Chapter II

REVIEW OF RELATED LITERATURE

The scholar has attempted in this chapter to locate the literature related to this study. The relevant studies gleaned from various sources which the research scholar has come across are cited below.

Shaw\textsuperscript{1,2} conducted a study to determine the differences on the selected bio-mechanical variables between one arm shoulder throw and both arm shoulder throw in relation to body weight and height. 16 male national level judo players were filmed at the speed of 100 frames/Sec and analysed from which the biomechanical variables were computed. From the results following conclusions were drawn. (1) The shorter judokas have advantage in one arm shoulder throw in relation to execution time as compared to taller judoka. (2) The weight was not found to be significant between one arm shoulder throw and both arm shoulder throw. (3) In the case of both arm shoulder throw greater right knee extension was required by judokas as compared to one arm

\textsuperscript{1}Dhananjoy Shaw, "Biomechanical Comparison of Different Variations of Selected Judo Skills" (Unpublished M.Phil Dissertation, Jiwaji University), 1987.

shoulder throw. (4) Greater right knee range of motion was required in case of both arm shoulder throw as compared to one arm shoulder throw. (5) Right hip flexion was found to be greater in case of both arm shoulder throw as compared to one arm shoulder throw. (6) Greater right hip range of motion was required to develop one arm shoulder throw as compared to both arm shoulder throw. (7) For both arm shoulder throw greater horizontal movement of the thrower's C.G. was found for efficient throw as compared to one arm shoulder throw. (8) In relation to final Velocity acceleration and force of impact in one shoulder throw and both arm shoulder throw were equally scoring and safe.

Ikai and Matsumoto in order to make scientific investigations on the principles underlying the various techniques used in Judo, first analysed the techniques, and made observations on their kinetics, and further wished to synthesize by adding psychological and physiological investigations. Among the throwing techniques a few were selected, and serial photographs of the performers in action were taken by means of a high speed camera. Each serial photograph was carefully analysed, and the kinetic principles of the techniques studied. Photography was made with 16mm camera with a speed of thirty two frames per

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second. The techniques studied were; from among the waist techniques Harai-goshi, Tsurikomi-goshi; from among the hand techniques Seoi-nage, Kata-guruma; from among the foot techniques Hiza-guruma; Osoto-gari; from among the Ma-sutemi techniques, Tomoe-nage, and from among the Yoko-sutemi technique, Uki-waza. The performers were selected from the students of the Tokyo University of education, namely, Iida, Higushi, Kodama, Enomoto and Matsumoto. Photographs were taken from the side and from above. From these serial photographs the centre of gravity were measured according to Knoll's construction method, and the following results and conclusions were obtained. (1) Seoi-nage. In this technique. The thrower throws down his opponent using a rotary force with his shoulder as the fulcrum. This force is a resultant of the combined forces of the thrower's bodily twist, the push at the knees and forward bend of his body. The angle formed by the line joining the centres of gravity of the thrower and his opponent and a horizontal line were obtained as approximate. This angle from the point of view of kinetics should be more obtuse, but as it is necessary for the offensive's right arm to fix the defensive's breast, this is not quite possible. The lack in the magnitude of the angle is well compensated by the forward momentum of the defensive. The offensive in order to set himself in a proper position to put on the trick, lowers his centre of gravity while drawing in his opponent and thus makes the distance between the two centres of gravity wider. The reason
for the drop in the velocity of the defensive at 25/32 m/sec, is not quite clear, but it may probably be related to the drop in velocity of the offensive at 20/32 sec, when the trick is put on from the standpoint of the theory of the technique, it leaves room for further consideration on the part of the offensive. The impact received by the defensive when he lands on the floor and the angle with which he lands were measured. The angle with which the defensive lands on the floor is the acuest in the Uki-waza, and the most obtuse in the Osoto-gari. The landing velocities were measured at 5/32 m/sec. prior to actually hitting the floor, and as a result it was found that in the Hiza-guruma velocity was the lowest with 1.95 m.p.s., and the highest in the Tsurikomi-goshi registering 7 m.p.s. The landing velocities measured were lower than expected and were approximately 1/4 of the landing velocity in a ski jump (30 m.p.s.). This assumption is due to the fact that unlike in other free falls, in judo the offensive and the defensive are mutually restraining their movements and also the defensive puts himself into a proper posture for the fall and breaks the impact. The force of impact when the defensive lands differs with the angle with which he hits the floor. It is the largest when the angle is 90° and gradually diminishes as the angle becomes more acute. The force of impact may be represented thus: \( mv \sin \theta \), where \( m \) is the body weight and \( v \) is the landing velocity. The force of impact calculated with the angle taken at the actual angle with which the defensive hits the floor, and
also with the angle corrected to 90°. These figures are nearly identical with the ones obtained during a ski jump when the skier lands smoothly in line with the flight course.

