A THREE-DIMENSIONAL KINEMATIC ANALYSIS OF LONG JUMP

By

BHANU PRATAP

A

Dissertation

Submitted to

Department of Sports Biomechanics

Lakshmibai National Institute of Physical Education,

Gwalior (M.P.) India for the

Degree of Doctor of Philosophy in Physical Education

August, 2017

Dedicated To

My Beloved Family, MyParents, Brothers and Teachers for motivating and inspiring me to attain all the big achievements of my life and always remaining with me in every circumstances of life.

Smt. Prem Vati Devi

&

Sh. Samundra Singh

Approved by-____________________

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CERTIFICATE

SUPERVISOR

I, **Prof. A.S. Sajwan** hereby certify that the dissertation entitled **"A Three-Dimensional Kinematic Analysis of Long Jump"** is genuine, authentic and original piece of research work and I declare that to the best of my knowledge and belief this research report/dissertation is completed by **Mr. Bhanu Pratap**, under my supervision and guidance for the Degree of **Doctor of Philosophy** in Physical Education at Lakshmibai National Institute of Physical Education, Gwalior, Madhya Pradesh, India.

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Last, but not the least for the immense love, enthusiasm and moral support of my mother.

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- Weight Training

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- Sports Training
- Research method

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- Coaching and Officiating.
- Teaching Classes.
- Organizing Competition.
- Organizing Intramural and Extramural Activity.
- Organizing Annual Sports Day.

LIST OF ABBREVIATIONS

ABBREVIATIONS	MEANING
3D	Three Dimensional
COM	Centre of Mass
Vx	Horizontal Velocity
Vy	Vertical velocity
V	Final Velocity
"OY"	Linear Velocity
"OX"	Angular Velocity
g	Gravity
TO	Take off
Hz.	Hertz
Ms^{-1}	Meter per second
SBJ	Standing Broad Jump
Std. Error	Standard Error
df	Degree of Freedom
Sig.	Significance
Et al.(et alia)	And other
Ibid.(ibidem)	In the same place
Viz. (videlicet)	Namely or "that is to say"
I.e.(idest)	that is
Cm	centimetre
M	Meter
gm	Gram
IAAF	International Association of Athletics Federations

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AN ABSTRACT

A THREE-DIMENSIONAL KINEMATIC ANALYSIS OF LONG JUMP

The purpose of the study was to determine a relationship of kinematic analysis of long jump performance. Five Long Jumpers were selected who was studied in Lakshmibai National Institute of Physical Education, Gwalior. The subjects were age ranging from 17-25 years . To obtain reliable measurement, standard and calibrated equipments like camera steel tape, and the study was conducted under controlled conditions. The subject was filmed all Planes. The camera used for analysis was Canon- 70D. After taking the video, the photos were taken by Pausing the video at the desired moment with the help of Kinovea software Version -08.25, and G* power software 3.1.9.2 used G*Power was a tool to compute statistical power analysis for many different *t* tests, *F* tests, $\chi 2$ tests, *z* tests and some exact tests. G*Power could also be used to compute effect sizes, sample size to display graphically the results of power analysis and the output shows that the power of this test was about 0.541 which was less than the power 0.80 found in the fixed model. This observation holds in general: The power in the random model was never larger than that found for the same scenario in the fixed model. In linear regression analysis model with 3 predictors there are 54.13% chance correctly rejecting the null hypothesis that the multiple correlation R^2 values equal to zero with 30 sample size.

Other video graphs camera used in study were filmed at 100f/s with three max 100 Max pro software Version 1.5.1.0 (3D Analyzer), and focal length 8mm. The cameras were placed perpendicular to the runway, about 5 m away in line with the take off board, so that sufficient no. of frames would be available after TO so as to calculate the take off parameters. Judges were asked to place themselves in order to had clear view of all sequential movements and second that they were not in the view field of the camera to obstruct analysis. The film was analyzed by using a segment Biochemical model which was defined by 14 (Marker) points using calibrating through software. For analysis purposes, the camera used for capturing the sequential movements was Canon- 70D and at the time of moment take off in Long jump

expected all various joints angles (Angular), Different Velocities i.e. horizontal Velocity, vertical velocity, linear velocities "*OY" ,* and angular velocities "OX" was developed by using Max pro software (3D Analyzer). After taking the video, the photos were taken by Pausing the video at the desired moment with the help of Kinovea Software Version-08.25, for referencing purpose, the take off board to long jump distance was taken to find out the actual height of centre of Mass of each subject at selected moment. The width of take off board & plasticine indicator board was 30 cm, vertical height of the camera was 1.25 meter and horizontal distance of the camera was 5.00 meter. The subjects were filmed at Lakshmibai National Institute of Physical Education, Gwalior. The Vediography sequence was taken under controlled condition. The subjects performed the technique six times. The statistical technique was used in Regression analysis.

The regression Models generated by the SPSS have been presented in the model, the value of R^2 was .878, which is maximum and, therefore, the model develop was used to develop the regression equation. All model, three independent variables, namely, Right knee angle, Vertical Velocity and Right Pelvis have identified and, therefore, Regression equation should be developed using these three variables only. The R^2 value for this model was 0.878, and, therefore, these three independence variables explain 87.8% variation in Right Pelvis angle for takeoff Long Jump performance. Thus, this Model could be considered appropriate to develop the regression equation. The entire model has been shown. Since F- value for the third model was highly significant, it might be concluded that the model selected was highly efficient also.

Thus, it might be concluded that the above regression equation was reliable as the value of R^2 was 0.878. In other words, the three variable selected in this regression equation explain 87.8% of the total variability in Right Pelvis (all the three independence variables) which was good Model. Since the F- value for this regression model was highly significant, the model reliable. At the same time, all the regression coefficient in this model were highly significant, and, therefore, it might be interpreted that all the three variables selected in the model, namely Right knee angle, Vertical Velocity and Right Pelvis had significant predictability in estimating value of Long Jump Performance.

The unstandardized and standardized coefficient in all models. unstandardized coefficient were also known as "B" coefficients and was by "β" and were used to explain the relative importance of independence variables in terms of their contribution towards the dependence variable in the model. In third model, t- value for all three regression coefficient were significant as their significance values (p values) were less than 0.05. Thus, it might concluded that the variables Right Knee angle Vertical Velocity and Right Pelvis significantly explain the variation in long jump performance.

- The angular kinematic variables i.e. Right knee angle and Right Pelvis angle had significant relationship with performance.
- The Linear kinematic variables i.e. Horizontal velocity and center of Mass had no significant relationship with performance of Long Jump.
- The Linear kinematic variable i.e., Vertical velocity at the time of moment take off had significant relationship with performance of Long Jump.
- The present study had increased our knowledge of the relationships between run-up velocity, Angles of different joint, Centre of Mass, take-off technique, and jump distance.
- The angular kinematic variables i.e. ankle joint (right, left), knee joint (left), Pelvis joint(left), shoulder joint (right, left), and elbow joint, (Right, left), has no significant relationship with performance of Long Jump.
- However, we were not yet able to provide scientifically rigorous advice to the individual athlete on how to optimize their take-off impulses and take-off technique so as to maximize their jump distance.

*****

Chapter I

INTRODUCTION

“Track doesn’t define me, my faith defines me, and I’m running because I have been blessed with a gift”

Allyson Felix

The term athletics is derived from the Greek word “ATHLON” which means a contest, and the word “ATHLETE” denotes a person who takes part in sort of contest involving physical activity. The modern long jump, standardized in England and the United States around 1860, bears resemblance to the ancient event although no weights are used. Athletes sprint along a length of track that leads to a jumping board and a sandpit. The athletes must jump before a marked line and their achieved distance is measured from the nearest point of sand disturbed by the athlete's body. The event was created and included in the Olympics because it was deemed important for warriors to be agile and able to avoid obstacles such as leaping across ditches or streams. The modern Olympics were started in 1896; the winner of the first long jump gold medal was Ellery Clark who jumped 6.35 meters. Another milestone in the history of the event was the world record set in 1935 by Jesse Owens who jumped 8.13 meters. This record would stay in place for 25 years until it was broken in 1960. The current long jump world record is 8.95 meters in the men's event and a women's competition was introduced at the1948 summer Olympics. The world record set 7.52 meters in the women's category. The women's record has been in place for more than 20 years. The sport of track and field athletics has much to offer the person who is bored and likely to kick against society. In no other sports does one witness such a wide variety of physiques, temperament and abilities. Even the most obese person, who would have problems with most other sports, is quite at home in one of the heavy throwing events. Last but not the least; it is a sport that caters to men, women and children at the same meeting. thus encouraging family participation.[1]

[1]WilfPaish, “Track and Field Athletics”London: Lepus Books, (1976) P.20.

Track and Field athletic is no different from choosing material dealing with any other subject. For example, an historical account of the sport can be omitted to advantage because numerous treatises are available that are devoted exclusively to this subject. There are two good reasons why performance records are changing continually and thus present records may be soon out of date, and in the second place, books of performance records, which are kept up to date, are published each year and are easily acquired by anyone. Only in special instances does one seem justified in documenting the material presented in a book such as this is intended to be. Sometimes it seems advisable, and when this is so, it is done. There are ample indices and bibliographies available to all those who wish to consult original sources. In attempting to present figures of acceptable form, one must not be misled by assuming that the techniques employed by any one champion in performing in a given track and field event is a perfect example of the best procedure for every aspirant to follow. A critical analysis of best form of the form employed by top – flight athlete in any event reveals the there are many variation among them in the detailed of the technique employed. Thus, one is forced to resolve this variation into one or more forms, which, in his judgment, appears best suited to the athlete involved.[2]

In all the Jumping events in track and field**,** there is a strong relation between the execution of the approach run and take off performance of jump. The more consistent and more technically correct the approach run and take off, the better jump performance. Most world record performances in the jumping events in track and field have resulted from successful approach run and take off. When a long jumper breaks contact with the ground, centre of gravity forms a parabolic curve. Once in the air, there is nothing that can be done to chance the predetermined flight path. Therefore, the majority of coaching time in the long should be spent developing a technically sound approach run and take off.[3]

The Basic technique used in long jumping has remained unchanged since the beginning of modern athletics in the mid-nineteenth century. The athlete sprints down a

[2]G.T. Bresahan and C.V.Mosbai “Track& Field Athletics, Iowa ,Fifth Edition, 1960, P.5.

[3] Joseph L. Rogers” USA Track & Field coaching manualUnited statehand Book Manual ISBN No. 0-88011-604-8 copy right, 2000 by USA Track and Field P. 141.

runway, jumps up from a wooden take-off board, and flies through the air before landing in a pit of sand. A successful long jumper must, therefore, be a fast sprinter, have strong legs for jumping, and be sufficiently coordinated to perform the moderately complex take-off, flight, and landing maneuvers. He analyzed data reported calculations included the relation between the release height and release angle, as well as between the release speed and release angle. The calculated optimum release angles for the athletes were in good agreement with their usual competition release angles (31–35°). Each athlete had his own specific optimum release angle because of individual differences in the rate of decrease in releasing speed with increasing released angle. The method was evaluated using measurements of three experienced male long jumpers who performed maximum-effort with jumps over a wide range of take-off angles. The optimum take-off angle of each jumper was calculated by combining the equation for the flight distance of a body in free flight with the measured relations between the take-off speed, the height difference between take-off and landing, and the take-off angle for the athlete. The calculated optimum take-off angle was then compared with the athlete's measured competition take-off angles. The best women long jumpers achieve distances of about 6.5–7.5 m, whereas the best men (who are faster and stronger) reach about 8.0–9.0 m. The objectives in each phase of the jump are the same regardless of the athlete’s gender or ability. To produce the greatest possible jump distance the athlete must reach the distance of the run-up with a large horizontal velocity and with the take-off foot placed accurately on the take-off board. During take-off the athlete attempts to generate a large vertical velocity while minimizing any loss of horizontal velocity, and in the flight phase the athlete must control the forward rotation that is produced at take-off and place their body in a suitable position for landing. During the landing the athlete should pass forward of the mark made by their feet without sitting back or otherwise decreasing the distance of the jump. This chapter presents a review of the most important biomechanical factors influence in technique and performance in the long jump. The biomechanical principles behind the successful execution of the run-up, take-off, flight, and landing phases of the jump are explained. The effects of changes in run-up velocity on the athlete’s take-off technique are also examined, as are the design principles of long jump shoes and the techniques used by disabled athletes.[4]

The entry into the take-off is usually performed using a ‘pawing’ action, where the take off leg is swept down and back towards the athlete. The take-off foot has a negative velocity relative to the athlete’s but the velocity of the foot relative to the ground is not quite reduced to zero (about 4–5 m/s). This ‘active’ landing technique is believed to reduce the braking force experienced by the athlete during the initial stages of the take-off. Take-off mechanism just before touchdown the athlete pre-tenses the muscles of the take-off leg. The subsequent bending of the leg during the take-off is due to the force of landing, and is not a deliberate yielding of the ankle, knee, and hip joints. Flexion of the take-off leg is unavoidable and is limited by the eccentric strength of the athlete’s leg muscles. Maximally activating the muscles of the take-off leg keeps the leg as straight as possible during the take-off. This enables biomechanics of the athlete’s to pivot up over the foot, generating vertical velocity via a purely mechanical mechanism. Over 60% of the athlete’s final vertical velocity is achieved by the instant of maximum knee flexion, which indicates that the pivot mechanism is the single most important mechanism acting to create vertical velocity during the take-off. The knee extension phase makes only a minor contribution to the generation of vertical velocity, and the rapid plantar flexion of the ankle joint towards the end of the take-off contributes very little to upward velocity. It is well known that take-off angles in the long jump are substantially less than the 45 angle that is usually proposed as the optimum for a projectile in free flight. Video measurements of world-class long jumpers consistently give take-off angles of around 21. The notion that the optimum take-off angle is 45 is based on the assumption that the take-off velocity is constant for all choices of take-off angle. However, in the long jump, as in most other sports projectile events, this assumption is not valid. The take-off velocity that a long jumper is able to generate is substantially greater at low take-off angles than at high take-off angles and so the optimum take-off angle is shifted to below 45. From a mathematical perspective the athlete’s take-off velocity is the vector sum of the

[4]Langhorne Nicholas P. Brunel, “University, Uxbridge Biomechanics of the Long jump Biomechanical Research Project Athen’s” 1997)P.344.

horizontal and vertical component velocities, and the take-off angle is calculated from the ratio of the component velocities. [5]

Physical Education seems to have taken new turn in the form of sports science. The sports science, in turn, has taken birth from various basic sciences. For many years, the research in sports was being undertaken within the frame work of these basic sciences. But with advancement of time, new specializations and micro specialization have taken a respectable position. As a matter of fact, the research in sports now-a-days embraces knowledge from various disciplines of human sciences.[6]

Professional long jumpers typically have strong acceleration and sprinting abilities. However, athletes must also have a consistent stride to allow them to take off near the board while still maintaining their maximum speed. In addition to the traditional long jump, a standing long jump contest exists requires that athletes leap from a static position without a run-up. Today it is still a popular track and field event, which is popular for athletes of all ages.

The science of biomechanics is concerned with the forces that act on a human body and the effects these forces produce. Physical education teachers and coaches of athletic teams, whether they recognize it or not are likewise concerned with forces and effect. Their abilities to teach the basic technique of a sport or physical activity depends very largely on their appreciation of both the effects they are trying to produce and the forces that cause them. It seems only logical therefore that physical educators, coaches and athletes should turn to biomechanics to provide a sound, scientific basis for the analysis of the techniques[7].

Biomechanics is an applied form of mechanics, and consequently the methods used to investigate it must be derived from those of mechanics. However, Biomechanics

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[5] Youlian Hong, and Roger Bartlett "Handbook of Biomechanics and Human Movement Science"Medical –Routledge,2008 pp. 420

[6]H.S. Sodhi& L.S. Sidhu, "Physique and Selection of Sportsmen" (Patiala: Punjab Publishing House, 1984), P.204.

[7] James G Hay., "The Biomechanics of Sports Techniques", (Englewoods Cliffs, N.J: prentice hall Inc,1985)P.15

have not developed in the wake of mechanics but as a bordering science in other scientific disciplines such as Anatomy, Psychology, and the technique of sport[8].

Kinematics is that branch of biomechanics that is concerned with describing the motion of bodies. Thus kinematics deals with such things as how far a body moves, how fast it moves and how consistently it moves. It is not concerned at all with what causes a body to move in the way it does. This latter aspect of motion is the preserve of kinetics-a complementary branch of biomechanics. Linear kinematics deals with the kinematics of translation or linear motion, while angular kinematics deals with the kinematics of rotation or angular motion.[9]

The application of modern science and technology to sports is an effort to analyze and improve performance and is not a new idea. These efforts command little attention until a number of small innovative countries begin to organize Programmers dedicated to the scientific development of Olympic athletes. The world of sports then became intrigued with the sports science areas of bio-mechanics, physiology, sports medicine, sports psychology and the application of practical methods including carbohydrate loading, blood doping, slow analysis attitude training, relaxation techniques and numerous others. There was a sudden realization that sports sciences offered the key to athlete domination.[10]

Usually, sequential photography is the technique most frequently used in sport biomechanics research for obtaining a record of human movement. These film records are quantitatively analyzed to obtain linear and angular displacement time data for total body or segmental movements. Typically, the basic displacement time functions of a motion do not provide sufficient information to describe the activity fully. Thus, thes e data are further treated mathematically to determine the respective velocity and acceleration functions.[11]

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[8]LigerlardHochmuth, “Biomechanics of Athletic Movement”,(Berlin:sportverlag,1984),P.9.
[9]James G Hay, “The Biomechanics of SportsTechniques”,Third edition , P.13
[10]Ralph Mann., “The Elite Athlete Project Sprints and hurdle”, Track Technique 5 December,1983),P.2672.
[11]John Newton, John Arononcher and Dee Abramson, “In Expensive Timing Method For Cinematography” Research Quarterly,vol.422nd May1971,P.480.

