than there were difference. The two throws were similar in ball velocities, Rate, sequence, and timing of joint center velocities and degree of elbow extension. Differences were found in the Y (lateral) and Z (vertical) component ball velocities, and in the trunk position at release as seen from a rear view. However, the differences between the

two throws were felt to be significant enough to warrant separate learning experiences for each type of throw.

Atwater\textsuperscript{21} used five fastest rights handed throwers from a university basketball team and photographed while throwers performing three trials of a maximum velocity. Initial ball velocities ranged from 110 to 125 ft./sec. three 16 mm Kodak cine special cameras, operating at 64 frames/sec were used to record simultaneously the side, rear, and over head view of each throw. One trial of each subject was selected for analysis. The basic measures consisted of X, Y and Z coordinates of the balls position in each film frame during the .40 sec. preceding release and immediately following release. From these measures the three-dimensional displacement; velocity and acceleration of the ball in space were determined. A descriptive analyze was then undertaken of the joint action which occurred and were associated with the displacement and resultant. Velocity of the ball prior to and at release on the basis of result obtained following conclusion were drawn:

Distinct phases of rapid acceleration and deceleration of the ball preceded final acceleration of the ball towards release in all five subjects in the brief time interval of .07 to .12 seconds before release, all subjects

accelerated the ball from a velocity of less than 20 ft./sec. to the velocity measured at release. The early increase in resultant ball velocity occurred as the right shoulder adducted and laterally rotated to move the ball upward in its backward swing.

The subsequent decrease in ball velocity, during which time the ball lagged briefly behind the head and shoulders, was associated with the increase speed of forward trunk rotation and shoulder lateral rotation with the elbow flexed 90 degree the on going but decelerating forward trunk rotation and the joint action of the right elbow extension. Shoulder midial rotation and forearm pronation contributed to the final acceleration of the ball during the .07 to .12 sec. before release.

Milanovic conducted a study is to compare javelin release characteristics performed by a single athlete, with those performed by the best male throwers at the Olympic games in Barcelona (1992).

The subject of this study was a Croatians javelin throw champion; ranked between best 20 in the world. The subject was videotaped during training in a preparation period of current year periodisation. The performance has been recorded by two VHS video cameras operating at 60 frames per second, positioned in such a way to provide a 3 - D

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analysis. Among twelve successful attempts, the best throw (75.5 m) was subjected to further analysis.

The comparison of the javelin throw performed by the subject of this study with model based on data collected on 11 finalists at the Olympic games (Barcelona, 1992) showed significant differences in numerous parameters. Basically, the discovered technical shortcomings could be explained in five points:

- Low knee minimum and knee release angle in final support phase.
- Changes in elbow angle which suggest a more "pushing" then "throwing" type of movement.
- Low release angle.
- Long grip distance at release (early type of release) Exemption of orderly progression in peak speeds from proximal to distal segments.

Since those technical errors significantly influence the length of the throw, they must be corrected during the training process, in an attempt to achieve a longer length of the throw.
Schleihauf carried out this study to measure and describe the propulsive forces and motion which are used in the sprint front crawlstroke. A first stage in the study involved the definition of an analysis procedure, which may be used to determine the hand and forearm propulsive forces and arm joint torques used in swimmers. The second stage of the study involved the cinematographically analysis of a sampling of 27 highly skilled male swimmers. The resulting data were analyzed to determine:

1. the types of propulsive forces (lift and drag force) which are used in the pull; and
2. the distribution of the hand propulsive force as it occurs during the underwater arm pull.

A three camera, underwater cinematographic analysis procedure was used to obtain data on the right and left arm pulling motion. The film was digitized and the vector equations used in the determination of hand angle of pitch and sweepbacks were described. Further, fluid laboratory data from schleihauf (1978) was utilized in the computation of the hand and forearm kinetic data.

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The swimmers were used diagonal pulling motions (angled at about 63 degrees to the line of progress) and hand force lift drag ratios of .95 at the point of largest propulsive force production. These data imply that "sculling motions " are fundamental to the production of propulsive force in swimming.