Shaw and associates\textsuperscript{4,5} studied Cinematographically the comparative relationship of force of impact (falling), Acceleration and Velocity with body weight and height between Ippon Seoi Nage and Morote Seoi Nage and the relative effectiveness of the throws performed by 16 National level Judo players. From the results following conclusions were drawn: (1) Both the techniques are equally scoring and safe, (2) Both weight and height are negatively and significantly related to acceleration and force of falling in one arm shoulder throw, (3) Body weight and height are not significantly related to acceleration and force of falling in both arm shoulder throw, (4) The relationship of weight and acceleration, height and force of falling between one arm shoulder throw and both arm shoulder throw are significantly differing.


Shaw and associates\(^6\) compared heavier and lighter weight group Judokas, taller and shorter height group Judoka, on the time variables of Morote seoinage. 16 male national level Judo players were studied cinematographically and it was concluded that height and weight are not significant factors in relation to preparatory time, execution time and total time of Morote Seoinage, that is, both arm shoulder throw.

In a study Tezuka and associates\(^7\), analysed judo technique on selected kinetic parameters. The purpose of the study was to investigate the use of combined cinematography and dynamography in the determination of: (1) Consistency of performance of skilled judoka, and (2) Differences among throwing techniques. A sixth and a third dan skilled judoka performed ten trials each of body drop and sweeping loin. Throws were analysed with respect to three phases: preparatory, step in and flight of receiver. Results indicated that different styles of performance may be utilized by different skilled judoka while successfully performing the same throwing techniques. Flight patterns of the receiver obtained from the film provided evidence for the


interpretation of force-time patterns. These flights also were correlated with the initial position of the thrower. When the receiver was unbalanced (weight mostly on the leg). The flight was shorter. Forces did not appear to be high as compared to collision type sports, it could not be ascertained which style was mechanically more efficient, more effective, or safer. Differences in weight and size may prevent the identification of any one pattern.

Harter and Bates studied GRF's of two judo hip throws i.e. the inner thigh throw and the sweeping hip throw. There were clear differences between the executions of the two throws. Although the kinetics and temporal patterns were fairly similar. The most experienced performers were the least consistent, indicating the importance of employing the suitable adjustments in response and attack situations warrant. This study is an excellent attempt at kinetically determining why and how some who are weaker can defeat a stronger opponent through the intelligent application of force.

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A study was conducted by Shaw\textsuperscript{9,10} to formulate a statistical model to predict the dynamic movement amplitude (Internal) i.e., right hip ROM with the help of selected static goniometric measurements considering the whole body as a system. Sixteen national level male Judo players were filmed with a Movie Camera (Biomechanics-500-Photosonic IPL) at a frequency of 100 frames per second. After development the film was analysed frame by frame on a film motion analyser (Nac-76-1) and then ROM of right hip was obtained as a criterion. To determine static goniometric measurements sit and reach test for hip and back flexion as well as extension of the hamstring muscles of the legs, Trunk and Neck extension Tests, planter flexion, Dorsi flexion, knee flexion and shoulder rotation test. The results of the study revealed that (1) right hip range of motion (ROM) significantly (Negatively) related to Trunk and Neck extension scores. (2) Trunk and neck extension are significantly related to planter flexion (3) Multiple Co-Efficient of correlation was not found to be statistically significant between criterion and all of the selected independent variables. (4) Multiple Co-efficient


of correlation between criterion (ROM right hip) and important predictor variables among the selected independent variables i.e. sit and reach test scores, trunk and neck extension test scores and Dorsiflexion test scores were found to be statistically significant following stepdown regression method with 29% of forecasting efficiency. (5) A multiple regression equation was constructed with the help of regression Co-efficients of Trunk and Neck test scores and Dorsiflexion test scores for predicting right hip ROM of one arm shoulder throw in Judo.