Success in long jump performance mainly depends on the ability of the athlete to transform his horizontal approach velocity into horizontal and vertical takeoff (TO) velocity during the support phase of the jump. Biomechanical analyses indicate that the TO is prepared by a lowering of the centre of gravity (CG) during the last strides of the approach run (e.g., 1–4). It was stated by that elite long jumpers lowered their CG during the flight phase of the second-last stride and stayed low until they raised it for them TO during the support phase of the jump itself (5). The same authors observed an increase of the touchdown (TD) distance for the last stride and the jump. Further, a lengthening of the second-last stride has been considered as a corresponding factor for the lowering of the CG (e.g., 4, 6, 7), but there are contradictory findings as well (e.g., 2, 8, 9). While it is a common approach for biomechanical analyses, in all studies mentioned above, time discrete data such as heights or velocities of CG at TO and TD of each stride were analyzed. Therefore, the results can only serve as an indicator of what the athlete has done up to this point in his performance or of what he may be able to do from this point. Relatively few investigations deal with the problem of how a long jumper should move his/her body segments to achieve the aspired positions. Relating to the movement technique, a backward sweeping or "active" landing of the supporting leg (that can be characterized by a negative touchdown velocity) has been recommended for the last strides as well as for the jump also stated in their study that elite long jumpers used a less "active" landing in the last stride than in the two preceding strides. Those results are mainly based on mathematical simulation, the analysis of discrete parameters, or more qualitative considerations.[12]

The development of vertical velocity at the expense of the loss in horizontal velocity during the sup- port phase of the jump. Similarly, concluded that a fast run-up and lowered centre of gravity (CG) help to place the leg well in front of the body, which permits the CG to ride up over the base of support and enables the takeoff leg to store elastic energy that can contribute to the change in vertical velocity. However, the strategies used in such tasks can vary among individuals. For example, the styles of Mike Powell (distance =8.95 m) and Carl Lewis (distance =8.91 m) at the Third World

[12]Bruggemann P, Nixdorf E, Ernst H .,"Biomechanical Investigation of the Long Jump". Leichtathletik (Lehrbeilage 49):1635-42. (In German 1982.)P. 236.

Championships in 1991 were quite different, achieved a greater vertical velocity and takeoff angle (23.1°=0.40 rad) due to inclination of the trunk, a more extended support leg, and larger hip rotation. In contrast, Lewis preserved horizontal velocity by limiting extension of the support leg, which resulted in a lower takeoff angle (18.3°=0.32 radian). Because these two individuals jumped a similar distance with different take-off.[13]

Angles, we were interested in the biomechanical details of the takeoff associated with various takeoff angles. Previously, we captured the relationship existing between movement output (i.e. the kinematics and ground reaction forces) and movement process leading to this output (i.e. electromyography (EMG) activity) by an analysis of the running jump executed with various takeoff angles using a short approach distance. For example, subjects achieved greater vertical and lesser horizontal velocities due to lesser EMG activation of the biceps femoris muscle, limiting extension of the thigh, and greater braking force. In contrast, subject's main- trained horizontal velocity by activating the lateral gastrocnemius and soleus muscle and experiencing greater propulsive force, which resulted in a lower takeoff angle. In this study, we found that there were distinctly different jumping strategies that varied from nearly horizontal to nearly vertical trajectories and how they affected the take-off velocities.[14]

Take-off is key to all flight. How an animal makes the transition from a surface to the air is critical not only to individual activity and survival, but to the evolution of powered flight from a non-flying ancestor. Unless the wings of birds appeared full-size and fully functional, evolutionary hypotheses need to address the problem of how a small- winged, weakly muscled fiber might be able to get into the air, in addition to determining whether it could support itself using its airfoil. Debate about the evolution of flapping flight in birds has been stalled for several years on the question of take-off since ideas of how a proto-flier supports itself in the air are strongly linked to proposals of how it got into the air. Although all hypotheses and scenarios of the evolution of flight from the ground or the trees must deal with this surface-to-air transition, the take-off mechanics of living birds are largely unknown. How the force to initiate take-off is

[13]Kakihana W., Suzuki S. "Journal of Electromyography and Kinesiology" 11 (2001) 365–372.
[14] James G. Hay, "Techniques used in the Transition from Approach to Takeoff in the Tong Jump". (Journal of Sport Biomechanics 1990) P. 88–.172.

generated is not known for any avian species, nor have the relative roles of the wings and the hind limbs been assessed. Without some modern baseline, realistic prediction of the behaviour of extinct forms is difficult. Given that the hind limbs of birds do not support the airfoil, are not reduced or lost in the majority of species and are three- element limbs well-suited to the mechanics of jumping.[15]

Several studies have shown that performance in the long jump is directly related to different mechanical and muscular mechanisms that occur from the touchdown of the take-off foot through the take-off itself. Basically, the jumper's goal is to generate vertical velocity of his/her centre of mass (CM) at take-off without losing too much horizontal velocity of the CM. It is well known that the greatest gain in vertical velocity takes place during the compression phase, which is associated with a loss in horizontal velocity.[16]

The takeoff distance for the last four strides, the landing distance for the last stride, and the takeoff height for the jump were significantly correlated with the distance of the jump. These three positions variables were significantly related to the distance of the jump by virtue of their relationship with the velocity of the approach and, to lesser extent, the vertical velocity at takeoff for the jumping. Considered alone, they were not influential in determining the distance of the jump (Hay and Nohara, 1990).Run-up is most important part of long jump. The best jump depends on the run-up. The purpose of the run-up is to get the athlete to the optimum position for takeoff with as much speed as he can control during that part of the jump (Bruggemann, 1994; Schmolinsky, 1982; Popov, 1991). The length of run-up that an athlete should use depends on the percentage of his top sprinting speed that he is capable of controlling at takeoff and on his capability to maintain a consistent pattern of striding from one jump to the next (Arampatzis et al., 1997; Hay, 1978).During the last 3 to 4 strides of his approach the athlete brings his trunk into an upright position and lowers his center of gravity in preparation for the takeoff to

[15]Alexander, R. MN., "Leg design and Jumping Technique for Humans, other vertebrates and insects".Phil. Trans. R. Soc. Lond(1995). B 347, 235–248.
[16]José Campos, Javier Gamez, Alberto Encarnacion, Marcos Gutierrez-Davila and Javier Rojas "Three Dimensional Kinematic Analysis of the Long Jump" at the 2008 IAAF World Indoor Championships in Athletics

follow. These changes in body position produce accompanying changes in the athlete's stride length and stride frequency (Hay, 1978).

The purpose of the takeoff is to obtain vertical velocity while retaining is as much horizontal velocity as possible. As the athlete's foot lands at the end of the last stride of the run-up; the hip, knee and ankle joints flex a little to cushion the shock of the impact and to position of the leg for the vigorous extension to follows moments later (Costa et al., 1997; Hanavan, 1964; Popov, 1991). The most important influence on the effective distance is the flight distance of the CM(Lees et al., 1983).This distance is determined by the CM's takeoff velocity, the takeoff angle and the height of CM from takeoff to landing (Lees et al., 1983; Hay, 1978). Correlation of the horizontal velocities at takeoff with the distance of the jump has yielded results that appeared to be heavily influenced by the nature of the sample. Studies of top-class long jumps have indicated that the horizontal velocity takeoff is the dominant influence in determining the distance of the jump. Nigg, for example, has reported correlations between the horizontal and vertical velocities and effective distance of the jump of r=0.79 and -0.08, respectively. According to Nixdorf and Bruggemann, "investigations which use less homogeneous test groups and consequently show a grater variability in vertical velocity [the standard deviation for Nigg's sample was only 0.04 m/s]come to a higher valuation of the verticalvelocity component (Arampatzis et al., 1997). According to, Popov this reduction becomes more pronounced when the angle of projection of the body's CG and the height of the jump are increased. "This statement has been supported in part by data showing a relationship between the loss in horizontal velocity and the jumping height"- that is the maximum height to which the CG is elevated above its height at takeoff (Hay and Nohara, 1990). The aims of the present study were to examine the stride lengths, height of center of gravity and velocities of last four strides. [17]

[17]Emel Çetin, Ozgur Ozdemir, Yeliz Ozdol, "Kinematic Analysis last four stride lengths of two different Long Jump Performance" 5thWorld Conference on Educational Sciences – WCESPublished by Elsevier Ltd2013.P. 145.

Research Question

- ➢ What was the contribution of different kinematic variables in Long Jump Performance?

Objective of the Study

- ➢ To find out which kinematic variable was most contributing in the enhancement of the performance of Long Jump.

Delimitations

- ➢ The study was confined to inter- university level of male athletes of Lakshmibai National Institute of Physical Education, Gwalior.
- ➢ The study was delimited to the subject's age ranging between 17-25 years.
- ➢ The study was further delimited to 5 (Five) Long Jumpers only.
- ➢ The study was further restricted to take off phase only.
- ➢ The study was further delimited to the following variables.

  ✓ **Linear Kinematic Variables**

  - Center of Mass at time of Moment Take - off
  - Vx- Horizontal Velocity
  - Vy-Vertical Velocity

  ✓ **Angular Kinematic Variables**

  - Angle at Ankle joint (right& left)
  - Angle at Knee joint (right& left)
  - Angle at Hip joint (right& left)
  - Angle at Shoulder joint (right& left)
  - Angle at Elbow joint (right& left)

- ✓ **Key Position**
    - TO - Takeoff (Phase)
- ✓ **Key Phase**
    - PTO - Period of Take off (Phase)

Limitations

- ➢ The knowledge of previous experience in training might have affected the performance hence this was also considered as limitation for the study.
- ➢ The diet, healthy habit, style of daily living might have affected the result of this investigation. These factors were considered as limitations for the study.

Hypothesis

Based on knowledge gained from available literature, research findings and the scholar's own understanding of the subject area, the following hypothesis was formulated: It was hypothesized that the selected kinematic variables were significant at the time of movement take off in Long Jump performance.

Definition and Explanation of Terms

Biomechanics

Biomechanics is the science concerned with the internal and external forces acting on the human body and the effects produced by these forces.

Biomechanics is the application of mechanical principles to living organisms.[18]

Kinematics

Kinematics is the branch of biomechanics about the study of movement with reference to the amount of time taken to carry out the activity.

Linear Kinematics

[18]Retrieved from https://www.brianmac.co.uk/biomechanics.htm on date: 22/01/2016.

Linear kinematics as such deals with the linear motion without taking into account the cause of the motion.

Angular kinematics

Angular kinematics deals with the rotation or the angular motion however; it does not study the cause of angular motion.[19]

Centre of Mass

The point at which all the body's mass seems to be concentrated. It is the balance point of the body. It is the point around which the sum of the torque of the segmental weight is equal to zero. It is the point of the application of gravity's force on a mass; the centre of the gravity.

Centre of gravity is the point around which the mass and weight of the body are balanced in all direction.[20]

Long Jump

The Long Jump is a power event that comprises of the following four phases:

- Approach run up
- Take off
- Flight through the air
- Landing

To achieve maximum distance in the long jump the athlete will have to balance three components - speed, technique and strength.

[19]Retrieved from https://www.brianmac.co.uk/biomechanics.htm on date: 23/01/2016.
[20] Retrieved from http://www.physio-pedia.com/Centre_of_Gravity on date: 26/01/2016.

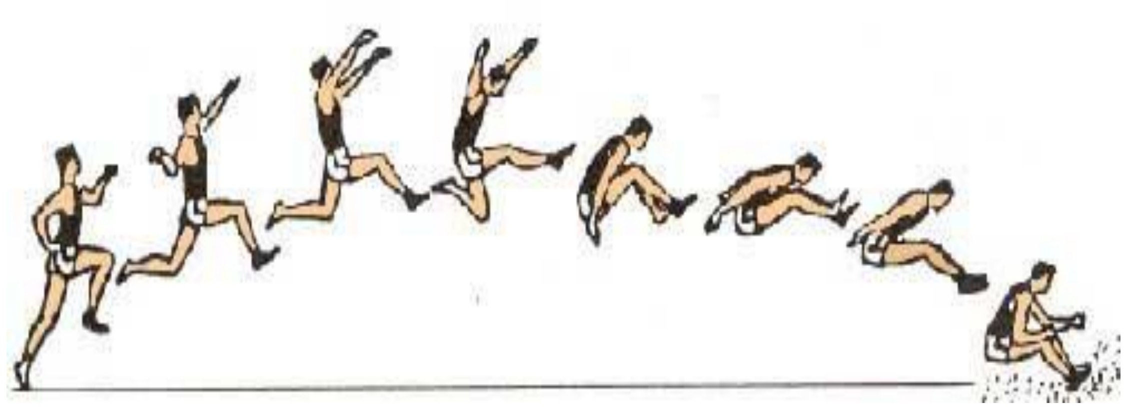

Fig.1. Different Phases of Long Jump

The Approach Run Up

The objective of the approach run is for the athlete to achieve the ideal speed. Rhythm in the approach run is important to ensure the ideal speed is achieved at take off and accuracy in hitting the take off board. It is important the athlete develops a good running rhythm before accuracy is addressed. The length of the run will depend on the athlete's age and speed. When first determining the number of strides in the approach run start by matching the number of stride with the athlete's age;

The start of the approach run should be marked and the athlete should commence the start from a standing start. Some athletes use a 'walk on start' or 'run on start' that will provide more initial speed but if not consistent will impact the accuracy of the approach run onto the take off board. The athlete begins the run with a marked forward lean to develop speed but before they reach the take off board, they should be upright. The athlete should be on the balls of the feet as in sprinting with a natural head position, the eyes focused beyond the pit and not at the take off board.

Accuracy of the approach run onto the take off board is established by:

- Determine the take off foot
- Stand with your back to the jumping pit and the heel of your non take off foot on the take off board scratch line

- Run up the runway the required number of strides, say 19, and place a marker where the 19th stride falls
- Place the non take off foot on the marker and run back towards the board and take off. The coach should note where the 17th stride lands in relationship to the take off board
- If the foot is behind the take off board, say 20cm, and then move the start marker 20cm forward. If the foot is beyond the take off board then move the marker back
- Repeat the run up and marker adjustment 4 or 5 times to establish a consistent approach run onto the take off board
- Once achieved measure the distance accurately and record it for future use
- It is important to bear in mind that a head or tail wind will affect the run up. A head wind may mean moving the marker slightly forward.

The Take off

The preparation for the long jump take-off begins in the later phases of the approach run. The long jumper prepares for takeoff by sinking the hips and then raising the hips into the take off phase. This usually results in the next to last stride being longer than normal and the final stride being up to 25 centimeters shorter than a normal running stride. It must be emphasized that the hip sink and stride adjustment all happen in response to the athlete's postural adjustments in preparation for the take off. At take off ensure the hips are slightly forward of the shoulders.

When the take off foot is placed on the board, it is slightly in advance of the jumper's hips and should strike the board on the mid line.

Fig. 2. Take off Steps of Long Jump

The final two foot contacts in the take off should be flat, almost slapping.

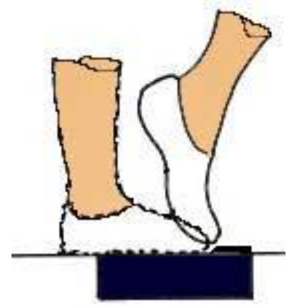

Fig. 3. Take off Position of Long Jump

The vertical impulse is achieved by the upward acceleration of the "free" limbs, the arms and the non take off leg, against the braced take off leg. These movements should be characterized by short radius (blocked), fast explosive actions.

The head should be carried in a normal position, in line with spine, and the eyes should be focused forward and slightly up.

Optimum Take off Angle

The take off speed of a male elite long jumper is about 10.5 meters/second in a "run through" (take off angle of zero degrees) and 3.5 meters/second for a vertical jump (take off angle of 90 degrees). This decrease in speed means that the optimum angle of take off is well below 45 degrees. **Langhorne et al. (2005)** identifies that the optimum take off angle for a world-class long jumper may be 21.5°± 3.5°. Research by (**Lees et al. 1994)** identifies that the optimum take off angle for a world-class male long jumper may be 21°± 6.[21]

[21]Retrievedfrom https://www.brianmac.co.uk/ Long Jump/ on date: 27/01/2016

Significance of the Study

The study may significant in the following ways-

- The result of the study may help coaches and trainees to train players for enhancement of long jump performance.
- This study may help the coaches, athletes and exercise scientists who were in great need of an additional investigation of this problem.
- The result of the study may be used as a screening tool in assessing the quality of Long Jumper on the basis of kinematic variables.
- This study may help the Physical Education Teachers and Coaches to develop training program for the Long Jumper to achieve excellence.
- The finding of this study may give certain guidelines based on kinematic parameter for selecting the right athletes for long jump.
- It may be helpful for giving conditioning program and selecting scientific training methods according to different level of Long Jumper.
- This study may stimulate many other researchers to attempt to bring further light to this particular problem.

Chapter II

REVIEW OF RELATED LITERATURE

A careful review and exploration of the literature related to the present study is essential to have insight into the research already carried out in this field. To provide the background materials for this study, the scholar made an attempt to go through the related literature, a brief review of which are presented in this chapter.