The propulsive force curve data showed that the finish of the arm pull commonly involved the largest production of hand force. Further, the distributions of hand force were decidedly non-uniform. In particular, some swimmers used bimodal force distribution, in which the hand force showed a clear reduction in size between the inward scull and finishing portions of the stroke.

Finally, a detailed inspection of nine example swimmers was used to define both the features of stroke technique held in common across skilled swimmers, as well as the range of stroke techniques associated with the sample.

Fleisig, et.al conducted this study on the kinematics and kinetics of baseball throwing were compared between pitching from a mound and throwing from flat ground. Differences may help explain why most baseball throwing injuries involve pitchers. Results may also help determine the

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appropriateness of flat ground throwing drills (such as long toss) for pitchers, as well as considerations for changing players between pitching and non-pitching positions.

The purpose of this study was to evaluate the hypothesis that minimal kinematic and kinetic differences exist between pitching from a mound and throwing from flat ground.

Twenty-seven healthy college baseball pitchers were tested. Their height was 1.84 ± 0.07 m, and their mass was 81.6 ± 8.8 kg. After providing informed consent, history, and physical information, each pitcher was tested in an indoor laboratory. Reflective markers were attached bilaterally to the distal end of the mid-toe, lateral malleolus, lateral femoral epicondyle, greater trochanter, lateral tip of the acromion, and lateral humeral epicondyle. A reflective band was wrapped around the wrist on the throwing arm and a reflective marker was attached to the ulnar styloid of the non-throwing arm. After stretching, the subject threw three balls from seven different conditions (i.e. 21 total trials) warm-up time was provided before testing each condition.

Three dimensional coordinates during the second trial of each condition was determined with a four-camera 200Hz automatic digitizing system (Motion Analysis corporation, Santa Rosa, CA). Root mean-square error in calculating the three-dimensional location of marker
randomly placed within the calibrated space was 1.0cm. Using the digitized data, and published anthropometric data, 23 kinematic and kinetic parameters were calculated. A one way repeated measures Analysis of variance was performed, using a Bonferroni t-test to identify significant (p<0.05) differences between pitching from a mound (i.e. control group) and the other conditions.

Throwing from flat ground corresponded with a shorter stride and less shoulder external rotation at foot contact. The drop of the mound appears to give the pitcher more time to stride forward a greater distance, and more time to externally rotate the shoulder. Arm and body motions and kinetics during arm cocking and acceleration were similar between mound and flat ground throwing. At the instant of ball release, a pitcher’s trunk was more vertical when throwing from flat ground. However, relative to the throwing surface, the trunk angle was the same for 60' throwing from flat ground and pitching from a mound. This is because the trunk was 50 less upright for pitching from the mound, but the mound was sloped 50 downward. The trunk was 30 more upright for the longer distance throws, which may help the athlete throw the ball with a slightly more upward trajectory in order to get more distance. During arm deceleration, compressive forces generated at the elbow and shoulder to resist distraction were less in long distance flat throws than in 60' mound or flat throws. This may be related to the low incidence of throwing injuries
in non-pitchers. Reduced deceleration forces in long toss support the concept that these are good training drills for pitchers. The biomechanics of these throws are similar to pitching; however, when converting from other from other positions or from flat ground training to pitching from a mound, an athlete should lengthen his stride and tilt his trunk forward.

Chow. The growing popularity of these events have illuminated the need for kinematic analyses to provide baseline data for coaching and instructional purposes.

The purposes of this study were to evaluate selected kinematic parameters of the javelin throw performed by skilled wheelchair field athletes and to identify those kinematic parameters that are significantly correlated to the medical classification of the athlete and the measured distance of the throw.

The subjects were 15 male participants (2 F2, 1 F3, 2 F4, 5 F5, 1 F6, 3F7, and 1 F8) of training camp organized by the Wheelchair Sports, USA (WSUSA). All but two subjects were right-handed. The data for the left-handed subjects were transposed and were treated as right-handed.