Matsumoto and associates[11] in the present study analysed the movements of the Uke during the kuzushi of the Nage was made by the following (1) Happ-no-Kuzushi which consists of fundamental movements (EMG. observation were made). 11) Kuzushi of seoiNage, Taiotoshi and Hizaguruma. The results of EMG. revealed identical tendencies of electrical discharge during the Kuzushi in the front direction side and back directions. In the kuzushi towards the front, the left and right gastrocnemius muscle and the rectus femoris muscle in the direction of kuzushi exhibited pronounced electrical discharge. In the kuzushi of Nagewaza the pulling hand of the Tori was pulled towards their front. Consequently the ankle was extended and marked discharge was

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noted in the gastrocnemious muscle. In the Taitoshi the pulling hand of the Tori was directed towards the lower front and moderate electrical discharge was noted in the gastrocnenious and tibialis anterior muscle. In the Hizagurma the pulling hand was pulled in some what the same direction as in the Taitoshi.

Asami, Matsumoto and Sasaki\textsuperscript{12} made to elucidate the problem of where to place the centre of gravity while firmly performing the osae-waza. As a result of determining the individual centre of gravity of the Tori and the Uke, and also the composite centre of gravity when the two were locked it was found that the distance between the centre of gravity of the Tori and Uke was the longest in the Kamishiho-gatame followed in order by the Kuzureshihio-gatame and Ushirokesa-gatame. The shortest distance was found in the Tateshiho-gatame. (1) The composite centre of gravity was approximately half way between the centres of gravity of the Tori and the Uke and coincided with the compound centre of gravity. (2) The angle formed between the long axis of the body of the Uke and the centre of gravity of the Tori was the widest in the Yokoshiho-gatame followed in order by Yokoshiho-gatame and Kata-gatame, and the narrowest angle was observed in the kamishiho-Gatame.

Miura\textsuperscript{13}, and Takhashi\textsuperscript{14} have conducted qualitative investigations of Judo technique, which correlated electrogoniometric data with electromyographic (EMG) data during progressive static positioning. Dynamic competitive situations were not investigated. Furthermore, these studies provided no quantitative values.

Uchida\textsuperscript{15} had studied eight Judo throws, selected on basis of frequency of success by competitors in national and international meets, they were filmed and analysed. Four competitors of national championship caliber attempted, in actual competition to execute two different throws each against black belt opponents. The analysis was divided into two columns. The left-hand column included a short description of the mechanical principle with an explanation of how and why the principle was applied. A comparison was made between the analysis and textbook descriptions of the eight throws.


\textsuperscript{15} George S. Uchida, "The External Mechanics of Eight Judo Throws" Completed Research in Health, Physical Education and Recreation 10(1968): 78
Ikai and his associates investigated the EMG pattern of Judoka while performing Judo throwing techniques. The experimental subjects were Ten Judoka of Olympic level. Electromyograms were taken while each of these Judoka were performing their favorite techniques. (1) From the "kuzushi" to the "Tsukuri" and the "kake" the muscles in the frontal aspect of the body do most of the work, whereas, during the "Nage", the back muscles go into action and contract powerfully. (2) In the Judoka who are right sided in their techniques, the action of the muscles on the left side of their bodies is important, whereas, during the "kake" the contraction of the muscles on the right side of their body take over the main role. (3) Antagonistic action of muscle groups of the forearm was not very evident, however, a marked antagonistic action between the m. biceps brachii and the m. triceps brachii was noted. It is important that the muscle groups not concerned with the movement be relaxed, and those concerned with the motion be contracted. (4) When the contraction phase and the relaxation phase of muscle activity are very distinct, it means that the nerves controlling the muscles are functioning adequately. (5) In the "yuchi-mata"

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"Hane-goshi" and "harai-goshi" in which the performer disturbs the opponent's balance to the front and attacks with one of his legs, the m. biceps brachii, m. deltoideus, and m. trapezius take over the main role of action. (6) And in the "Tsuri-komi-goshi" "Seoi-nage" and "Tai-otoshi" in which the performer uses both legs in his attack, the m. teres major goes into action, besides these three muscles. (7) In the "ouchi-gari" and "kouchi-gari" in which the performer attacks after disturbing the balance of his opponent to the rear, the m. triceps brachii, and m. deltoideus take over the main role of action while the m. extensor carpi radialis, m. trapezius act in an auxiliary manner. From the foregoing it will be understood that in Judo, the m. biceps brachii, m. triceps brachii, m. trapezius, m. teres major and m. rectus femoris take the main role of action. However, depending on the kind of "Nega-waza" the manner of action of the muscles differ, and consequently, training should be performed in a way to match the favorite technique of each judoka.