Gregory et al. (2016)[1] this study examined the acute effects of a conditioning plyometric exercise on long jump performance during a simulated long jump competition. Eight national level track and field decathletes performed six long jump attempts with a full approach run separated by ten minutes of recovery. In the experimental condition subjects performed three rebound vertical jumps with maximal effort three minutes before the last five attempts, while the first attempt served as baseline. In the control condition the participants performed six long jumps without executing the conditioning exercise. With baseline, long jump performance was progressively increased only in the experimental condition from 3.0% or 17.5 cm in the third attempt (p=0.046, d=0.56) to 4.8% or 28.2 cm in the sixth attempt (p=0.0001, d=0.84). The improvement in long jump performance was due to a gradual increase in vertical take-off velocity from the third (by 8.7%, p=0.0001, d=1.82) to the sixth jump (by 17.7%, p=0.0001, d=4.38). Horizontal approach velocity, take-off duration and horizontal velocity at take-off were similar at all long jump attempts in both conditions (p=0.80, p=0.36 and p=0.15, respectively).Long jump performance was progressively improved during a simulated competition, when a plyometric conditioning exercise was executed 3 min before each attempt. This improvement was due to a progressive increase in vertical velocity of take-off, while there was no effect on the horizontal velocity.

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[1]Gregory C. “ Bogdanis,AthanasiosTsoukos and PanagiotisVeligekas “Improvement of Long Jump Performance During Competition Using a Plyometric Exercise”Physical Education and Sports Science, University of Athens, GreeceVolume:0 Issue: 0, 2016P. 1-19

Cetin et al.(2014)[2] examined the last four strides of athlete's who had two different long jump performances. Twenty male long jumpers' long jump performances were recorded two video cameras (50 Hz). Differences the lengths of last four strides, velocity of center of gravity (CG) which was formed during the last four strides in two groups were investigated. It was determine significant differences the lengths of last four strides; the height of the athlete's CG during the last four step (except the last step); the fourth to last stride velocity between two Group I and Group II ($p<0.05$). There were significant differences horizontal and vertical velocity at the instant of touchdown and horizontal velocity after the touchdown between in two Groups ($p<0.05$).[3]

Flora et al. (2013)[4] study examined the contribution of instructional self-talk and observational learning on the development of Long Jump technique. Sixty-nine beginner athletes were randomly assigned to four groups self-talk, video, self-talk + video' and control group. All groups performed 24 practice sessions, consisting of a cognitive intervention program in the form of either instructional self-talk or observational learning, or a combination of both, and the practice of specific drills. A significantly higher performance improvement was recorded for the self-talk group in post test, whereas when kinematic variables of the motor skill (center of mass displacement) were assessed, "observational learning" proved to be more effective. The findings of the current study suggest that young, beginner athletes, participating in complicated tasks, may benefit from cognitive intervention techniques, through enhanced attention focus on the most critical elements of the motor skill.[5]

Baozhai et al. (2013)[6] the study conducted on treading and jumping is the hardest and most important stage in long jump technique. From the point of mechanics, Treading and jumping can be divided into two parts of tread and jump.

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[2]Emel Çetin, OzgurOzdemir&YelizOzdol, "Last Four Stride Lengths of two Different Long Jump Performance,"Social and Behavioral Sciences, Volume 116, 21 February 2014,P. 2747-2751.

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[4] Flora Panteli, Tsolakis, Efthimiou, and Smirnioto "Acquisition of the Long Jump Skill, Using Different Learning Techniques" Sport Science, Track and Field Department, National and Kapodistrian University of Athens, Athens, Greece, Volume: 27 Issue: 1, 2013P. 40-52.

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[6]Baozhai Li , Xue Ding and Xincheng Shi "The 3D Jumping Technical Analysis of Long Jump Athletes Based onthe Statistics"Department of Physical Education, Hebei Institute of Physical Education, 2nd International Conference on Management Science and Industrial Engineering (MSIE 2013) P. 125.

Jumping task is in rapid run-up conditions, through the reasonable jumping action to change human body movement direction, the athletes get an appropriate take-off angle of body gravity and the initial jump velocity. So, the stand or fall of jumping skills of the athletes themselves is one of the important symbols of its movement level. The essential to improve the performance of long jump is completing jumping technique. This paper discusses the influence factors of treading and jumping, from the angle of statistical computing science, and provide theoretical basis for athletes training.

Yoshinori et al. (2013)[7] conducted the study on factors affecting the increase in jump distance when the novice increased the number of steps in their approach run in the long jump, and discusses a training task designed to improve performance in the long jump. Twenty-eight male students who were novices in long jump and did not take part in any sport activity regularly participated in the study. They performed the long jump with run-ups of six and twelve strides. The take-off motions of the participants were captured with a high-speed digital camera (120 fps) for two-dimensional motion analysis. When students increased the number of steps in their approach run, the jump distance and approach velocity increased, horizontal deceleration during the take-off phase remained almost unchanged, and the vertical velocity at take-off and the contact time decreased. The change rate of the jump distance between six and twelve steps for the approach run had positive correlation with the change rates of the approach velocity and vertical velocity and negative correlation with the change rate of the contact time. In a previous study using athletes as participants, all athletes increased their jump distance as they increased the number of steps in their approach run. In the present study, however, many students did not increase their jump distance, and the change rate of the jump distance had a wide distribution. Therefore, we divided the students into groups according to whether the participant's change rate of the jump distance was lower or higher than the average change rate for all participants. Although both groups had increased horizontal velocity at touchdown for the lengthened run-up, participants in the low group did not increase their jump distance and their vertical velocity at take-off decreased.

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[7]Yoshinori Kinomura, Nobuaki Fujibayashi& Koji Zushi, "Characteristics of the Long Jump Take-off as the Novice Increases the Number of Steps in the Approach Run",Engineering, Volume 60, 2013, P. 313-318.

Additionally, in comparison with athletes, students had lower vertical velocity at take-off and horizontal deceleration during take-off. A novice should thus learn the proper technique of take-off to generate vertical velocity through horizontal deceleration.

Elliott et al. (2012) [8]investigated eight college level runners were filmed using high speed photography at the 500m, 1,300m, 2,100m and 2,900 m stages of 3000 m time trial. Kinematic and spatiotemporal data were obtained through an interfaced digitizer computer system. Mean horizontal velocities of 5.18 m/s, 5.17, 5.18 m/s and 5.16 m/s indicated that minimal variations occurred from the four stages of the trial. No Significant changes in biomechanical data were apparent between the first three stages of the trial; however, changes were evident when Stage 4, the 2,900 m mark, was compared to the earlier sections of the trial. With the development of fatigue stride length decreased while stride rate increased to maintain the constant velocity. There was also a small shift to increase the period of support and correspondingly decrease the period of support and correspondingly decrease the period of non-support. The leg was more angled at foot strike, the thigh was less extended at the end of the support phase, and the trunk was carried further forward during the running cycle. Success in middle-distance running required the athlete to maintain an efficient co-coordinated movement pattern over the entire race. The coach who can identify the changes in movement patterns over a race increases the likelihood of success for his athletes.

Szerdiova et al. (2012)[9] the study conducted on analysis of impact of upper extremities momentum on the jump length and analysis of selected kinematic data changes during the standing long jump. Four young sportsmen participated in the initial study. They have performed standing long jump in two measuring conditions: with and without arms swinging. Motion was captured using a 3D optoelectronic camera system SMART (BTS) and selected kinematic data were evaluated using software packages and data processing: trajectory of body centre of gravity (COG), velocity of COG, maximal vertical distance of COG, take-off angle together with

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[8]B.C. Elliott, Eight college level runners were filmed using high speed photography at the 500m, 1,300m, 2,100m and 2,900 m stages of 3000 m time trial. Volume-15, No.26, July, 2012 P. 140-147.

[9]Szerdiova, Simsik& Dolna, “Assessment of Kinematics Of Sportsmen Performing Standing Long Jump In 2 Different Dynamical Conditions”, Metrology and Measurement Systems. Volume 19, Issue 1, 2012P. 85-94.

momentum of upper extremities were analyzed. The data were statistically evaluated using descriptive statistics and analysis of variance. Statistical significance of the kinematic data and jump length were analyzed using the Kruskal-Wallis test and post-hoc test ($p<0.05$) in Statistics toolbox of program. Statistically significant differences were assessed within intra individual and intra class comparison of data.

Matic et al. (2012)[10] conducted the study on paper was to perform a kinematic analysis of the take-off, and especially to examine the relationships of active landing (AL) and run-up velocity (RUV) with the take-off variables and the length of jump (L), as well as to determine the influence of our model and individual influence of each independent variable on the dependent variable – (L). The authors' intention was to apply the obtained results in practice – with the possibility of helping a population of average women long jumpers to approach the model of an elite woman long jumper. An experimental method was applied in the research to the sample of 25 successful long jumps of different length and the velocity of the approach of the junior world champion Ivana Spanovic. The results were measured by the Quality’s Pro Reflex MCU 240 motion capture 3D infrared system. The Pearson correlation analysis was used to establish the correlation between the variables. The standard multiple regression was used to measure the percentage of the influence of the model and each variable at L. It was found that the variables of the take-off change with the increase of RUV. The highest correlation with RUV was determined for the variables: (L) $r = 0.696$ and $p = 0.000$ and (TA) $r = 0.603$ $p = 0.001$. The standard multiple regression was used to calculate that our model (RUV, AL, KATD, AATD, LATD, TA, TOD) explained the variance L with 69%. It was concluded that TOD, LATD and RUV statistically significantly explain the variance L. To realize the maximum length of the jump, the jumpers should achieve the highest possible RUV and minimize the loss of the resulting take-off velocity with AL, the LATD should be about 63°, the KATD and TA should be increased, while the TOD should be shortened with the increase of RUV. It was found that AL does not correlate with RUV, but there is statistically significant correlation of AL with TOD, which has a large impact on L.

[10]MilanMatic1, Vladimir, Mrdakovic1 & Jankovic Nenad, “Active Landing and Take-off Kinematics of the Long Jump” Physical Education and Sport Volume 10, N3, 2012 P. 243 - 256.

Vladimir et. al. (2012)[11] the study was conducted on the take-off phase (approximately 6m) of the jumps of all athletes participating in the individual HS-106m hill ski jumping competition at the Torino Olympics was filmed with two high-speed cameras. The high altitude of the ski jumping venue (1600m) and slight tail wind in the final jumping round were expected to affect the results of this competition. The most significant correlation with the length of the jump was found in the in-run velocity (r=0.628, p<0.001, n=50). This was a surprise in Olympic level ski jumping, and suggests that good jumpers simply had smaller friction between their skis and the in-run tracks and/or the aerodynamic quality of their in-run position was better. Angular velocity of the hip joint of the best jumpers was also correlated with jumping distance (r=0.651, p<0.05, n=10). The best jumpers in this competition exhibited very different take-off techniques, but still they jumped approximately the same distance. This certainly improves the interests in ski jumping among athletes and spectators. The comparison between the take-off techniques of the best jumpers showed that even though the more marked upper body movement creates higher air resistance, it does not necessarily result in shorter jumping distance if the exposure time to high air resistance is not too long.

Wang et. al. **(2012)**[12] the flight safety is threatened by the special flight conditions and the low speed of carrier-based aircraft ski-jump takeoff. The aircraft carrier motion, aircraft dynamics, landing gears and wind field of sea state are comprehensively considered to dispose this multidiscipline intersection problem. According to the particular naval operating environment of the carrier-based aircraft ski-jump takeoff, the integrated dynamic simulation models of multi-body system are developed, which involves the movement entities of the carrier, the aircraft and the landing gears, and involves takeoff instruction, control system and the deck wind disturbance. Based on Multi body similar environment, the multi-body system simulation is realized. The validity of the model and the rationality of the result are verified by an example simulation of carrier-based aircraft ski-jump takeoff. The simulation model and the software are suitable for the study of the multidiscipline

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[11]Vladimir Mrdakovic1,Milan Maticand Nenad Jankovic1 "Active Landing and Take-off Kinematics of the Long Jump Physical Education and Sport Volume - 10 No 3, 2012, pp. 243 – 256.

[12]Wang Yangang , Wang Weijun and Qu Xiangju· "Multi-body dynamic system simulation of carrier based aircraft ski-jump takeoff by Beizhang University, 2012.P. 27.

intersection problems which are involved in the performance, flight quality and safety of carrier-based aircraft takeoff, the effects of landing gear loads, parameters of carrier deck, etc.

Mohammad et al.(2011)[13] compare the selected kinematical parameters of successful and unsuccessful Fosbury's' flop high jump technique present study was structured. For the accomplishment of the purpose of this study six intervarsity level male high jumpers were randomly selected from the 70th All India Intervarsity Athletic Championship, held at Chennai, 2009. Their mean age, height and weight were 21yrs, 170.87 cm and 60.5 kg, respectively. To acquire kinematical data during the competition, one high speed Sony DCR SX40E camcorder mounted at a height of 5 feet was placed at 10 meters away, perpendicular to the bar. All subjects were performed three jumps, and the successful and unsuccessful jump for each athlete was selected for further analysis. Video footages were downloaded, slashed to desired footages and edited for biomechanical analysis. Ankle angle, knee angle, hip angle, shoulder angle and elbow angle in different five phases (take-off preparation phase, take-off phase, flight phase, 'L' position phase and landing phase) were digitized with the help of Silicon Coach Pro7 motion analysis software. All statistical procedures were conducted using the SPSS (16.0 Version) software. A level of significance was set at 0.05. The acquired data of the variables were subjected to descriptive statistical analysis followed by t test. The results showed that insignificant differences were found between successful and unsuccessful jump on selected parameters.

Darren et al. (2011)[14]conducted a study on "Biomechanical analysis of the snatch during weightlifting competition". This study was performed on five elite Malaysian weightlifters during competition. Three digital video cameras were used to determine the motion in three dimensions of the CG of the weights and the CG of the lifter plus weights. For the pull phases, lifters showed consistent patterns of the greatest peak Weight acceleration in the First Pull and greatest system power in the Second Pull. Individual subject differences were greater than differences between successful and unsuccessful lifts. All the unsuccessful lifts were those that failed in the

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[13] Khan, Mohammad & Hussain, "Comparison of Kinematical Variables between Successful and Unsuccessful Fosbury's-Flop High Jump Technique", Golden research thoughts, volume 1, 2011, P. 1.

[14]J. Darren "Biomechanical Analysis of the snatch during weightlifting competition", Volume 23, July 2011,P-14 1-146.

squat, the subject could not even begin to stand upright. System velocity may be a better indicator of why a lift is failing than are Pull Heights or Weight velocities. The purpose of this study was to determine the bar plus weights and system (body plus bar plus weights) CG kinematics in the Snatch lift to determine the factors associated with successful and unsuccessful lifts for lifters during competition.

Stefanyshyn et al. (2010)[15]the study examined on contribution of the lower extremity joints to vertical jumping and long jumping from a standing position has previously been investigated. However, the resultant joint moment contributions to vertical and Long Jumps performed with a running approach are unknown. Metatarsal phalangeal joint to these activities has not been investigated. The objective of this study was to determine the mechanical energy contributions of the hip, knee, ankle and metatarsal joints to running long jumps and running vertical jumps. A saggital plane analysis was performed on five male university basketball players while performing running vertical jumps and four male long jumpers while performing running long jumps. The resultant joint moment and power patterns at the ankle, knee and hip were similar to those reported in the literature for standing jumps. It appears that the movement pattern of the jumps is not influenced by an increase in horizontal velocity before take-off. The metatarsal phalange us joint was a large energy absorber and generated only a minimal amount of energy at take-off. The ankle joint was the largest energy generator and absorber for both jumps; however, it played a smaller relative role during long jumping as the energy contribution of the hip increased.

Panoutsakopoulos et al. (2010) [16] conducted the study to describe the kinematics of the long jump approach and take-off and their effect upon the flight and the landing. Three digital video cameras, were used to capture the last two strides of the approach, the take-off phase, the flight and the landing of the eight jumpers participating in the men's long jump competition at the 2006 European Cup 1st League-Group B Event in Thessaloniki, Greece, on 17 June 2006. A 3D-DLT analysis was conducted for the two final strides of the approach and the take-off and a 2D-DLT analysis for the landing. Results indicate that all participants seemed to utilize

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[15]Darren J. Stefanyshyn & Benno M. Nigg, "Contribution of the lower Extremity joints to Mechanical energy in running vertical jumps and running long jumps." Published online: 01 December 2010.

[16]PanoutsakopoulosVassilios& I. PapaiakovouGeorgios, "Biomechanical Analysis of the Preparation of the Long Jump Take-Off" New Studies in Athletics no. 1/2010, IAAF.

the "longer penultimate-shorter last stride" ratio. Two types of approach were revealed, the "straight forward" and the "imbalanced". These approach types did not affect the long jumping technique, but the stride angles of the last stage of the approach were highly correlated ($r > .70$, $p < .05$) with the placement of the take-off foot on the board and with the lateral flight path of the Body Centre of Mass.

Bouchouras (2009)[17] conducted the study on amount of angular momentum and the efficiency of landing for the hang and 2½ hitch kick long jump techniques. Twelve male long jumpers participated in this investigation and were divided into two groups based on their flight technique (hang group, n=6; hitch kick group, n=6). The participants performed three jumps with full run-up, the best of which was selected for analysis. A two-dimensional DLT analysis of the take-off, flight, and landing was conducted for the two groups. Three cameras (JVC GR-DVL 9800 GL, Victor Company, Japan) with a sampling frequency 50 Hz were used. Two of the cameras were placed perpendicular to the run-up, on the right and left side of the take-off board, to record the take-off and the flight of the athletes (from both sides of the movement); the third was placed perpendicular to the pit, on the right side, to record the landing. The two groups differed in their angular momentum at the instant of take-off (hang: −11.92 kg·m2·s−1; hitch kick: −22.69 kg·m2·s−1; $P<0.001$) in the front direction, and in linear and angular velocity, mainly of the arms, at the instant of take-off. According to the results, the 2½ hitch kick group had greater angular and linear velocities ($P<0.05$). The 2½ hitch kick group had better landing efficiency than the hang style group ($P<0.05$), as the athletes in the former group managed to land their pelvis in front of their heels during landing. On the other hand, the hang style group landed their pelvis almost 5.81 cm behind the heels during landing and shortened their final distance. It seems that the 2½ hitch kick group had better landing efficiency because of their greater amount of angular momentum. The hang style group could have achieved better landing through an increase in angular momentum, which depends on an increase of the linear and angular velocities of the two arms during take-off.