25 John W. Chow, Kinematic Analysis of the Javelin Throw Performed by Wheelchair Athletes of Different Medical Classes, hermes.hhp.ufl.edu/apk/ces/labs/biomech/Biomechresearch.htm.
Javelin throw performances were recorded using two S-VHS video cameras (Panasonic AG-455, 60 fields s⁻¹). Each subject performed 6 trials, and the best two trials were selected for subsequent analysis.

The direct linear transformation (DLT) procedure was used to obtain 3D coordinates of selected landmarks of the body and javelin. The horizontal, vertical, and resultant velocities at release, the angle of release, and the attack angle of the javelin were calculated. Inclination angles and angular speeds at release, and the range of motion (ROM) and average angular speeds during the forward thrust were computed for the trunk, shoulder girdle, and right upper arm, forearm, and hand. The mean and standard deviation of each parameter were computed for each medical class. Pearson product moment coefficients of correlation were computed between selected parameters and the medical classification, and between selected parameters and the measured distances. Correlation coefficients 0.46 and 0.57 were required to attain statistical significance at the 0.01- and 0.001 levels of probability, respectively (n=30, df=28).

Kinematics Characteristics of Javelin at Release due to their anatomical and functional limitations, wheelchair athletes are unable to make use of the full kinetic chain. As a result, the kinematics of a javelin throw performed by a wheelchair athlete differs from those of the able-
bodied. The distances of throws performed by our subjects ranged from 8.77 to 26.44 m. In comparison, able-bodied athletes can throw up to four times as far. The average speeds of release for different classes, ranging from 9.1 to 14.7 m s\(^{-1}\), are considerably smaller than those reported for the javelin throws performed by male able-bodied athletes, 25.78 to 20.12 m s\(^{-1}\). The average angles of release for different classes, ranging from 29.6\(^{0}\) to 35.8\(^{0}\), are smaller than those performed by male able bodied athletes, 34\(^{0}\) - 42\(^{0}\). The average angular speeds at release for different classes ranged from: 1.52 to 2.16 rad s\(^{-1}\) for the trunk; 1.41 to 7.78 rad s\(^{-1}\) for the shoulder girdle; 2.90 to 13.38 rad s\(^{-1}\) for the upper arm; 10.63 to 25.98 rad s\(^{-1}\) for the forearm; and 6.14 to 30.88 rad s\(^{-1}\) for the hand. The range of average angular speeds during forward thrust for different classes were: 1.23 to 2.40 rad s\(^{-1}\) for the trunk; 2.64 to 5.34 rad s\(^{-1}\) for the shoulder girdle; 3.01 to 6.05 rad s\(^{-1}\) for the upper arm; 3.24 to 6.56 rad s\(^{-1}\) for the forearm; and 4.12 to 8.32 rad s\(^{-1}\) for the hand. The range in speeds increased as the segments became more distal. This demonstrates that the functional differences among different classes are more evident in the distal body segments than the proximal ones. The high correlation coefficients for the velocities of the javelin at release indicate that the speed of release is the most important determinant of measured distance and is highly correlated to the classification. The speed of release is determined by the motions of the upper body segments during the forward thrust. The high correlation
between speed of release and classification signifies the overall fairness of the classification system. The height of release of the javelin is significantly correlated to both the classification and the measured distance. This suggests that all else being equal, the thrower who has a higher release height will have a longer throw. The release height is limited by the maximum chair height of 75 cm allowed by the rules.

The angular speed at release, ROM (during the forward thrust), and average angular speed during the forward thrust of the shoulder girdle are all significantly correlated to both the classification and the measured distance. These results imply that wheelchair athletes should strive to maximize their potential in their trunk movements.

Williams\textsuperscript{36} investigated the effectiveness of a multimedia performance principle training protocol on subjects' ability to analyze and diagnose throw like sport skill movements. This study also examined the extent to which subject analytic and diagnostic skills generalized to untrained throw like movements.