Asami 17 had undertaken a study to determine the positions of the center of gravity of the body and also of the "Tanden" during the fundamental posture of Judo, kendo, and kyudo (Japanese arches) and also during the standing erect posture. He also studied relationship between "Shizentai" and the centre of

gravity of the body and the "Tanden". The results indicated that
(1) the center of gravity in the recumbent posture was the
highest in the kyudoist. (2) The center of gravity line in the
erect standing posture of the kendoist passed the 51.4% point
from the heel with the length of the foot as 100%. (3) The center
of gravity line of the Judoist in the natural standing posture
passed the 40.5% point from the heel indicating that body weight
was put more to the rear. (4) The centre of gravity line of the
kendoist shifts comparatively to the front. Consequently the
center of gravity line of the judoist is more to the rear when
compared to that of the kendoist. (5) In the judoist, kendoist
and kyudoist the positions of the Tanden lines passed more to the
front than the center of gravity lines in all the five groups.

Kawamura and his associates measured the center of
gravity of back and front (y Axis) gravity in standing posture of
26 Judoka and 30 kendo which was measured by Akita system, center
of gravity measurement apparatus consisting of a homogeneous
board, a weight measure, and a wedge-shaped supporting from which
the following conclusions were drawn (i) The center of gravity
(C.G.) line in a static standing posture of a Judo player was
slightly backward from the center of foot length (46.5%) (ii) The

C.G. line in Shizentai of Judo players was 40.5% from the heel, which showed that the body weight was more backward than during the static posture; (iii) By setting the Tanden position by the method of drawing figures, and comparing it to the C.G. it was found that Tanden height was lower than the height of centre of gravity in both Judo and Kendo players and Tanden vertical line was far more forward from the C.G. line; (iv) Results indicated that shizentai is not only a simple static sitting position but also a dynamic sitting posture containing active elements.

Kawamura and his associates 19 analysed the somatotypes and postures of Judoists from which following conclusions were drawn (i) According to reinforced All Japan players showed the tendency of corpulence in comparison with the reinforced French players. It is conjunctured that it is because of the large volume of body fat, (ii) Observing the element of Endomorphy, mesomorphy and ectomorphy by the heath carter method, it was found that the Japanese heavy weight class players had a large accumulation of fat as well as well developed muscles; (iii) From the measurement of curvature angle of spines, it was found that the french players had a tendency to stick their head

forward with round back; (iv) Both French and Japanese players showed the tendency of right shoulder drop (v) In the position of the center of gravity the French players showed a tendency to being much closer to the heel than the Japanese players; (vi) The Tendency of over weight on the left foot—was stronger among the Japanese players; (vii) From the observation of "three position ratio" of body weight distribution the French and the Japanese players showed unbalance in the right foot. The tendency is rather strong among the French players (viii) The Japanese obtained higher point in the perpendicular line test.

Matsumoto and his associates in the present study made an investigation on the distribution of body weight during the "kamae" (natural position) "kuzushi" (disturbing balance) "Tsukuri" (preparatory position) and "kake" (attack). The results revealed in general that distribution of body weight was more in the front foot than in the rear. This tendency was greater in the defensive posture than in the basic natural posture and greater in the hold than in the defensive posture. The distribution of body weight during the basic natural posture, and when assuming the right natural posture the right and left sides were well

balanced. When assuming left natural posture the distribution of body weight was to the right foot, but no significant change was found in the balance. While breaking the posture of the opponent to the front, he put most of his body weight forcefully to the frontal aspect of both the feet when the subject applied the Seoi Nage.

21 Haga and his associates analysed women Judokas to find out in what pattern the muscle strength in the Judo waza, Kuzushi, Tsukuri and kake is to be manifested as a real power. How it is converted into the speed of waza, and how it is used as attacking power in respect to energy cost. The muscle strength, motion velocity, muscle power and energy output of women Judokas were largely low in the values compared with the values of male Judokas. The size and pattern of generating muscle strength and muscle power produced in the process of Nagewaza depends upon the kinds of waza.