[17]Bouchouras ,"Angular Momentum and Landing Efficiency in The Long Jump", European Journal of Sport Science, volume 9, 2009 ,P..53-59.

Michiyoshi (2008)[18] describe the men's high jump at the 2007 IAAF World Championships in Athletics in Osaka was notable for both the high level of results the first three all cleared 2.35m, and an interesting contrast in jumping techniques. As a part of a larger study of the event, the authors produced this interim report on the kinematic analysis of the best jumps of the medal- lists. Their examination of winner Donald Thomas's technique variously described as unusual-looking and like a shot in basketball, produces the surprising conclusion that, in fact, it is highly effective on account of his double-arm swing, almost vertical body at the take- off, and the highly raised thigh of the swing leg at take-off.

Walsh et al. (2007)[19] the study examined on gender differences during drop jumps, to evaluate the effect of a set of simple instructions on kinematic and kinetic parameters during a drop jump, and to determine if there are gender differences in the effects of instruction on those parameters. Twenty-five basketball players, 13 men and 12 women, performed drop jumps from a box (height 30.5 cm) after being asked to perform a land and jump movement as they normally would do when aiming at maximum jump height. The experimental group received a set of instructions designed to make them land softer. The measured parameters were impact force at landing, ground contact time, flight time, frontal plane knee angle, sagittal plane knee angle, and distance between the knees. When the groups were examined by gender, no differences in the parameters were seen in men after instruction, but in women the following significant differences were detected: an increase in contact time, a decrease in landing force, and a decrease in inward movement of the knees after landing. These data indicate that females respond differently to jumping/landing instructions.

Graham et al. (2007)[20]conducted a study on "The long jump has been widely studied in recent years". Two models exist in the Literature which defines the relationship between selected variables that affect performance. Both models suggest

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[18] AeMichiyoshi ," Biomechanical analysis ofthetopthreemale High Jumpersatthe2007 World Championships inAthletics", New Study in athletics by IAAF, Volume.23., 2008, P.45-52.

[19]S.Walsh, Waters & G. Kersting, "Gender Bias on the Effects of Instruction on Kinematic and Kinetic Jump Parameters of High-Level Athletes", Research in Sports Medicine,Volume .15, .2007 P. 283-295.

[20]Philip Graham-Smith and Adrian Lees "A three-Dimensional Kinematic Analysis of the Long Jump Take-off, University of Salford , Frederick Road, Salford, Greater, ManchesterPublished online: 18 Feb 2007.

that the critical phase of the long jump event is the touch-down to take-off phase, as it is in this phase that the necessary vertical velocity is generated. Many three dimensional studies of the long jump exist, but the only studies to have reported detailed data on this phase were two-dimensional in nature. In these, the poor relationships obtained between key variables and performance led to the suggestion that there may be some relevant information in data in the third dimension. The aims of this study were to conduct a three-dimensional analysis of the touch-down to take-off phase in the long jump and to explore the interrelationships between key variables. Fourteen male long jumpers were filmed using three-dimensional methods during the finals of the 1994 (n=8) and 1995 (n=6) UK National Championships. Various key variables for the long jump were used in a series of correlation and multiple regression analyses. The relationships between key variables when correlated directly one-to-one were generally poor. However, when analyzed using a multiple regression approach, a series of variables was identified which supported the general principles outlined in the two models. These variables could be interpreted in terms of speed, technique and strength. We concluded that in the long jump, variables that are important to performance are interdependent and can only be identified by using appropriate statistical techniques. This has implications for a better understanding of the long jump event and it is likely that this finding can be generalized to other technical sports skills.

Harst et al.(2007) [21] investigated on Anterior cruciate ligament (ACL) deficiency can be a major problem for athletes and subsequent reconstruction of the ACL may be indicated if a conservative regimen has failed. After ACL reconstruction signs of abnormality in the use of the leg remain for a long time. It is expected that the landing after a single-leg hop for distance (horizontal hop) might give insight in the differences in kinematics and kinetics between uninjured legs and ACL-reconstructed legs. Before the ACL-reconstructed leg can be compared with the contra lateral leg, knowledge of differences between legs of uninjured subjects is needed. Kinematic and kinetic variables of both legs were measured with an optoelectronic system and a force plate and calculated by inverse dynamics. The dominant leg (the leg with

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[21] J.J. van der Harst, A. Gokeler& A.L. Hof, “Leg Kinematics and Kinetics in Landing from a single-leg hop for distance. A comparison between dominant and non-dominant leg”, Clinical Biomechanics, Volume 22, Issue 6, July 2007, P. 674-680.

biggest horizontal hop distance) and the contra lateral leg of nine uninjured subjects were compared. No significant differences were found in most of the kinematic and kinetic variables between dominant leg and contra lateral leg of uninjured subjects. Only hop distance and hip extension angles differed significantly. This study suggests that there are no important differences between dominant leg and contra lateral leg in healthy subjects. As a consequence, the uninvolved leg of ACL-reconstructed patients can be used as a reference. The observed variables of this study can be used as a reference.

Julien et al. (2007)[22]the study conducted on pole-vaulting focus mostly on energy transfer data. Simulation of “smart” pole vaulting .Journal of Biomechanics Influence of pole length and stiffness on the energy conversion in pole-vaulting. Journal of Biomechanics, Energy loss in the pole vault take off and the advantage of the flexible pole. Sports engineering reproducibility of energy parameters in the pole vault. Journal of Biomechanics and often fail to take into account the actions exerted on the pole Effect of the pole–human body interaction on pole-vaulting performance. Journal of Biomechanics The present study integrates the 3D kinematics data of the athlete but also the actions measured at the end of the pole in the planting box and on the track during the last stride before take-off. It proposes a mechanical model allowing determination of the pole-vaulter's actions on the pole. The model is based on a global mechanical approach. The pole-vaulter's action on his upper and lower hand is concentrated on one middle point to solve the dynamics problem. The model was applied to seven experienced pole-vaulters. The force and the moment exerted on the pole by the pole-vaulter during the last stride before takeoff and during jump stage, were calculated. This analysis of the compressive force and bending moment for seven pole-vaulters helps to highlight the impact of the moment in the performance. The conclusion is confirmed by an additional comparative study carried out on two pole-vaulters, with comparable morphologies and performing with the same pole.

[22]JulienMorlier and Michel, “MesnardInfluence of the Moment exerted by the Athlete on the Pole in Pole-vaulting performance.”Journal of Biomechanics, Volume 40, Issue 10, 2007 ,P. 2261-2267.

Nolan et al.(2006) [23] investigated whether female lower-limb amputees conform to the established long-jump model and to compare the kinematics of the approach and take-off phases for elite female transtibialfemoral and transtibial amputee long jumpers. Eight female Trans femoral and nine female transtibial amputee athletes where videotaped (Saggital plane movements at 50 Hz) from third-to-last step to take-off during the 2004 Paralympics Games long-jump finals. After digitizing and reconstruction of 2D coordinates, key variables were calculated at each stride and during contact with the take-off board. Additionally, approach speed during the run-up of each jump was recorded (100Hz) using a laser Doppler device (LDM 300 C Sport, Jenoptic Laser, Jena, Germany). The transfemoral amputees had a consistently higher center of mass height on the last three steps before take-off than the transtibial amputees. However, at touch-down onto the take-off board, they lowered their center of mass excessively so that from touch-down to take-off, they were actually lower than the transtibial amputees. This resulted in a greater negative vertical velocity at touchdown and may have inversely affected their jump performance. Female transtibial athletes conformed to the long-jump model, although adaptations to this technique were displayed. Female transfemoral athletes, however, exhibited no relationship between take-off speed and distance jumped, which may be attributable to their excessive lowering of their center-of-mass height at touchdown onto the take-off board. It is recommended that coaches and athletes proceed with caution when trying to replicate techniques used by able-bodied athletes because adaptations to the constraints of prosthesis should be considered.

Greg et al. (2006)[24] the study conducted on three-dimensional world that is discontinuous on many spatial scales. As the scale of substrate discontinuity increases, many arboreal animals rely on leaping or gliding locomotion between distant supports. In order to successfully move through their habitat, gliding animals must actively modulate both propulsive and aerodynamic forces. Here we examined the take-off and landing kinetics of a free-ranging gliding mammal, the Malayan

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[23]L Nolan, BL&KJ, "A Biomechanical Analysis of the Long Jump Technique of Elite Female amputee athletes", (Medical Science sports exercise, volume .38 (10). 2006, P. 1829-1835.

[24]Greg Byrnes1,Norman T.-L Lim2&Andrew J. Spence, "Take-off and Landing Kinetics of a free-ranging gliding mammal, the Malayan colugo Galeopterus variegatusSeptember 1, 2006 P.209, 3358-3369.

colugo *(*Galeopterusvariegatus*)* using a custom-designed three-dimensional accelerometer system. We found that colugos increase the propulsive impulse to affect longer glides. However, we also found that landing forces are negatively associated with glide distance. Landing forces decrease rapidly as glide distance increases from the shortest glides, then level off, suggesting that the ability to reorient the aerodynamic forces prior to landing is an important mechanism to reduce velocity and thus landing forces. This ability to substantially alter the aerodynamic forces acting on the palatial wing in order to reorient the body is a key to the transition between leaping and gliding and allows gliding mammals to travel long distances between trees with reduced risk of injury. Longer glides may increase the access to distributed resources and reduce the exposure to predators in the canopy or on the forest floor.

Wakaiet al. (2005)[25] conducted the study to identify and explain the optimum projection angle that maximizes the distance achieved in a standing long jump. Five physically active males performed maximum-effort jumps over a wide range of take-off angles, and the jumps were recorded and analyzed using a 2-D video analysis procedure. The total jump distance achieved was considered as the sum of three component distances (take-off, flight, and landing), and the dependence of each component distance on the take-off angle was systematically investigated. The flight distance was strongly affected by a decrease in the jumper's take-off speed with increasing take-off angle, and the take-off distance and landing distance steadily decreased with increasing take-off angle due to changes in the jumper's body configuration. The optimum take-off angle for the jumper was the angle at which the three component distances combined to produce the greatest jump distance. Although the calculated optimum take-off angles (19–27°) were lower than the jumpers' preferred take-off angles (31–39°), the loss in jump distance through using a sub-optimum take-off angle was relatively small.

Blakeet al. (2005)[26] optimal control simulations of the standing long jump were developed to gain insight into the mechanisms of enhanced performance due to

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[25]Masaki Wakai, Nicholas P. Linthorne, "Optimum Take-off Angle in the Standing Long Jump", Human Movement Science, Volume 24, Issue 1, February 2005, P. 81-96.

[26]Blake M. Ashbyand Scott L. Delp**,**" optimal control simulations reveal Mechanisms by which arm movement improves standing Long jump performance of Biomechanics 2005.04.017.

arm motion. The activations that maximize standing long jump distance of a joint torque actuated model were determined for jumps with free and restricted arm movement. The simulated jump distance was 40 cm greater when arm movement was free (2.00 m) than when it was restricted (1.60 m). The majority of the performance improvement in the free arm jump was due to the 15% increase (3.30 vs. 2.86 m/s) in the take-off velocity of the center of gravity. Some of the performance improvement in the free arm jump was attributable to the ability of the jumper to swing the arms backwards during the flight phase to alleviate excessive forward rotation and position the body segments properly for landing. In restricted arm jumps, the excessive forward rotation was avoided by "holding back" during the propulsive phase and reducing the activation levels of the ankle, knee, and hip joint torque actuators. In addition, swinging the arm segments allowed the lower body joint torque actuators to perform 26 J more work in the free arm jump. However, the most significant contribution to developing greater take-off velocity came from the additional 80 J work done by the shoulder actuator in the jump with free arm movement.

Smith et al. (2005)[27] the study examined on two models exist in the literature which defines the relationship between selected variables that affect performance. Both models suggest that the critical phase of the long jump event is the touch-down to take-off phase, as it is in this phase that the necessary vertical velocity is generated. Many three dimensional studies of the long jump exist, but the only studies to have reported detailed data on this phase were two-dimensional in nature. In these, the poor relationships obtained between key variables and performance led to the suggestion that there may be some relevant information in data in the third dimension. The aims of this study were to conduct a three-dimensional analysis of the touch-down to take-off phase in the long jump and to explore the interrelationships between key variables. Fourteen male long jumpers were filmed using three-dimensional methods during the finals of the 1994 (n = 8) and 1995 (n = 6) UK National Championships. Various key variables for the long jump were used in a series of correlation and multiple regression analyses. The relationships between key variables when correlated directly one-to-one were generally poor. However, when analyzed using a multiple regression approach, a series of variables was identified which supported the general principles

[27] P. Smith Graham & A. Lees, "A Three-Dimensional Kinematic Analysis of the Long Jump Take-off" Journal of Sports Sciences, Volume 23, Issue 9, 2005 P. 891-903.

outlined in the two models. These variables could be interpreted in terms of speed, technique and strength. We concluded that in the long jump, variables that are important to performance are interdependent and can only be identified by using appropriate statistical techniques. This has implications for a better understanding of the long jump event and it is likely that this finding can be generalized.

Vanezis et al. (2005) [28]describe that vertical jump is widely used as a field test of performance capability, particularly in games like soccer. Invariably some players perform better than others and, while this is usually put down to greater strength or 'explosive power', there is no detailed information to explain how the muscles around the major joints contribute to this performance and what the nature of this contribution is, or indeed whether aspects of technique are important to performance. Detailed knowledge of this type would be useful to help understand which muscle characteristics are important in successful performance of jumping and may enable insights to be gained in terms of strength training for players. The aim of this study was to investigate the contribution made by the lower limb joints to vertical jump performance by good and poor performers of the counter-movement jump. Two groups of players were selected who were found to be good and poor jumpers, respectively. Each player was required to perform three maximal vertical counter-movement jumps with, and three jumps without, an arm swing. The jump performance was recorded simultaneously by means of a force platform and a Pro Reflex automatic motion analysis system at 240 Hz. Values at the ankle, knee and hip were computed from these data for joint moments and power. Generally, better jumper's demonstrated greater joint moments, power and work done at the ankle, knee and hip, and as a result jumped higher under both conditions. It appears that the superior performance of the better jumpers was due to greater muscle capability in terms of strength and rate of strength development in all lower limb joints rather than to technique, which differed less noticeably between the groups. It is concluded that the muscle strength characteristics of the lower limb joints are the main determinant of vertical jump performance with technique playing a smaller role.

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[28] Vanezis& Lees, "A Biomechanical Analysis of Good And Poor Performers of The Vertical Jump",Taylor& Francis , Volume l.48. 2005,P. 594-1603.

Parchman et al (2003) [29]conducted a cinematographically and mechanical analysis of the golf swing of female golfers. The purpose of this study was to analyze the movement and timing of selected body segments during the execution of the golf drive by female golfers Cinematography was the method used to analyze the mechanics of the action of body segments during the golf swing. The filming for the study occurred on November 15th, 1969, at Centenary Collage Gymnasium, Shreveport, Louisiana. Four women golfers of amateur status, who were former state and regional champions, served as subjects for the study. The subjects were filmed from the side. Front and overhead, by three sixteen millimeter movie cameras set at sixty-four frames per second. The movement and timing of the body segments were analyzed while the film was projected by a microfilm reader. Tracings were drawn from selected frames of pertinent views of the body during the swing A descriptive analysis of the movement that occurred in all three views and liner velocity contributions of the body segments to the club head were computed. The percentage contribution of the linear velocity of each body segment was determined.

Bartlett et al. (2002) [30] this paper overviews the importance for sports biomechanics of movement variability, which has been studied for some time by cognitive and ecological motor skills specialists but, until quite recently, had somewhat been overlooked by sports biomechanics. The paper considers biomechanics research reporting inter- and intra-individual movement variability in javelin and discus throwing, basketball shooting, and locomotion. The overview does not claim to be comprehensive and we exclude such issues as the theoretical background to movement and coordination variability and their measurement. There are overview evidences, both theoretical and empirical, of inter-individual movement variability in seeking to achieve the same task goal, in contrast to the concept of "optimal" movement patterns. Furthermore, even elite athletes cannot reproduce identical movement patterns after many years of training, contradicting the ideas of motor invariance and "representative" trials. We contend that movement variability, far from being solely due to neuromuscular system or measurement "noise"—as sports biomechanics may have previously supposed is, or could be, functional. Such

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[29] Parchman “Cinematographically and Mechanical Analysis of the Golf Swing of Female Golfers .Dissertation Abstracts International 2003Pages 229.

[30] R. Bartlett, J Wheat, M Robins. This Paper overviews The Importance For Sports Biomechanics of Movement Variability, Dissertation Abstracts international 31L9 , March 2002 .4517-A

functionality could allow environmental adaptations, reduce injury risk, and facilitate changes in coordination patterns. We conclude by recommending that sports biomechanics should focus more of their research on movement variability and on important related topics, such as control and coordination of movement, and implications for practice and skill learning.