Gustavson\textsuperscript{27} Developed a computer simulation of the soccer instep drive penalty kick using engineering simulation software. The simulation allowed for changes to be made in foot – to – ball contact angles and initial (immediately after being kicked) soccer ball velocities. Knowledge revolution, Inc, Working model version 2.0 was used to create a hominoid which kicked a simulated soccer ball at a target. The target location was 1.5 ft inside the goal post of a simulated soccer goal. Official FIFA rules and regulations were applied to all simulation objects including ball goal and field dimensions. The ball was propelled from a spots 36 ft from the center of the goal equidistant from both goal posts. Ball trajectories were calculated and displayed on a Gateway 2000 p-5, Pentium microprocessor, 75 MHz computer and a 15\degree Gateway 2000 Vitron color monitor. Hard copies of the simulations were printed using a Hewlett Packard laser jet 4 printers. Trajectories studied were the result of numerous trials in which initial soccer ball velocities were >= 50mph and foot –to –ball contact angle were set at 0\degree, 5\degree, 10\degree, 15\degree, 20\degree. All simulations that did not result in a goal in <0.7 s were considered unsuccessful. Final ball positions (ball completely over the goal line and under the crossbar) <3 ft were considered minimally successful. Kicks which resulted in initial ball velocities >=56 mph at 10\degree contact angle produced minimally

successful penalty kicks. Initial ball velocities >= 57 mph at a 15° foot – to
ball contact angle produced successful penalty kick. A contact angle of
20° had a limited initial velocity range of 58 mph to 66mph that produced
successful penalty kicks.

Chow and others conducted a study to identify those kinematic
characteristics that are most closely related to the functional classification
of a wheelchair athlete and measured distance of a javelin throw. Two S-VHS
camcorders (60 fields s⁻¹) were used to record the performance of 15
males of different classes. Each subject performed 6-10 throws and the
best two legal throws from each subject were selected for analysis. Three-
dimensional kinematics of the javelin and upper body segments at the
instant of release and during the throw (delivery) were determined. The
selection of kinematic parameters that were analyzed in this study was
based on a javelin throw model showing the factors that determine the
measured distance of a throw. The average of two throws for each subject
was used to compute Spearman rank correlation coefficients between
selected parameters and measured distance, and between selected
parameters and the functional classification. The speed and angles of the
javelin at release, ranged from 9.1 to 14.7 m s⁻¹ and 29.6 to 35.8°,
respectively, were smaller than those exhibited by elite male able-bodied

78 John W. Chow, Ann F. Kuenster and Young-h-tae Lim, "Kinematic Analysis of Javelin
Throw Performed by Wheelchair Athletes of Different Functional Classes", Journal of Sport
throwers. As expected, the speed of the javelin at release was significantly correlated to both the classification (p<0.01) and measured distance (p<0.001). Of the segmental kinematic parameters, significant correlations were found between the trunk inclination at release and classification and between the angular speed at release and measured distance (p<0.01 for both). The angular speed of the shoulder girdle at release and the average angular speeds of the shoulder girdle during the delivery were significantly correlated to both the classification and measured distance (p<0.05). The results indicate the shoulder girdle movement during the delivery is an important determinant of classification and measured distance.

Campose and others\textsuperscript{29} conducted a Kinematic analysis on 3D photogrammetric technique to try to describe and to compare the differences between Spanish and World-class javelin throwers. Results showed significant differences between groups (p<0.05) in 11 of 35 kinematic variables. The major differences occur in the final phases of the throw. These differences show that those throwers belonging to the world-class group have a greater ability to use the power of the body to accelerate the javelin. Therefore it makes possible to know the technical lacks of Spanish throwers, which could help to lead their individual coaching programs.

\textsuperscript{29} Jose Campose et al., "Analysis of Kinematic Parameters Between Spanish and World Javelin Throwers" file://G:/physical%20education-II/phpeducation/word\Abstracts.htm.
Compared the kinematics and kinetics of baseball throwing between pitching from a mound and throwing from flat ground. Differences may help explain why most baseball throwing injuries involve pitchers. Results may also help determine the appropriateness of flat ground throwing drills (such as long toss) for pitchers, as well as considerations for changing players between pitching and non-pitching positions.

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