22 Ikai investigated the rationality of the various


techniques of Judo from the point of view of postural reflex of both the offensive and defensive during a throwing performance. It was observed that the offensive by utilizing the neck reflex strengthens the pull of his arms and the supporting power of his legs, also the offensive in order to perform the technique smoothly and advantageously, leads his opponent into a posture that the latter's neck reflex will not come into force. The offensive takes advantage of the rotatory motion while throwing his opponent. The defensive while being rotated and thrown, extends and abducts his legs. This posture is the result of the static and kinetic labyrinthine reflexes. The lack of symmetry in extension of the legs may be seen when the subject is being rotated, and in the present study, it is thought to be due to the twist of the trunk in relation to the hip. It is advantageous to know and utilize the various postural reflexes during the performance of Judo.

Deusinger has studied on two experts with the help of cinematography, holders of black belts taken at 54 frames/sec and used it to make a composite tracing of the movement from which segment angle, lengths, mass, weight, and centre of gravity were collected. These data were applied to plagendorf's computer.

program, which yielded instantaneous angular velocities and accelerations for each segment in each position and joint forces and moments of force. Films taken at 2.204 frames/sec. yielded times of impact of the arms and trunk, which were inserted into the force of impact formula \( F = mv/t \). After total body force of impact was determined, the contributions which the arms, legs, and head-neck made to decrease total body impact were subtracted respectively from total force of impact, yielding trunk force of impact.

Gil'ad\textsuperscript{24} had tried a bio-mechanical approach to study "ukemi" falling technique in the martial arts, used several movies of throws, both demonstrations and contests to ascertain the relative speed of the slamming arm’s C.G. at the movement of impact and appeared into following as fair description—there was an initial period of approx. 0.1 sec. during which the arm accelerates, moving through about 1/3 of its total path. Having reached the end of the acceleration, the movement is a ballistic one. Terminal velocity was at least 10 m/sec. (relative to the trunk). If breakfall is initiated too soon, objectively terminal velocity is lower and subjective feeling is of a bad breakfall,\textsuperscript{24}

\textsuperscript{24} Amos Gil'ad. "Falling Technique in the Martial Arts" Bio-mechanics of games and sports activities ed. by Alberto Alyalon (Wingate : wingate institute of physical education and sport, 1978), pp.87-89.
he concluded that the upper extremity absorbs a large part of the body. K.E., There is no need for the contact of arm with the mat to precede the body's contact when contact is simultaneous, adequate projection is furnished. A minimal time must elapse between the first awareness of the athlete that he is about to be thrown and landing for ukemi to be executed, probably at least 0.12 sec.

Xiong has selected following methods to replenish judo's ukemi, dodging exercises include bent rolling, straight body rolling, forward roll, backward roll, flying roll-turn and back dropping and dropping exercises include fallout, puhu, zaibai, side dropping & cross legged dropping. Combining the above methods with judo's ukemi, 3200 students were trained in teaching of Judo, no one was hurt and the effect is obvious. To train the learners with the above method together with ukemi, can enforce their balance organs, cool their mind, make their movements harmonizing and nimble, increasing their effectiveness to counter falling and make it easy for them to give full play to their skill.

The effect of various knee angle and foot spacing combinations on the vertical jump of college men were studied by the Martin and Stull. The results revealed that (a) Knee angle, lateral foot spacing, and anterior-posterior foot spacing have an insignificant interaction F ratio, so they exert independent effects on jump performance (b) The most effective stance seems to be in which the knee angle is approximately 115 degrees with the feet spread 5" to 10" laterally and slightly in excess of 5" anterior-posteriorly.

Yokobori and Suzuki studied 13 Judo players and reported that 6 were mesomorph, 3 mesomedials and 4 endomeomorph. Their average was 362 and were classified as mesomorph. Their somatotype was generally described as having large amount of subcutaneous adipose, although it was less than that of Japanese style wrestlers. They also have well developed bones and muscles.