Blake et al. (2002)[31] investigated three males performed a series of jumps with free (JFA) and with restricted (JRA) arm motion to determine if arm swing improves jumping distance. The subjects jumped off a force platform and the motion of the body segments were recorded with a four-camera, passive motion-capture system. Jumping performance was defined as the horizontal displacement of the toe between the initial and landing (TD) positions. The subjects jumped 21.2% further on an average with arm movement (2.09±0.03 m) than without (1.72±0.03 m). Seventy-one percent of the increase in performance in JFA was attributable to a 12.7% increase in the take-off (TO) velocity of the center of gravity (CG). Increases in the horizontal displacement of the CG before TO and in the horizontal position of the toe with respect to the CG at TD accounted for the remaining 29% of the improvement in jumping distance. The added balance and control provided by the arms throughout the jumping motion contributed to performance improvement in JFA. The subjects were able to remedy excessive forward rotation about the CG by swinging the arms backwards during the flight phase. Without the freedom to swing the arms during flight, the subjects had to eliminate any excessive forward rotation [32]while still in contact with the ground. This tendency in JRA was manifest in the premature decline in the vertical ground reaction force (VGRF) and the development of a counterproductive backward-rotating moment about the CG.

Wilson et al. (2001)[30]the study used a subject-specific model with eight segments driven by joint torques for forward dynamics simulation to investigate the effects of initial conditions and takeoff technique on the performance of running jumps for height and distance. The torque activation profiles were varied in order to

[31]Blake M Ashby, Jean H Heegaard , “Role of Arm Motion in the Standing Long Jump”, Journal of Biomechanics, Volume 35, Issue 12, December 2002 , P. 1631-1637.

[32]Cassie Wilson, Mark A. King & Maurice R. Yeadon, “Effects of Initial Conditions and Takeoff Technique on Running Jumps for Height and Distance”, Journal of Biomechanics, Volume 44, (Issue 12, 11 August 2001, P. s 2207-2212).

obtain matching simulations for two jumping performances (one for height and one for distance) by an elite male high jumper, resulting in a simulated peak height of 1.98 m and a simulated horizontal distance of 4.38 m. The peak height reached/horizontal distance travelled by the mass centre for the same corresponding initial conditions were then maximized by varying the activation timings resulting in a peak height of 2.09 m and a horizontal distance of 4.67 m. In a further two optimizations the initial conditions were interchanged giving a peak height of 1.82 m and a horizontal distance of 4.04 m. The four optimized simulations show that even with similar approach speeds the initial conditions at touchdown have a substantial effect on the resulting performance. Whilst the takeoff phase is clearly important, unless the approach phase and the subsequent touchdown conditions are close to optimal then a jumper will be unable to compensate for touchdown condition shortcomings during the short takeoff phase to achieve a performance close to optimum.

Larkin's et al.(2002) [33] the long jump is composed of four distinct but continuous phases: an approach run, a takeoff, a flight, and a landing of these four phases, the flight and the approach run receive most of the coach's and athlete's attention during practice. Little or no training time, however, is spent practicing the takeoff actions. Coaches probably avoid teaching this phase because of its complexities. First, many coaches do not realize the importance of this phase to the success of the horizontal jumps. Second, because of the speed at which the takeoff develops, it is very difficult to isolate individual actions without the help of slow motion photography. Third, there are so many important actions that occur over this very short period of time that it is difficult for the coach to identify the most important actions. If the coach cannot identify the most important actions of the takeoff phase, he/she cannot develop a drill to teach them. This is very unfortunate because the takeoff phase is by far the most critical of the four phases to the success of the performance (Linger, 1980; and Stewart, 1981; Ramey, 1982). This article, therefore, has three purposes. The first is to identify the most important mechanical variables that occur during the takeoff phase. The second is to identify the takeoff actions used by horizontal jumpers in order to optimize the takeoff variables. The third is to present a step by step teaching progression designed to teach the most important

[33] Larkin's, "The Takeoff Drill for the Long Jump", University of Michigan 2002.

takeoff actions to horizontal jumpers. The presentation of the teaching progression also includes an analysis which explains the relationship between the takeoff actions and the mechanical variables. The teaching progression is divided into four stages. In Stage 1, the jumper learns the starting or "Power Position.” The Power Position simulates the position of the body when the jumper makes contact with the takeoff board and is used during each stage. Stage 2 teaches the jumper how to position the body in order to help control the magnitude and direction of forward rotation generated. Stage 3 teaches the jumper how to perform the trunk and knee extension movement necessary to generate vertical lift. Finally, in Stage 4 the jumper learns to coordinate the swinging body segments with the movements previously learned. The focus of the discussion below is on the long jump, but in fact, this drill is applicable to each takeoff of the triple jump and possibly the high jump takeoff as well.

Xie et al. (2001) [34]conducted a study on “Biomechanical analysis of the men's javelin throw at the 21st south east Asian games”. A three-dimensional video analysis was performed on four finalists in the javelin throw of the 21" South East Asian (SEA) Games. The release parameters of the performances of the men's javelin finals are presented in this paper. The performance parameters were compared with that of the 19th SEA Games to evaluate if improvements were made. The release parameters were also compared with the 1995 World Championship reported by provide an international perspective for the level of performance. The data collected from this SEA Games facilitated the comparison between the South East Asian athletes and the world-class athletes to provide an international perspective of sports performance.

Seyfarth et al. (1999)[35]the study proposed which quantitatively describes the dynamics of the centre of gravity (C.G.) during the take-off phase of the long jump. The model entails a minimal but necessary number of components: a linear leg spring with the ability of lengthening to describe the active peak of the force time curve and a distal mass coupled with nonlinear visco-elastic elements to describe the passive peak. The influence of the positions and velocities of the supported body and the

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[34]Xie A study on “Biomechanical Analysis of the Men's Javelin Throw at the 21st South East Asian Games. “Volume-14, No. 26, July 2001, P-145-154.

[35]A. Seyfarth, A. Friedrichs, V. Wank& R. Blickhan, “Dynamics of the Long Jump,” Journal of Biomechanics, Volume 32, Issue 12, December 1999 , Pages 1259-1267.

jumper's leg as well as of systemic parameters such as leg stiffness and mass distribution on the jumping distance were investigated. Techniques for optimum operation are identified: (1) there is a minimum stiffness for optimum performance. Further increase of the stiffness does not lead to longer jumps. (2) For any given stiffness there is always an optimum angle of attack. (3) The same distance can be achieved by different techniques. (4) The losses due to deceleration of the supporting leg do not result in reduced jumping distance as this deceleration results in a higher vertical momentum. (5) Thus, increasing the touch-down velocity of the jumper's supporting leg increases jumping distance.

Demes et al. (1999)[36] conducted the study on forces that animals generate and are exposed to during locomotion is an important prerequisite for understanding the musculoskeletal correlates of locomotors modes. We recorded takeoff and landing forces for 14 animals representing seven species of strep serine primates with a compliant force pole. Our sample included both specialized vertical clingers and leapers and more generalized species. Takeoff forces are higher than landing forces. Peak forces during acceleration for takeoff ranged from 6 to 12 times body weight, and the peak impact forces at landing are between 5 and 9 times body weight. There is a size-related trend in peak force magnitudes. Both takeoff and landing forces decrease with increasing body size in our sample of animals from 1 kg to over 5 kg. Peak forces increase with distance leapt. The distance effect is less clear, probably due to the narrow range of distances represented in our sample. A comparison of sub adult and adult animals of two species of reveals a tendency for the young animals to exert relatively higher peak forces in comparison to their adult nonspecific's. Finally, Lemur and the "generalists" in our sample, tend to generate higher forces for equal tasks than the specialized vertical clingers and leapers (i.e., the Hip lemur*)*.A broad-scale comparison of peak leaping forces and peak forces for quadruped and bipedal walking and running shows that leaping at small body size is associated with exceptionally high forces. Whereas relative forces (i.e., forces divided by body weight) decrease with increasing body mass for leaping, forces for walking and running do not change much with size. Leaping forces in our sample scale to (mass) $^{-1/3}$, which is consistent with expectations derived from geometric similarity models.

[36] B. Demes, J.G. Fleagle, &W.L. Jungers, "Takeoff and Landing Forces of Leaping Strepsirhine Primates." DOI: 10.1006/jhev.1999 .0311.

Forces associated with other locomotors activities do not appear to follow this pattern. The very high forces found in strep sirhine leapers do not seem to be matched by bone robust city beyond that documented for quadruped species.

Sagi (1998)[37] analyzed the performance of 100 male subjects in standing broad jump and vertical jump with varying knee angles i.e. 65^0, 90^0 and 115^0 with and without arm swing. the data pertaining to the performance in standing broad jump and vertical with varying knee angles and with and without arm swing were analyzed by two-way analysis of variance, he found the knee angle of 90^0 was found to be more conduct to obtain the best performance in case of standing broad jump. However, vertical jump performance did not differ significantly due to varying knee angles. He also found that the relative effect of arm swing was found to be considerably higher in case of vertical jumps as compared to the standing broad jump.

Chaudhri (1998)[38] conducted the study during the all India inter-university athletics meet (1987-88) at Patiala. All the female long jumpers were filmed using a bio-mechanics 500 camera. The camera was operated at 100 frames per second and was positioned perpendicular to the plane of motion. The film was processed and analyzed using a film motion analyses. The performance in the competition was taken from official records. The results of the study reveal inter relationship between various observed parameter and the performance. The Jumpers were divided into groups on the basis of their performance and significant difference were observed in velocity of takeoff, time of takeoff and the time of last stride in the approach.

Áragón and Melissa (1997)[39] purpose of the study was to examine the changes in both the coordination patterns of segmental actions and the dynamics of vertical jumping that accompany changes in vertical jump performance (VJP) occurring from trial to trial in single subjects. Ground reaction forces and video data were analyzed for 50 maximal vertical jumps for 8 subjects. It was possible to predict

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[37]Sagi Joseph, "Performance in Standing Broad Jump and Vertical Jump with Varying Knee Angles and with and without Swing." Unpublished M.Phil Dissertation .Jiwaji University, 1998.

[38] Chaudhri, "Biomechanical Analysis of Long Jump", Abstracts: National Conference of Biomechanics,Volume. 34.1988. P. 147

[39]F. Áragón-Vargas and M. Melissa Gross "Kinesiological Factors in Vertical Jump Performance: Differences Within individuals Department of Movement Science, The University of Michigan Volume: 13 Issue: 1 1997, P. 45-65.

VJP from whole-body or even segmental kinematics and kinetics in spite of the small jump performance variability. Best whole-body models included peak and average mechanical power, propulsion time, and peak negative impulse. Best segmental models included coordination variables and a few joint torques and powers. Contrary to expectations, VJP was lower for trials with a proximal-to-distal sequence of joint reversals.

Nesser et al. (1996) [40] examined on 20 male athletes on a number of physiological variables to determine which may account for the most variation in 40-m sprint performance. The athletes were tested on 40-m sprint, 10-m sprint, a 5-step jump, vertical jump, Wingate anaerobic cycle power, and isokinetic peak torque of the knee and hip at speeds of 1.05, 3.14, and 7.85 radian [middle dot] sec-1 and ankle at speeds of 1.05, 3.14, and 5.24 radian [middle dot] sec-1. With R = 0.897 (p <= 0.05) and SEE = 0.151 (sec), the 10-m sprint and ankle dorsi flexion peak torque at 5.24 radian [middle dot] sec-1 were identified as predictors of 40-m sprint performance. With the 10-m sprint removed as an independent variable, stepwise multiple regression was performed again. With R = 0.909 and SEE = 0.146 sec, the 5-step jump, knee flexion peak torque at 7.85 radian [middle dot] sec-1, and ankle plantar flexion peak torque at 1.05 radian [middle dot] sec-1 were identified as predictors of 40-m sprint performance. The results indicate that both 10-m sprint and 5-step jump can be used to predict 40-m sprint performance.

William et al. (1995)[41]study determined the kinematics of the final 11 steps of the long jump approach (LJA) for 19 novice long jumpers. Associations between takeoff accuracy and jump performance were identified, and comparisons of LJA kinematics were made with previous investigations of horizontal jumps performed by expert long jumpers. Results indicated that absolute takeoff error was not an important determinant of jump distance for the novice long jumpers. Additionally, novice jumpers differed from expert jumpers in terms of the relationships among specific variables. The results suggest that kinematic variables that appear to be

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[40]Nesser, Thomas W.; Latin, Richard W.; Berg, Kris; Prentice, Ernest, “Physiological Determinants of 40-Meter Sprint Performance in Young Male Athletes.”Journal of Strength & Conditioning Research November 1996.

[41]William P. Bergand Nancy L. Greer “A Kinematic Profile of the Approach Run of Novice Long Jumpers” Kinesiology and Leisure Studies, University of Minnesota, Minneapolis, MN 55455Volume: 11 Issue: 2, 1995Pages: 142-162.

causally related to jump performance in experts may not pay a similar role in the performance of novices. Hypotheses for these differences were offered. Differences between the LJAs of novice and expert long jumpers warrant further investigation, so that their origins can be determined and used to develop effective training regimes.

Adrian et al. (1994) [42] study was concerned with the measurement of performance variables from competitors in the men's long jump final of the World Student Games held in Sheffield, England, in July 1991. Several performances of 10 finalists were recorded on cine film at 100 Hz. Resulting sagittal plane kinematic data were obtained for the last stride, touchdown, and takeoff for a total of 27 jumps. It was confirmed that takeoff velocity was a function of touchdown velocity, and that there was an increase in vertical velocity at the expense of a reduction of horizontal velocity. It was concluded that there was evidence for mechanisms which may be termed mechanical, biomechanical, and muscular. The former relates to the generation of vertical velocity by the body pivoting over the base of support during the compression phase, and a lifting of the arms and free leg during the lift phase; the second is the elastic reutilization of energy; and the third is the contribution by concentric muscular contraction.

Koyama et al. (1993)[43]study investigated on the effects of inclined and raised flat boards on the take-off motion of the long jump to determine the effectiveness of these boards as training tools. Eight male long jumpers were videotaped with two high-speed video cameras (250 Hz) set perpendicular to the runway. Four different jumps were performed with in four conditions, all with their medium length run-up: a long jump with their normal technique, long jumps on upward inclined boards of two different inclinations (2.5 and 5.0 degrees), and a long jump on a raised flat board (0 degrees, 50 mm). The raised flat board enhanced the pivot of the body over the take-off foot, and reduced flexion of the take-off leg knee. However, the inclined boards did not produce the same effects as the raised flat board. The use of the inclined boards increased the vertical velocity of the centre of mass of the body at toe-off,

[42]Adrian Lees, Philip Graham-Smith, and Neil Fowler "A Biomechanical Analysis of the Last Stride, Touchdown, and Takeoff Characteristics of the Men's Long Jump Journal of Applied Biomechanics, 1994,10, 61-78.

[43]Koyama H,Muraki Y & A. M, "Effects of an Inclined Board as a Training Tool on the Take-off Motion of the LongJump". Jounral Sports Sciences.1993 August;11(4):303-14.

resulting in increased airborne time. These results suggest that the raised flat board and inclined boards would be effective in improving long jumpers' techniques during the take-off and airborne phases.

Lees et al. (1993) [44] study conducted on measurement of a selection of performance variables from competitors in the women's long jump final of the World Student Games held in Sheffield, Several performances of each of six finalists were recorded on cine-film at 100 Hz. Resulting planar kinematic data were obtained for the last stride, touch-down and take-off. For the analysis, the point of maximum knee flexion was established and this was used to represent the point at which the compression phase had ended. A variety of variables describing the position, velocity and angular changes are presented as descriptive data. In addition, these were used to compute energies on the basis of a whole body model. The data were interpreted on the basis of a technique model of long jumping established from the literature. It was confirmed that take-off velocity was a function of touch-down velocity, and that there was an increase in vertical velocity at the expense of a reduction of horizontal velocity. An attempt was made to identify the mechanisms acting during the touch-down to take-off phase which were responsible for generating vertical velocity. It was concluded that there was evidence for mechanical, biomechanical and muscular mechanisms. The former relates to the generation of vertical velocity by the body riding over the base of support; the second is the elastic re-utilization of energy; and the third is the contribution by concentric muscular contraction.

Jameset al. (1990) [45] investigated the characteristics of the positions adopted by long jumpers during the final strides of the approach are significantly related to the distance of the jump, and that they are so related only by virtue of their relationships with the horizontal velocity at touchdown and/or the vertical velocity at takeoff. Trials by 20 male and 26 female long jumpers were recorded cinematographically and subsequently analyzed. The takeoff distance for the fourth-last stride, the landing distance for the last stride, and the height of the center of gravity (CG) at takeoff into

[44] Lees A, Fowler N, Derby D., “A Biomechanics analysis Of The Last Stride, Touch-Down And Take-Off Characteristics of The Women's Long Jump.” Journal Sports Sciences. 1993 August 18(4):304-16.

[45] James G. Hay, Hiroshi Nohara , “Techniques Used By Elite Long Jumpers In Preparation For Takeoff.” Journal of Biomechanics, Volume 23, Issue 3,1990, P. 229-239.

the jump were significantly correlated with the distance of the jump. These three position variables were significantly related to the distance of the jump, through their relationships with the velocity of the approach and the vertical velocity of the CG at takeoff into the jump. Considered alone, they were not influential in determining the distance of the jump.

James et al. (1986)[46] the preceding review has been based on over 200 publications in Czech, English, French, German, Japanese, Polish, and Russian. Even a cursory perusal of these materials is sufficient to show that much has been done to try and obtain a scientific understanding of long jump techniques. It is clear, too, that still more remains to be done. Much of the work to date has been focused on just a few aspects of long jump technique. Other important aspects have received relatively little attention. The latter include the accuracy of the approach, the techniques used during the final strides of the approach, the role of elastic energy in the takeoff, the initiation and control of the jumper's angular momentum, and the techniques used in the landing. Future research efforts might well be directed towards resolving major issues concerning these aspects of long jump technique. The methods used to gather data in the studies reviewed have been rather unimaginative. Two-dimensional cinematography has been used in the vast majority of the studies and force platforms in a few. Other data-gathering procedures like three-dimensional cinematography, electromyography and accelerometer have rarely, if ever, been used. In only one or two studies was anything remotely approaching experimental or technological innovation in evidence. The methods used to analyze data have also been very limited. With the notable exception of a study by Ballreich, few papers have involved anything more sophisticated than means, standard deviations, correlation coefficients and an occasional multiple regression equation. Given these facts, it is hard to avoid the conclusion that our knowledge of long jump techniques might be greatly improved if the full range of available and appropriate procedures were turned to the purpose. Finally, no review of the literature on long jump techniques would be complete without reference to the level of scholarship displayed in the works under consideration. With only a few exceptions, the level shown in the scientific papers

[46]James G. Hay, “The Biomechanics of the Long Jump”, Exercise Sport Sc Review”, Exercise sports sciences review, volume 14 1986, P. 401-446.

reviewed here left much to be desired. Time and again, variables were not defined, crucial measurement techniques were not described and major results were not presented or discussed. In addition, much of the data presented in tables and graphs were patently in error. In light of all this, it is clear that unless the level of scholarship improves, future progress in this area of sports biomechanics is likely to be very slow.