Ikai, Fukunaga and Toheda studied body composition of Judoists. The purpose of the present study was to analyse the body composition of Judoist (age 18-21 years). The following results were obtained (1) The cross-sectional area of the upper and forearm was photographed by means of ultrasonic radiation (2). The maximum muscle strength of the arm flexor was observed about 26% higher in Judoists. No significant difference was observed in strength per unit cross-sectional area of the arm flexor between both groups: 6.4 ± 0.1 kg/cm² in Judoists, 6.7 ± 1.1 kg/cm² non-trainees. The strength per unit cross-sectional area of these Judoists could be improved by 30% through intensive strength training (3) The total mass of body fat, solid and body water about 18% higher in Judoists. No significant difference was observed in the ratio of body compartment between both groups.

The purpose was studied by Claessens and his associates to describe the somatic characteristics and the somatotype of 38 world top Judoists. The mean age found to be 25.3 years. It was observed that Judoists were broad, develop


athletes with high girth values. The low amount of somatotypes were principally localized, in the endomesomorph, area.28 Judoists were estimated as endo-mesomorph,5 as balanced mesomorph 4 as ecto-mesomorph. It was concluded that the somatotype distribution of this sample of world class judoists was very homogeneous.

Mitsutsugu et.al.30 studied the influence of the juvenescent Judo practice on their bodies (N = 133). The subjects were grouped into Judoists. Soccer players basketball players of each 5th and 6th grades and 7th and 8th grades. The number of subjects in each group was 10 to 12. Fourteen anthropometric measurements were taken. He found that the percentage of body fat of the Judo group was larger than the other groups and it was much larger in junior high school students. He also concluded that the physique of Judo group consisting 5th, 6th, 7th, 8th grades were far above the national average.

Shaw, Naruka and Luthra31 studied on forty six male


judokas who had participated in the 1st All India Intervarsity Judo Championship during January, 1988. Depending upon the findings following conclusions were drawn:— Judokas of different geographical regions i.e. North, South and West are significantly different in height, trunk length, forearm length, chest girth and calf girth. Where as weight, lean body mass, body fat, body fat percentage, bust height, sitting height, trunk length, upper arm length, height decyilion, leg length, thigh length, fore-leg length, shoulder width, hip width, upper arm girth, forearm girth, thigh girth, Ponderal index and crural index are not found to be statistically significant. North Indian Judokas are significantly higher than those of the westerns in height and total arm length. South Indian Judoka are superior in height, arm length and forearm length than those of West Indian Judo players. The westerns are found to be higher in chest girth and calf girth than those of Northern Indian Judo Players.

Sira and his associates studied a simple procedure for event marking when filming with one or two cameras. Experiments have shown that it is possible, by means of two flash units, to synchronize one 16mm photosonic camera with start and for conclusion of an event, with a second camera (either super

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8mm or 16mm) not equipped with an internal timing mechanism or with other measurement devices when the event can be activated by a switch on contact or release. This synchronization is possible even in difficult recording situations when one or more devices are positioned under dimensional analysis, it does provide reasonably accurate information when the primary analysis relates movement in a single plane with additional information provided by a second camera for movement in a different plane. When it is possible to a less technically sophisticated camera and two flash units one can thus synchronize measurement devices, events, and camera with a minimum of expanse and electronic technology.

Harvey has compared one and two camera procedures, three cameras and a force platform measuring system were used to collect data. The true data from the oblique view were compared to those generated from the anterior and lateral views as provided by several computer programs. The comparisons of the computed forces following one-and two camera procedures with each other and with the force platform generated forces based on graphical representations were to be used to answer selected questions relating to an acceptable methodology of procedures and software for bio-mechanical analysis of human performance.

Notable findings relating to derivatives from the polynomial curve fitting component of one of the programs rendered it in appropriate to use force platform generated forces for further analysis, subsequent comparison, and final resolution of the one- and two camera procedures. The use of digital filtering curve fitting technique and a bivariate spectral analysis program would have allowed selected kinetic and kinematic variables to be studied.

Dapena calculated three dimensional coordinates of 48 points of a 5 x 5 x 2.3 m grid from film data using three methods: (a) direct linear Transformation (DLT) with a triaxial control object, dimensions = 1.77 x 1.67 x 1.90 m, (b) DLT with a cuboid control object (DLT) dimensions = 1.67 x 1.67 x 1.15 m, (c) Nonlinear Transformation (NLT), cross spans = 1.10, segment length = 2.15 m. The error analysis included the calculation of the eigen values, or principle tension-compression values (max, min, and intermediate), at each point of the grid. The average of the eigen values were: 4.3% (DLT), 2.1% (DLT), and 2.0% (NLT). The results indicated that the accuracy of the DLT method is similar to that of the NLT method when a cuboid control object is used and inferior when a triaxial control object is used.

\[34^\text{Jesus Depena, "Systematic Error in Three-Dimensional Coordinates Within a large Object-Space when Using the DLT X NLT Methods of Three-Dimensional Cinematography"} \textit{Journal of Biomechanics} \textbf{18} (1985) : 230.\]
Plaggenhoef presented methods for obtaining kinetic data to analyse human motions. The aim of the study was to develop the adequate methods of analysis through a combination of anatomical data-gathering and obtaining of photographic records and the proper application of mechanics. The steps necessary to obtain the magnitude of the joint forces and moments of force are presented, and general principles of motion are presented that are applicable to all whole body motions. The horizontal and vertical forces may be obtained in any desired plane of any whole body action. However, most movement presented are limited to selected, symmetrical motions in the sagittal plane as seen from the side view.

Beach investigated the relationship of kinematics to spatial and temporal timing error measurements in a rapid timing task. Movement Velocity provided the major influence on temporal errors in that these errors were seen to decrease with increased Velocity. Kinematic information revealed that the initial portion of all movements was relatively more valuable than later portions, and that the rate of decrease of this relative variability across the movement duration was related to the rate

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of acceleration of movement. This is substantial effect of movement velocity on spatial errors. Kinematic information indicated that extended practice altered the manner in which movements were carried out such that the movements were characterized by lower initial levels of relative variability and some what higher levels of variability later in the movements.

Ray and Sen\textsuperscript{37} studied the whole body centre of gravity (C.G.) and it was determined as a point of intersection of transverse (X-axis), frontal (Y-axis) and sagittal (Z-axis) plane on 27 East Indian Males. The CG in X-axis was 40.93\% of total foot length from the posterior end of the feet, whereas, the CG in Y-axis was 48.43\% of the foot breadth from the right side of the foot mark. The respective values of CG in 'X', 'Y' and 'Z' axis in case of standing (feet held together) arm up condition were 40.96, 48.18 and 59.61\%. A significant change in the CG in 'Z' axis was observed with change in posture. The values, were compared with western studies. It was observed that increased body height shifts the CG towards the head, whereas, the CG is shifted down-ward if height is unaltered but body weight is increased. age has practically no influence over the change in the CG.

Lusin and his associates\textsuperscript{38} reviewed the related literature pertaining to goniometry includes instrumentation, numerical expression, starting position, axis of motion, and reliability. Procedures for using the universal goniometer were emphasized specifically and recommended for all purposes.

The purpose of the study conducted by Andrews\textsuperscript{39} was to show that the concept of a strength curve for a single joint, one degree of freedom (DOF) exercise can be generalized to include multiple joint, one DOF exercise using an arbitrarily chosen characteristic angular variable as the one DOF exercise coordinate, the strength curve is defined as the plot of the system joint torque $T_j$, the exercise coordinate. Here, $T_j$ is the algebraic sum of the $N > 2$ resultant joint torque components $T_i$ ($i = i, \ldots, N$) that (a) act on the distal body segment at each of the subjects $N$ active joints (i.e. joints that change their configurations during the exercise), and (b) correspond to the $N$ angular variables $j$ that define the configurations of these $N$ active body joints.


Jaric and his associates\(^{40}\) evaluated the 'Hill' equation parameter by studying in Vivo the Voluntary isometric contraction of the quadriceps femoris muscle in human beings under various loading conditions. The obtained estimates of \(\frac{a}{f_0}\) and \(V_0 = BF_0/a\) are proved approximately consistent with data from in Vitro and in Vitro experiments. Incomplete agreement between their and other authors results are probably due to the influence of the leg inertial forces and insufficient time to reach maximum quadriceps force which are not considered in the experiments of other authors.

An early factor analysis study in which the McCloy chinning score was included as a variable was reported in 1938 by Hutto\(^{41}\). Factor I, Strength, highest loading with dynamometric strength tests; the highest loading were .938 for Roger's strength Index, .855 for McCloy's Chinning score, and .828 for chinning with 25 pound weight followed by other strength tests. Factor II, dead weight, highest loadings were .694 for body weight, .632 for chinning with 25 pound weight, and .551 for McCloy's score.

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