Jubela (1981)[47] investigated the optimum angle of projection and the vertical force available at take off in the performance in the performance of the long jump. Five high school athletes served as subjects and were selected solely on the basis of their ability to long jump a distance of 21 feet .The performance were filmed using one camera with the filming speed set at 64 frames per second. It was assumed that force available at take off is equal to the subject's body weight plus the momentum (change in force from a horizontal direction to a partially vertical direction).The result indicated that as a long jumper. In the long jump as the angle of projection increases the vertical force exerted at take off increases. The optimum angle of projection for skilled jumpers is in the range of 17 to 21 degrees. As the jumpers become more highly skilled the optimal angle of projection is greater and in the range of 23 to 27 degrees. The optimal ratio of vertical velocity after takeoff to horizontal velocity after takeoff is in the range of .031 to .038 for skilled jumpers. The optimal ratio appears to increase to near 0.5 for the highly skilled performance. For highly skilled jumpers, angle of projection tends to decrease as distance jumped increase. A linear relationship exists between vertical velocity and approach velocity until approach velocity reaches about 90 per cent of maximum horizontal velocity and an inverse relationship exists between distance jumped and vertical force.

Nelson (1980) [48]conducted a study on the technique for the cinematographic and dynamometric analysis of the twisting back somersault in floor exercise. Having long been plagued with misconceptions and a general lack of understanding concerning the physical laws governing twist rotations. This is due in a large part to

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[47]Jubela Robert, "Angle of Projection and Available Force in Long Jump", Dissertation abstracts international, 42. 198, P.1047.

[48]Ng, Nelson Kwok .A Technique for the Cinematographic and Dynamometric Analysis of the twisting back somersault in floor exercise. Dissertation University of Northern Colorado, (1980).

the neglect with which the topic has been accorded, particularly the insufficient attention give to the factor causing the twist, that is, the torque. Over the years a number of cinematographic studies on twisting in gymnastics have appeared, however, the utilization of dynamometry as a research tool in this area is quite lacking, particularly in a sport where applications appear inexhaustible. The purpose of this study was to develop a technique for the cinematographic and dynamometric analysis of the backward somersault with full twist performed in floor Exercise, whereby kinematic and kinetic variables. In particular, torque and angular momentum can be quantified.

French et al. (1981)[49] conducted a study on the validity and reliability of kinematic data from two dimensional cinematography. 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 film. A sub-problem was to test the reliability of similar kinematic data between two independent 16mm films. The effects of film emulsion, frame rate and film format on displacement values were determined in two experiments. In the first, the angular displacement of a rotating device was measured at regular intervals and in the second, the horizontal displacement of the total body center of gravity of human subject was determined during the leg recovery phase of one complete running cycle of the right leg. Each experiment was simultaneously filmed by three cameras, two 16mm and one Super 8, under nine filming conditions produced by the combination of three film emulsions, Kodak Tri-X, 4-X, and chrome EF, and three camera speeds, 50,100 and 200 fps. The mean displacement from three observations per filming condition served as data for analysis in each experiment. The data were statistically analyzed by two planned comparisons among camera means and a three factor analysis of variance with repeated measures on one factor (cameras). The running data were analyzed twice, once with Super 8 data from an image that was relative size to 16mm and again with Super 8 data from an image the same size as 16mm (1) No significant differences were found in the mean angular displacement of the rotating device between the 16mm cameras of between the Super 8 and the mean of the 16mm cameras. (2) For relative size data, the mean horizontal displacement of the total body center of gravity did not differ significantly between

[49] French Elton Keith, "Validity and Reliability of Kinematic Data from Two Dimensional Cinematography" Dissertation Abstracts International 41; 12 June 1981; 5023-A.

the 16 mm cameras. But the mean of the Super 8 camera was significantly different from both the individual and the combined means of the 16 mm cameras. (3) With like size data, no significant differences were founding the mean horizontal displacement of the 16 mm cameras. (4) Film emulsion and frame rate were found to have inconsistent effects on measured displacement values and on the performance of individual cameras.(1) 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. (2) Reliable kinematic data of the same event can be obtained from the films of independent 16 mm cameras. (1)Two Supper 8 cameras should be including in a similar study to verify the reliability of the supper 8 format. (2) Future research should be conducted with other human movement, such as the ballistic actions of throwing, striking or kicking. (3) Since the effects of film emulsion and frame rate were inclusive, future studies should be conducted to examine these factors in more detail.

Harvey et al. (1981)[50]conducted a comparative study of one and two - camera procedures for the biomechanical analysis of human performance. Three cameras and a force platform measuring system were used to collect data. The true data from the oblique view were compared to 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 the biomechanical analysis of human performance the suggested procedures the digitizing process, the disposition of the data and all computer programs appeared to indicate that an acceptable methodology was followed however notable preliminary findings relating to derivatives from the polynomial curve fitting component of one of the programs rendered it inappropriate to use force platform generated forces for further analysis subsequent comparison and final resolution of the one and two camera procedure. The use of digital filtering

[50]Ray Walter Harvey, "A Comparison of one and Two-Camera Procedures for the Biomechanical Analysis of Human Performance," Dissertation Abstracts International 45:5 November , 1984: 1333-A

curve fitting technique and a bivariate spectral analysis program would have allowed selected kinematic and kinetic variables to be studied.

Bedi et al. (1977)[51] conducted the study on angular momentum produced at take off in the long jump was studied thought the use of cinematography and strain gauge technology. The resulting force and positional data from the best performance of several trials by each of eight intercollegiate and interscholastic long jumpers performing several trials was integrated to obtain angular momentum values. The results indicate that a forward rotation about a transverse axis through the center of mass occurred for all jumpers. In addition a high mean angular momentum value of 72.2 ft-lb-sec was caused by a dominance of braking force at foot plant. Estimates of possible error indicate a high sensitivity to positional data and possible errors of one-third of the obtained value with normally obtainable data.

Deshon et al. (1964)[52] the study examined the relationship of velocity of running (a)the angle to which the leg is raised in front of the body;(b)the length of two strides(a cycle);and(c) the angle that the leg makes with the ground at point of touch down. He selected 19 varsity athletes from the University of Maryland, of them ten were track sprinters and nine were baseball players. Prior to the collection of the data, the sprinters had weeks training and the baseball players had two weeks practice of sprinting. All the subjects were filmed from a distance of 15 yards. Each was given a distance of 25 yards to build up maximum velocity before entering filming zone. Inter correlations were computed between the velocity .The angle to which the leg is raised .The length of two strides and the angle that the leg makes the ground at touchdown. The result of the study showed that all the relationships are liner. All of the correlations were statistically significant at 0.05 levels with one exception. There was no relationship between the mean angle of left lift and the mean angle of the leg at touchdown.

[51]J.F. Bedi, and J.M. Cooper, "Take off in the Long Jump Angular momentum considerations"' Journal of Biomechanics, Volume 10, Issue 9, 1977, P. 541-548.

[52]Deshon and Nelson, "Cinematographical Analysis of Sprint Running" ,Research quarterly,vol.35(4) 1964 P. 51

OVERVIEW OF THE REVIEWS

After detailed analysis of these reviews, they were further divided into sub topics they are as follows:

Long jumpers may increase their run-up velocity through technique training (where the athlete learns to use more appropriate movement patterns when sprinting and during the transition onto the take-off board) or through physical training (where the athlete increases their muscular strength, particularly in the muscles of the hips and legs that are used in sprinting). We contend that the relationships between run-up velocity, jump distance, and take-off technique seen in the present study are indicative of those that will result from an increase in run-up velocity arising from technique training. Extrapolating the athlete's curves indicates that for a 0.1 m/s increase in run-up velocity we expect the athlete's jump distance to increase by 6 cm, the horizontal braking impulse to increase by 1.2 N·s, the vertical impulse to remain constant, the take-off velocity to increase by 0.06 m/s, and the take-off angle to decrease by 0.2°. A force platform could be used to monitor an athlete's take-off forces during training. Diagnosing an athlete's technique is probably easiest when it is known that certain technique variables should be either maximized or minimized (e.g., run-up velocity; fall-back distance). Unfortunately, the generation of optimum take-off forces is a compromise between the conflicting desires of generating vertical impulse and minimizing the horizontal braking impulse. To increase the duration of the foot contact the athlete plants their foot ahead of the centre of mass. However, the resulting increase in vertical propulsive impulse is accompanied by an undesirable increase in horizontal braking impulse. (Nicholas P. Linthorne et al. 2011) this study examined the acute effects of a conditioning plyometric exercise on long jump performance during a simulated long jump competition. Eight national level track and field decathletes performed six long jump attempts with a full approach run separated by ten minutes of recovery. In the experimental condition subjects performed three rebound vertical jumps with maximal effort three minutes before the last five attempts, while the first attempt served as baseline. In the control condition the participants performed six long jumps without executing the conditioning exercise. With baseline, long jump performance was progressively increased only in the experimental condition from 3.0% or 17.5 cm in the third attempt ($p=0.046$, $d=0.56$)

to 4.8% or 28.2 cm in the sixth attempt ($p=0.0001$, $d=0.84$). The improvement in long jump performance was due to a gradual increase in vertical take-off velocity from the third (by 8.7%, $p=0.0001$, $d=1.82$) to the sixth jump (by 17.7%, $p=0.0001$, $d=4.38$). Horizontal approach velocity, take-off duration and horizontal velocity at take-off were similar at all long jump attempts in both conditions ($p=0.80$, $p=0.36$ and $p=0.15$, respectively).Long jump performance was progressively improved during a simulated competition, when a plyometric conditioning exercise was executed 3 min before each attempt. This improvement was due to a progressive increase in vertical velocity of take-off, while there was no effect on the horizontal velocity(Gregory et al. 2016).The purpose of the study was to find out kinematic analysis of take off in long jump and what is the contribution of different kinematic variables in long jump performance. The kinematic variables revealed that significant relationship of Right knee angle, Vertical velocity y, right pelvis and Right Elbow angle with the performance in long jump also provides further insight into long jump performance, although not all variables associated with real jumping performance were studied.(Alexander's 1990).They found that jump performance was enhanced by a high approach speed, a high knee angle at touch-down and high (concentric and eccentric) muscle strength. Factors which did not have a great influence on jump distance were tendon compliance, muscle fibre contraction speed and some aspects of muscle architecture. Thus it appears that the important factors identified can also be clearly related to speed, technique and strength, and are closely related to those identified from the present regression analysis. Knee extensors, Peak knee flexion velocity but also in the hip abductors and extensors. This insight will be of value to coaches who should ensure that as an athlete develops, attention is paid to not just the development of speed but also to the development of technique and strength (Seyfarth et al. 2011).The angle of the take-off leg placement in the frontal plane is correlated with the frontal torso inclination during the take-off phase from the board. The rapid plantar flexion of the ankle joint towards the end of the take-off, contributes very little to upward velocity. Long jumpers spend a lot of time on exercises to strengthen the muscles of their take-off leg. Greater eccentric muscular leg strength gives the athlete a greater ability to resist flexion of the take-off leg, which enhances mechanical pivot mechanism during the take-off and hence, produces a greater take-off velocity (Nicholas P. Linthorn et al. 2011).

Long jumpers may build their keep running up speed through procedure preparing (where the competitor figures out how to utilize more fitting development designs while sprinting and amid the move onto the take-off board) or through physical preparing (where the competitor expands their solid quality, especially in the muscles of the hips and legs that are utilized as a part of sprinting). We fight that the connections between keep running up speed, bounce separation, and take-off strategy found in the present review are demonstrative of those that will come about because of an expansion in keep running up speed emerging from procedure preparing. Extrapolating the competitor's bends shows that for a 0.1 m/s increment in keep running up speed we expect the competitor's hop separation to increment by 6 cm, the flat braking motivation to increment by 1.2 N•s, the vertical drive to stay consistent, the take-off speed to increment by 0.06 m/s, and the take-off point to diminish by 0.2°. A constrain stage could be utilized to screen a competitor's take-off strengths amid preparing. Diagnosing a competitor's procedure is most likely least demanding when it is realized that specific strategy factors ought to be either expanded or limited (e.g., keep running up speed; fall-back separation). Lamentably, the era of ideal take-off strengths is a take off between the clashing yearnings of producing vertical drive and limiting the level braking motivation. To build the span of the foot contact the competitor plants their foot in front of the focal point of mass. Be that as it may, the subsequent increment in vertical propulsive drive is joined by an undesirable increment in flat braking motivation. this review analyzed the intense impacts of a molding plyometric practice on long bounce execution amid a reproduced long hop rivalry. Eight national level Olympic style sports decathletes performed six long hop endeavors with a full approach run isolated by ten minutes of recuperation. In the test condition subjects performed three bounce back vertical hops with maximal exertion three minutes before the last five endeavors, while the main endeavor filled in as benchmark. In the control condition the members performed six long bounced without executing the molding exercise. With gauge, long bounce execution was continuously expanded just in the exploratory condition from 3.0% or 17.5 cm in the third endeavor ($p=0.046$, $d=0.56$) to 4.8% or 28.2 cm in the 6th endeavor ($p=0.0001$, $d=0.84$). The change in long hop execution was because of a continuous increment in vertical take-off speed from the third (by 8.7%, $p=0.0001$, $d=1.82$) to the 6th hop (by 17.7%, $p=0.0001$, $d=4.38$). Even approach speed, take-off term and level speed at take-off were comparative at all long bounce endeavors in both conditions ($p=0.80$, $p=0.36$

and p=0.15, separately). Long bounce execution was logically enhanced amid a reproduced rivalry, when a plyometric molding activity was executed 3 min before each endeavor. This change was because of a dynamic increment in vertical speed of take-off, while there was no impact on the even speed. The reason for the review was to discover kinematic examination of take off in long bounce and what is the commitment of various kinematic factors in long hop execution. The kinematic factors uncovered that critical relationship of Right knee point, Vertical speed y, right pelvis and Right Elbow edge with the execution in long hop additionally gives assist knowledge into long bounce execution, in spite of the fact that not all factors related with genuine hopping execution were considered. They found that hop execution was improved by a high approach speed, a high knee point at touch-down and high (concentric and erratic) muscle quality. Elements which did not have an incredible influence on bounce separation were ligament consistence, muscle fibre compression speed and a few parts of muscle engineering. Along these lines it creates the impression that the essential components identified can likewise be unmistakably identified with speed, method and quality, and are firmly identified with those identified from the present relapse examination. Knee extensors, Peak knee flexion speed additionally in the hip abductors and extensors. This knowledge will be of an incentive to mentors who ought to guarantee that as a competitor creates, consideration is paid to the improvement of speed as well as to the advancement of system and quality The edge of the take-off leg position in the frontal plane is corresponded with the frontal middle slant amid the take-off stage from the load up. The fast plantar flexion of the lower leg joint towards the finish of the take-off, contributes almost no to upward speed. Long jumpers invest a great deal of energy in activities to reinforce the muscles of their take-off leg. More noteworthy whimsical solid leg quality gives the competitor a more noteworthy capacity to oppose flexion of the take-off leg, which improves mechanical turn component amid the take-off and consequently, produces a more prominent take-off speed The purpose of the study was to find out kinematic analysis of Long jump and what is the contribution of different kinematic variables in long jump performance. The kinematic variables revealed that significant relationship of Right knee angle, Vertical velocity y, right pelvis and Right Elbow angle with the performance in long jump also provides further insight into long jump performance, although not all variables associated with real jumping performance were studied the vertical speed is a mix of the speed conveyed in from the keep running, and also the stature picked up from the push off the ground. Nearby the speed of the jumper, we additionally realize that the point of take off assumes an expansive part in the last separation of the hop. The take off point is typically somewhere close to 43 and 45 degrees, yet it changes on the competitor on the grounds that not all competitors are a similar stature, weight, and in this manner apply diverse strengths at take off. While these factors work autonomously to guarantee a maximal hop, they additionally have awesome importance to each other.

It is a mix of these factors that will permit our jumper to expand his separation. Keeping in mind the end goal to comprehend this, we have to begin with the powers utilized by the competitor to push off the ground. At the point when the competitor moves into the snapshot of remove, his feet are applying weight on the ground, and on account of Newton's third law of movement, the Law of Action and Reaction, the ground pushes back on the competitor . This permits the competitor to utilize his body to make vertical speed from flat speed. By pushing off the ground and permitting the ground response compel to wind up plainly more prominent than that of the drive his foot is putting on the ground, the competitor can exchange some of his speed into the vertical bearing. Since the competitor has both types of speed, we should take a gander at how that will impact the separation he ventures. The vertical speed made by the push off decides the time that the competitor will spend noticeable all around, and in addition the most noteworthy stature he comes to. We can foresee and even figure these qualities because of the way that we know our competitor is experiencing consistently quickened movement, and accordingly gravity is influencing the jumper along the vertical pivot. When we have possessed the capacity to ascertain the time spent noticeable all around and the tallness of the competitor, we can then compute the separation the jumper will travel. Since even separation voyaged (the separation we need to expand) is a component of the level speed and the time the competitor spends noticeable all around, we can without much of a stretch anticipate how far the competitor will go. Basically, the powers delivered by the competitor comfortable start of take off will bring through and affect the general long jump performance.

Something else that we have to remember with the take off is the rakish force that is made as the jumper dispatches himself into the air. Since he should have the capacity to swing his feet underneath him. The jumpers snapshot of dormancy will be the separation from his feet to his focal point of mass, which will be his pivot. In the sagittal plane the competitor will swing his feet underneath him and forward with a specific end goal to get ready for landing and trying to ensure that his feet hit the sand as far out as would be prudent. While this will be taken a gander at additional inside and out in the flight area, it is essential to realize that rakish force is made at take off and is then preserved all through the rest of the bounce.

These factors will convey steady into the flight period of the hop, and will likewise be put into thought amid the arrival stage. A projectile (the jumper) is launched into the air at an angle, θ, to the ground with a velocity, V_0. Their motion through the air is described by a parabola that is symmetric about its highest point. Once the jumper reaches this highest point they have zero velocity in the y-direction. Gravity then accelerates their motion back to the ground where they land a distance, R, from their take off point. Due to the symmetry, the velocity with which they land has the same magnitude, but opposite direction, to their take off velocity.

Chapter III

PROCEDURE

In this chapter the selection of subjects, selection of variables, the criterion measures, collection of data, filming protocol, analysis of film and statistical technique employed for analysis are described.

Selection of Subjects

For the purpose of study 5 (Five) male Long Jumpers of all India Inter-varsity level from Lakshmibai National Institute of Physical Education, Gwalior and 17-25 years of age group were selected as subjects for the study. It was assumed that they possess good level of technique. The purpose of the research was explained to the subjects and also subjects were motivated to put their best effort during each attempt.

Selection of Variables

From researcher's own understanding of the problem and on the basis of discussion with experts, gleaned through the literature, the following kinematic variables (linear & angular) were selected:

Linear kinematic variables:

- Center of Mass at the time of Movement Take-off
- Vx- Horizontal velocity
- Vy-Vertical velocity

Angular kinematic variables:

- Ankle joint (right & left)
- Knee joint (right & left)
- Pelvis joint (right & left)
- Shoulder joint (right & left)
- Elbow joint (right & left)

Criterion Measure

- Six trials were given to each performer and all the performances were recorded by the qualified officials and distance was measured in meters .Measurements of Angle were taken to its nearest degree at selected joints during Take-off moment of Long Jump. Measurements of centre of mass were taken to its nearest centimeters/meters at selected point during take-off moment of Long Jump.
- Measurements of linear velocity were taken to its nearest m/s at selected point during take-off moment of Long Jump.
- Measurements of horizontal velocity were taken to its nearest m/s at selected point during take-off moment of Long Jump.

Instrument's Reliability

To obtain reliable measurements, standard and calibrated equipments like camera, steel tape, Nails, video graphs camera were used in this study. The study was filmed at 100 Frame per second with three max 100 with Max pro software Version 1.5.1.0 (3D Analyzer).There were no differences in within-session reliability for peak angular rotations between planes with all discrete variables combined (sagittal Interclass Correlation Coefficient ICC $\geq$ 0.933, frontal ICC $\geq$ 0.955, transverse ICC $\geq$ 0.934) Similarly, the between-session reliability of kinematic measures were not different between the three planes of motion but were lower than the within-session ICC. The Canon- 70D and Kinovea software Version -08.25, SPSS version -20 and G* power software 3.1.9.2 the study was filmed by a professional researcher and on the basis of the reliability ensured by the manufacturers various measurement values were obtained for the study and was considered reliable.[1]

3D Motion Analysis System (Max Pro Innovision Version 1.5.1.0)

MaxPro is a kind of Motion Analysis software by 3D motion capture using non proprietary cameras. MaxPro have the ability to interface with a wide range of cameras as not all cameras are equal but one can fit the right camera for his/her application. Everything from standard camcorders to high speed, high resolution

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[1]Kevin R. Ford, Gregory D. Myer, and Timothy E. Hewett "Reliability of Landing 3D Motion Analysis: Implications for Longitudinal Analyses KEVIN "Article in Medicine & Science in Sports & Exercise · November 2007DOI: 10.1249/mss.0b013e318149332d.

cameras. This software is able to give the capabilities of those “proprietary, hi-end expensive optical systems” in fraction of seconds.

Objectives

- Building Model
- Data Visualization
- Command Processing Pipeline
- Signal and Event Processing
- Analysis and Reporting

Procedure

- Subject standing calibration
- Validate movement data and associate the movement data with the model
- Perform any desired signal/events
- Define any Biomechanical Model Based Calculation for moments, power and other metric.
- Generate the desire kinematic and kinetic analysis report

Features

- Tracking(any high speed camera, 255 markers)
- Use up to 15 cameras.
- 3D tracking in one camera view
- Dynamic wand calibration
- Creates C3D and ASCII files
- Integration of analog

- ➢ Quick ID for fast marker identification
- ➢ Marker templates (name, size, color + stick figure defining)
- ➢ Delete or filter out short trajectories
- ➢ Interpolation
- ➢ Filters
- ➢ Video overlay
- ➢ Graphs
- ➢ Analysis/Calculations (tools) angles, velocity, acceleration

Applications

- ✓ Biomechanics (Gait Analysis, etc)
- ✓ Research(Sports, Rehabilitation)
- ✓ Performance
- ✓ Simulation
- ✓ Movement analysis

Kinovea Software (Version -08.25)

Kinovea is free software which was utilized to analyse videos. Kinovea is used by athletes and coaches to find tune techniques. It can measure distance, speed and height etc. on a particular video with the assistance of Kinovea. The integrated file explorer allows us to browse the video collection visually. Thesefiles, which are displayed as animated thumbnails and as a shortcut manager it lets you preserve bookmarks of frequently accessed directories for a quick lockup.The video controls permit you to closely observe a specific action within the video and examine the motion frame by frame in slow motion because Kinovea operates almost any file natively; you do not need to care too much about formats and codes. There are several amazing, interesting and diverse features of Kinovea, such as Analysis, Measurement, Comparison and Observation.

Observation is the feature of Kinovea which entails the close examination of motion on a video frame by frame in slow-motion. Comparison is comparing performances simultaneously in other words synchronizing the videos. Analysis is enriching the video with arrows and descriptions and other key positions. Wiki is an on-line database that could possible work as server software that allows users to freely create web page content using any web browser. It usually applies to group communication mechanisms in that it allows the organization of contributions to be edited in addition to the content itself.[2]

Why Kinovea is used for?

Kinovea was a free and open source solution for video analysis. It was mostly used by sports coaches and athletes to explore study or comment a performance. In addition to this primary focus, Kinovea was also used by artists, podiatrists and ergonomics engineers. The integrated file explorer lets us browse the video collection visually. Supported tile share displayed as animated thumbnails. A shortcut manager lets our gave bookmarks of frequently accessed directories for faster look up. The video controls let us focus on a specific action within the video and explore the motion frame by frame or in slow motion. Kinovea plays almost any file natively, so we don’t need to care too much about formats and codes. The drawing tools let you enrich the video by adding arrows, descriptions and other content to key positions. The line and chronometer tools let us measure distances and times. A semi-automated tracking tool let you follow motion path and measure speeds.

Kinovea is designed to view and to analyze the sequence of sports videos. Its functions are similar to those of a video player: to play back, to pause, to view in slow motion and to export images. It comes along with a feature called “two videos” to allow you to compare two sequences for the tutorials. Its handling does not require any particular skill and it is easy to use.

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[2]Retrieved from https://gteck.wikispaces.com/Introducation/on 10/03/2017.

G* power software 3.1.9.2

G*Power is a tool to compute statistical power analysis for many different *t* tests, *F* tests, $\chi 2$ tests, *z* tests and some exact tests. G*Power can also be used to compute effect sizes, sample size and to display graphically the results of power analysis.[3]

Administration of the Tests Collection of Data

The performance of the subjects in the long jump, filming protocol and analysis are described as under:

For the collection of data, 5 subjects were selected purposely among the Long Jumpers of Lakshmibai National Institute of Physical Education, Gwalior. Total observations and collection of the data was done in the evening session and observations were recorded each day in the evening session simultaneously.

Measurement of the Performance of the Subjects

The performance of each subject was measured by using the standard procedures of IAAF, the horizontal distance covered by the subject was considered as his performance or score and the horizontal distance was measured in meters. Six trials were given to each subject and the all attempts were considered.

Filming Protocol and Analysis

Five male Long jumpers of Inter-varsity level from Lakshmibai National Institute of Physical Education, Gwalior, were filmed at the moment of take off. Participants in the men's Long jump trials were filmed by Max pro software version 1.5.1.0 (3D Analyzer) and were assessed by using 3D photogrammetric techniques with three synchronized high-speed video cameras at 100 F/s and focal length 8mm. The cameras were placed perpendicular to the runway, about 5 m away in line with the take off board, so that sufficient number of frames would be available after TO so as to calculate the take off parameters. Judges were asked to place themselves in order to have clear view of all sequential movements and also they were not in the view field

[3] Retrieved from http://www.gpower.hhu.de/ on date: 25/02/17

of the camera to obstruct analysis. The film was analyzed by using a segment Biochemical model which is defined by 14 points using calibrated through the software. Data was first calculated by direct differentiation and basis of the whole body model can be defined by using equations given by **Lees et al. (1992).**

For analysis purposes, the camera used for capturing the sequential movements was Canon- 70D and at the time of moment take off in Long jump expected all various joints angles(Angular), Different Velocities i.e. horizontal Velocity, vertical velocity, linear velocities "*OY*" , and angular velocities "OX" were developed by using Max pro software (3D Analyzer). After taking the video, the photos were taken by Pausing the video at the desired moment with the help of Kinovea Software Version-08.25. For referencing purpose, the take off board to Long Jump distance was taken to find out the actual height of center of Mass of each subject at selected moment. The width of take-off board &plasticine indicator board was 30 cm, vertical height of the camera was 1.25 meter and horizontal distance of the camera was 5.00 meter from the take-off board. The subjects were filmed at Lakshmibai National Institute of Physical Education, Gwalior. The Vediography sequence was taken under controlled condition. The subjects performed the technique six times and G* power software 3.1.9.2 G*Power was a tool to compute statistical power analysis for many different *t* tests, *F* tests, $\chi 2$ tests, *z* tests and some exact tests. G*Power can also be used to compute effect sizes, sample size and to display graphically the results of power analysis.

MAX PRO SOFTWARE VERSION 1.5.1.0 (3D ANALYZER) SOFTWARE FEATURES

Recording Setup	
Frame Rate (Hz)	*100*
Exposure (0-100)	*10*
Gain (0-255)	*150*
Threshold (0-255)	*150*
Marker Settings	
Min Marker Size	*1*
Max Marker Size	*70*
Centroid	*Centre of Mass*
Reverse Video	*No*
Trigger Setting	
External	*off*
Pretigger	*0*
Camera Setup	
Number of Camera (Master)	*3*
Camera 1	
Camera 2	
Camera 3	
Tracking Setup	
Trajectories	
No of Marker	*14*
Auto Assign	*No*
Min Length	*1*
Preview	*Yes*
Tracking	
Predictor Error	*30.0*
Max Residual	*5.0*
Acceleration Factor	*Normal*
Max Autojoin Gap	*10*
Interpolation	
Max Gap	*50*

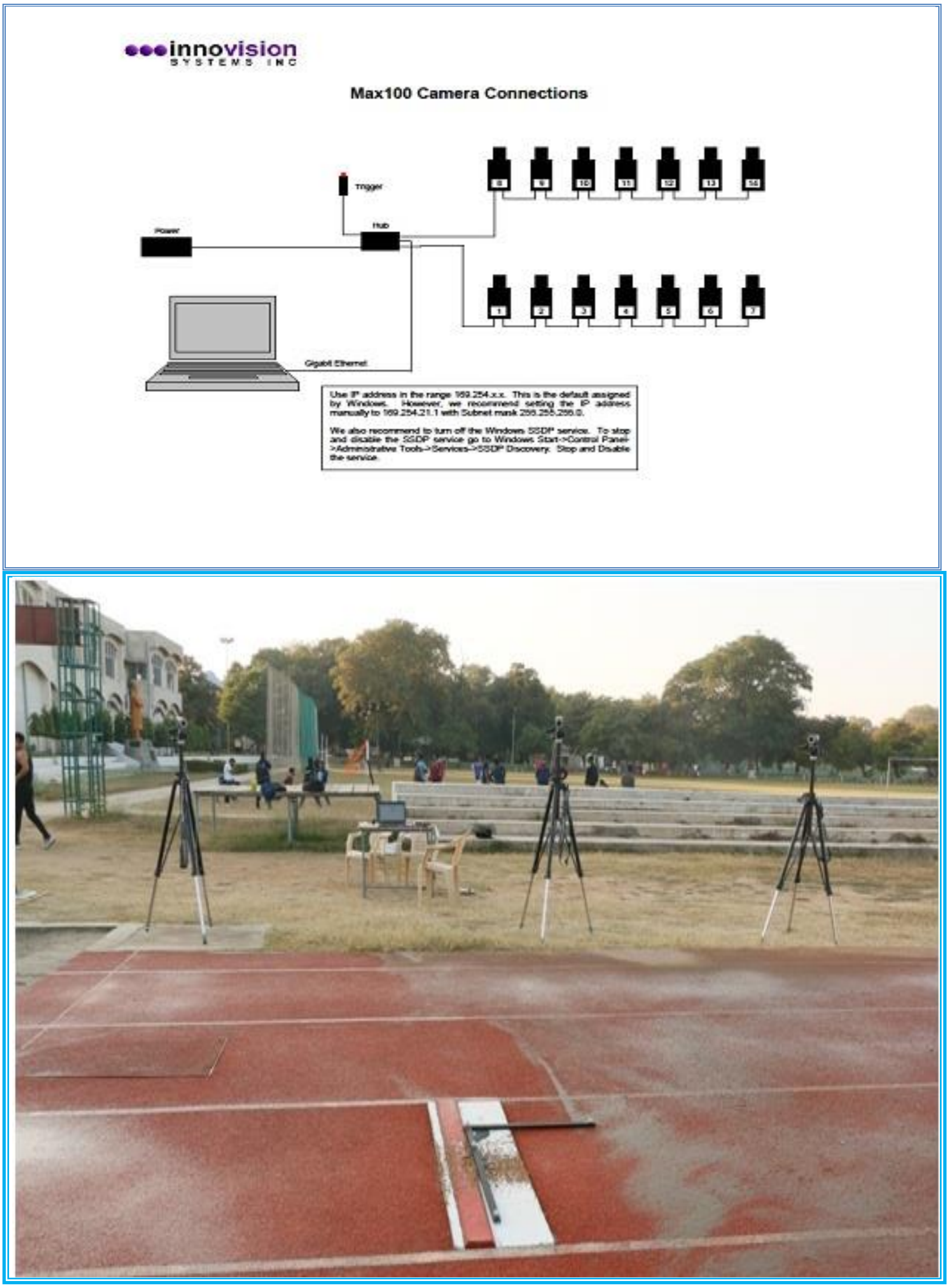


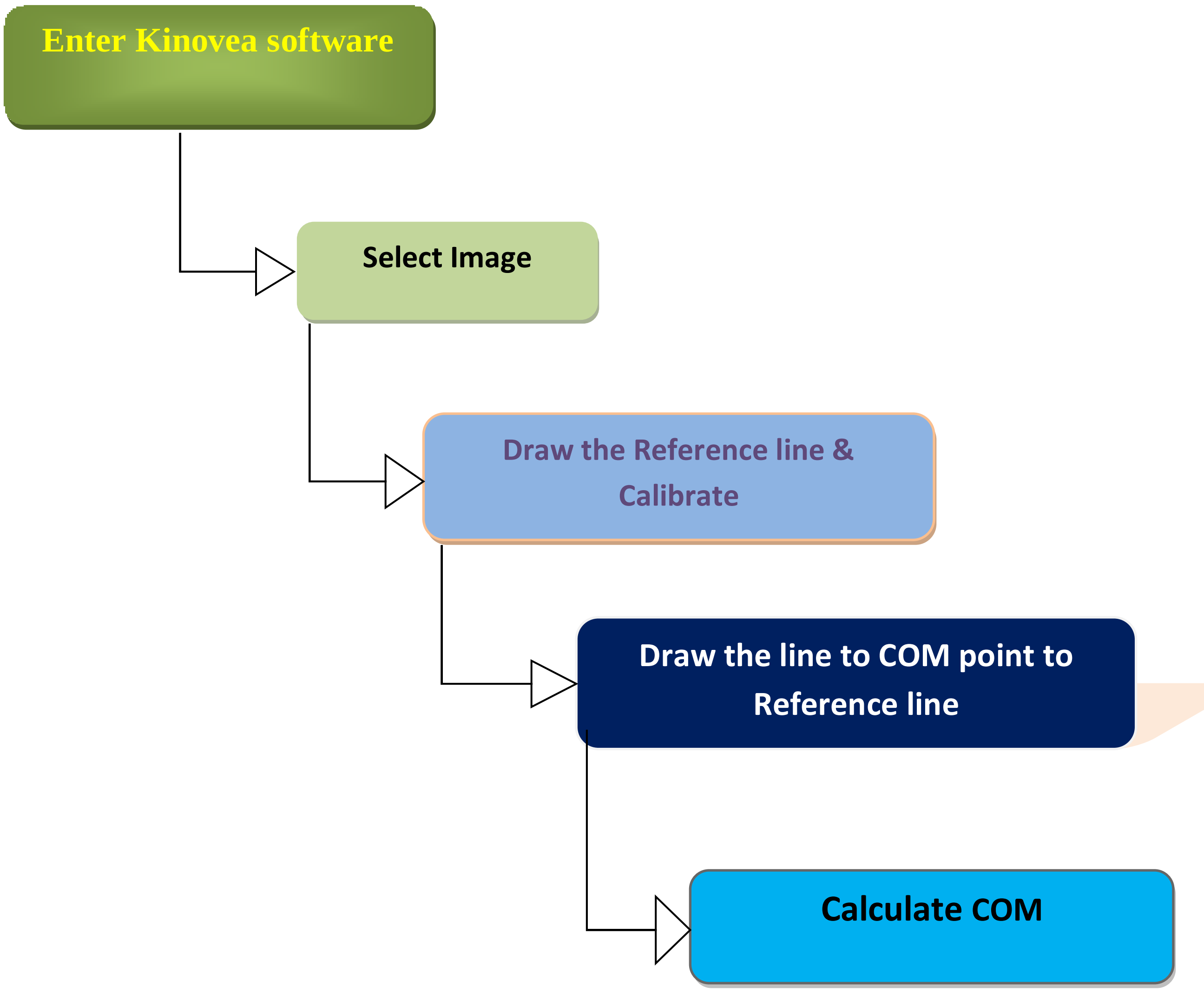
Fig. 4.3D Software Setup

Fig.5. Experimental set up at the time of Data collection

Fig.6. Position Markers on the body

Fig.7. Position Markers on the Leg

<u>Centre of Mass</u>: - the centre of mass was calculated with the help of Kinovea software version-08.25. For referencing purpose, the width of take off board and plasticine indicator board were taken so to find out the actual height of center of Mass of each subject at selected moment. The width of take off board & Plasticine indicator board was 30 cm. To measure the center of Mass at the selected moment, a line is drawn equal to the width of the take off board (30 cm), calibrated in accordance and then from the centre of point of the subject, a straight line perpendicular to the take off line (calibrated) line was drawn to give the distance of COM of the subject from the ground at the selected moment.



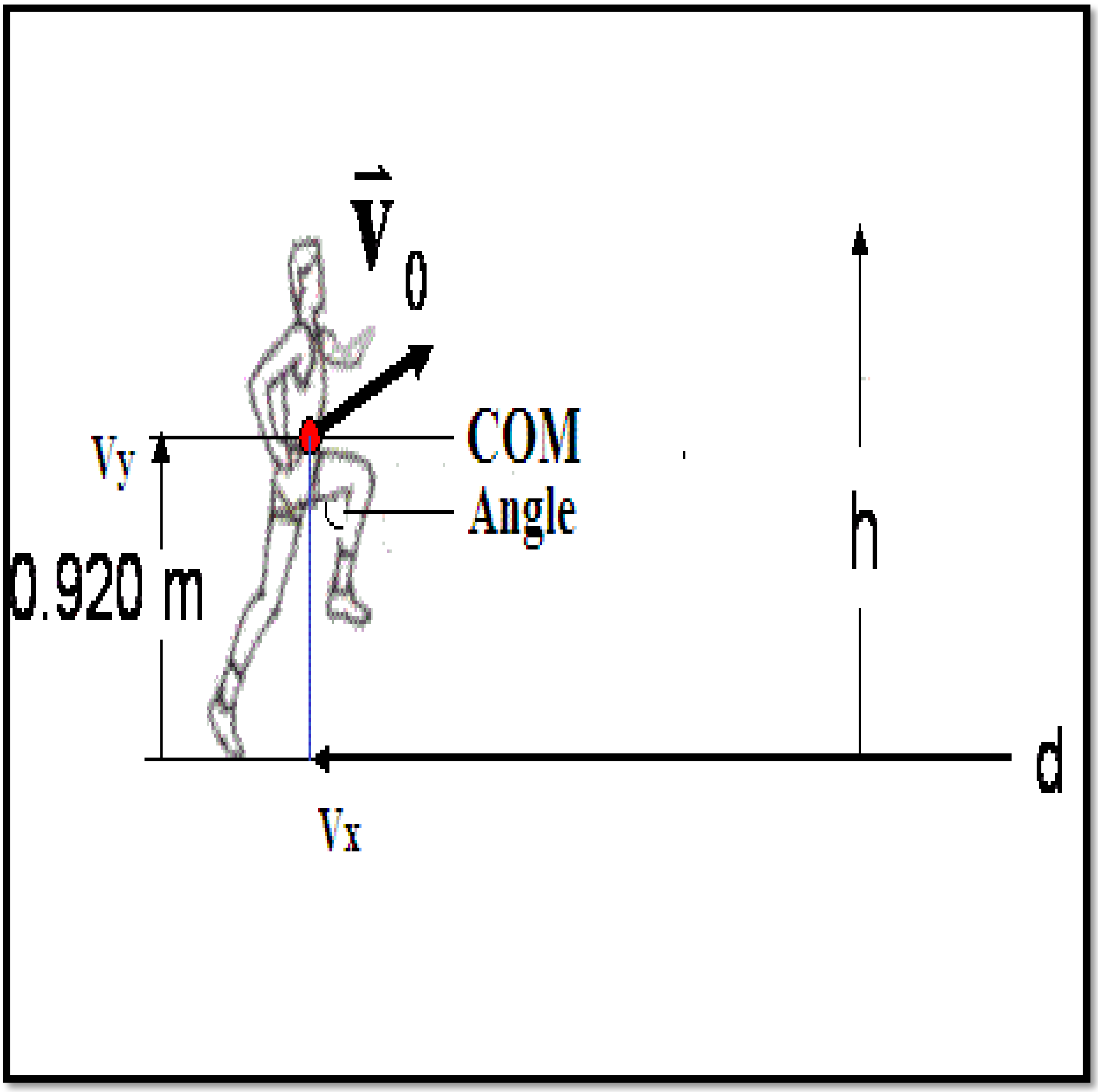


Fig.8. Stick Figure & Calculate COM at the time of Moment Take off in Long Jump

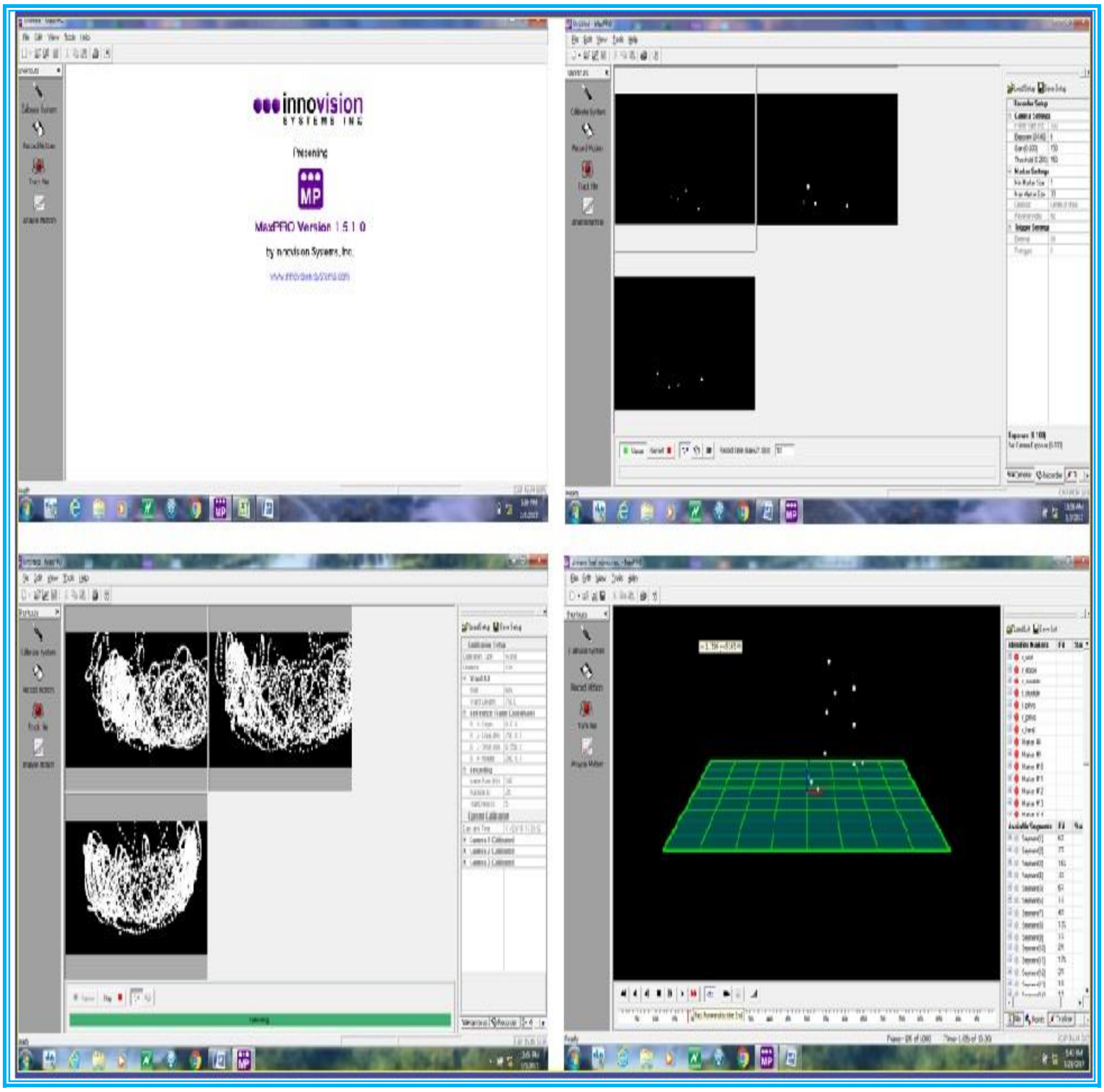
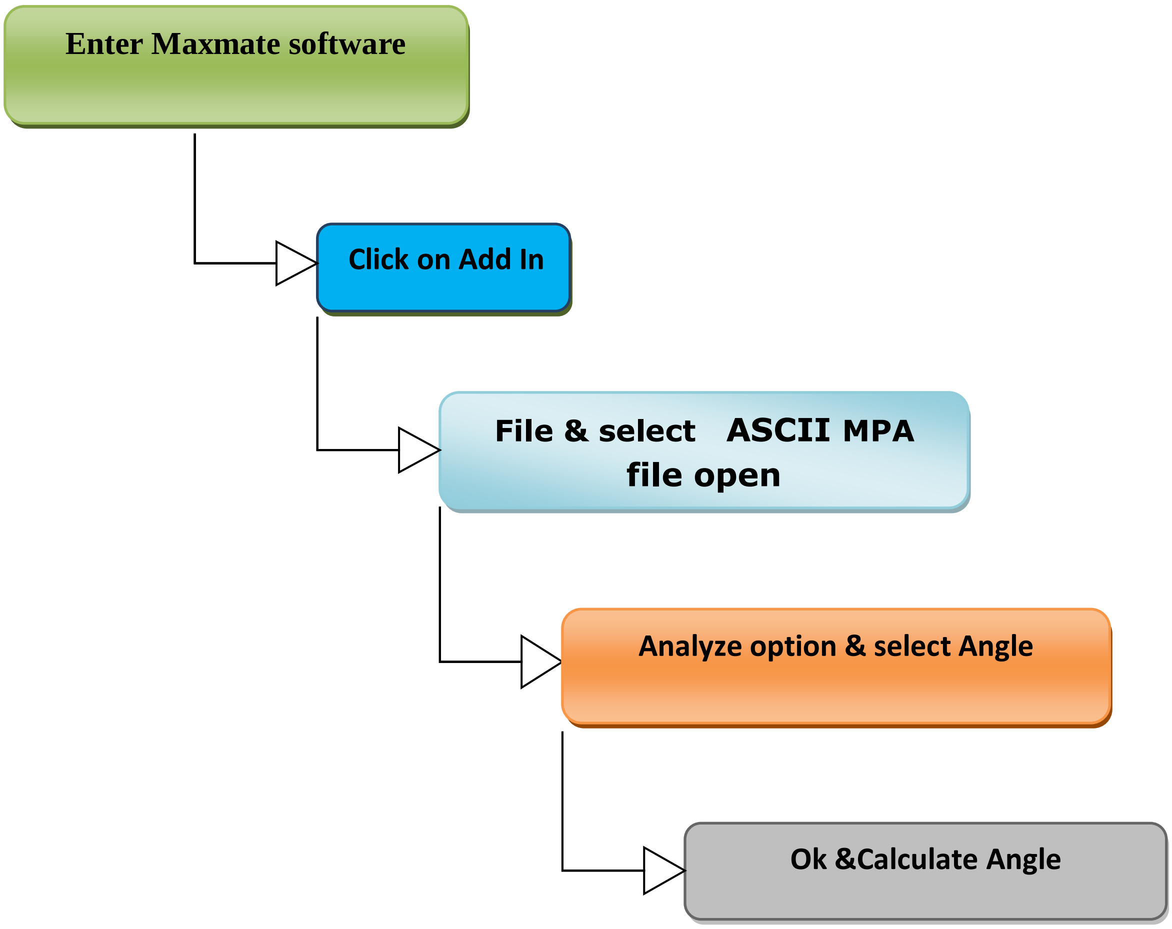


Fig.9. Calibration & Recording video with MaxPro software

Angle:- From the recorded Vediography, the scholar developed the stick figures of the selected moment in which data pertaining to various angular kinematic variables was taken. The stick figures were developed by using Max pro software (3D Analyzer).In this the particular angle which was considered to measure the body projection was selected, after that file was simply saved in ASCII MPA file and then Maxmate software was opened and file was selected and opened. After that in the analysis option and the Angle was selected for which you had to find out taken as a centre, value of starting time of movement came and finish time was entered and then OK option was clicked and the angle came whereas joint facing camera was considered to the measure various angles at various joints and the inclination of torso was measured by the deviation of the torso from vertical axis. The steps to calculate the angle are as follows:



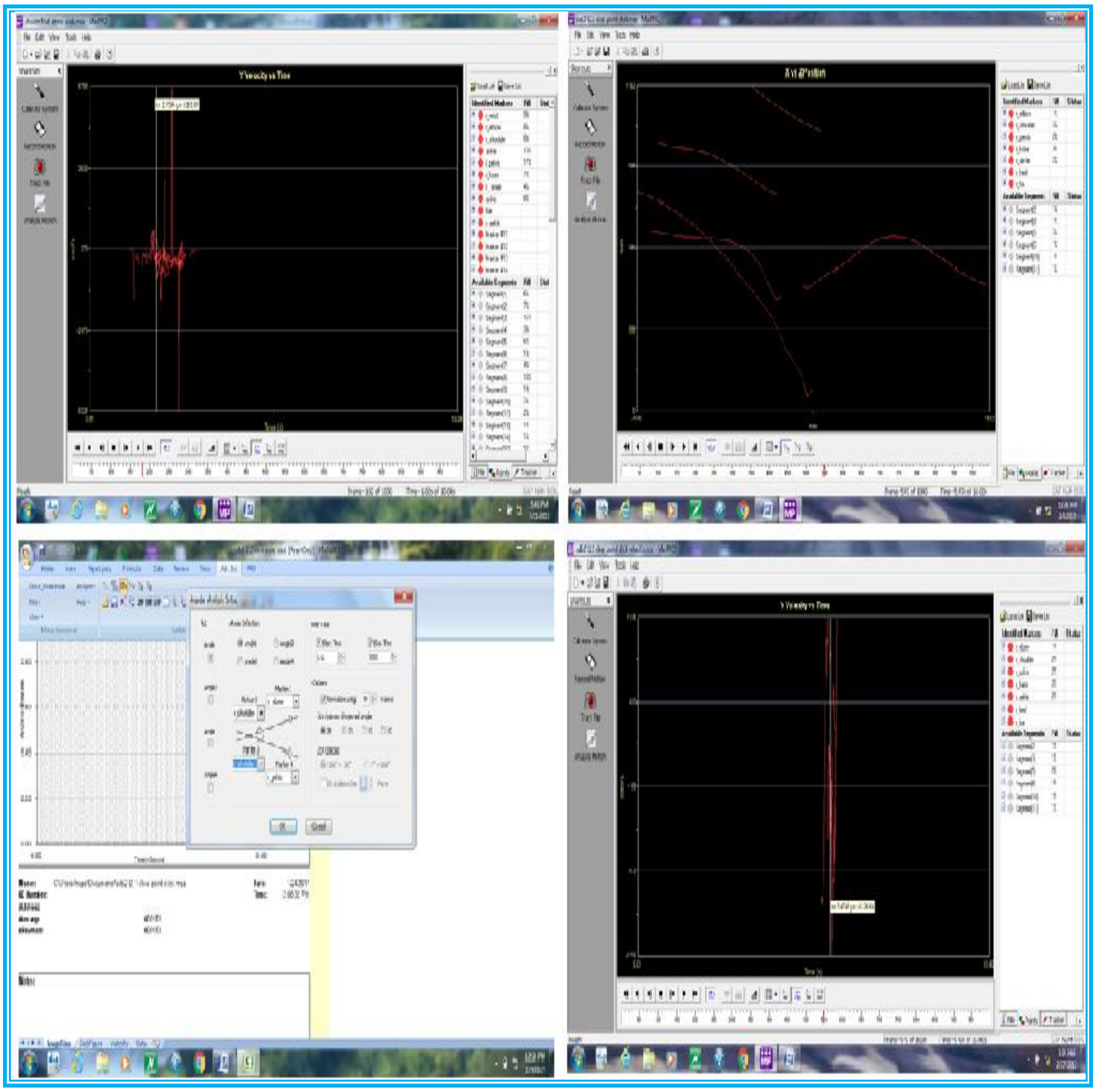


Fig.10.To find out Velocity & Angle at the moment of take off in Long Jump

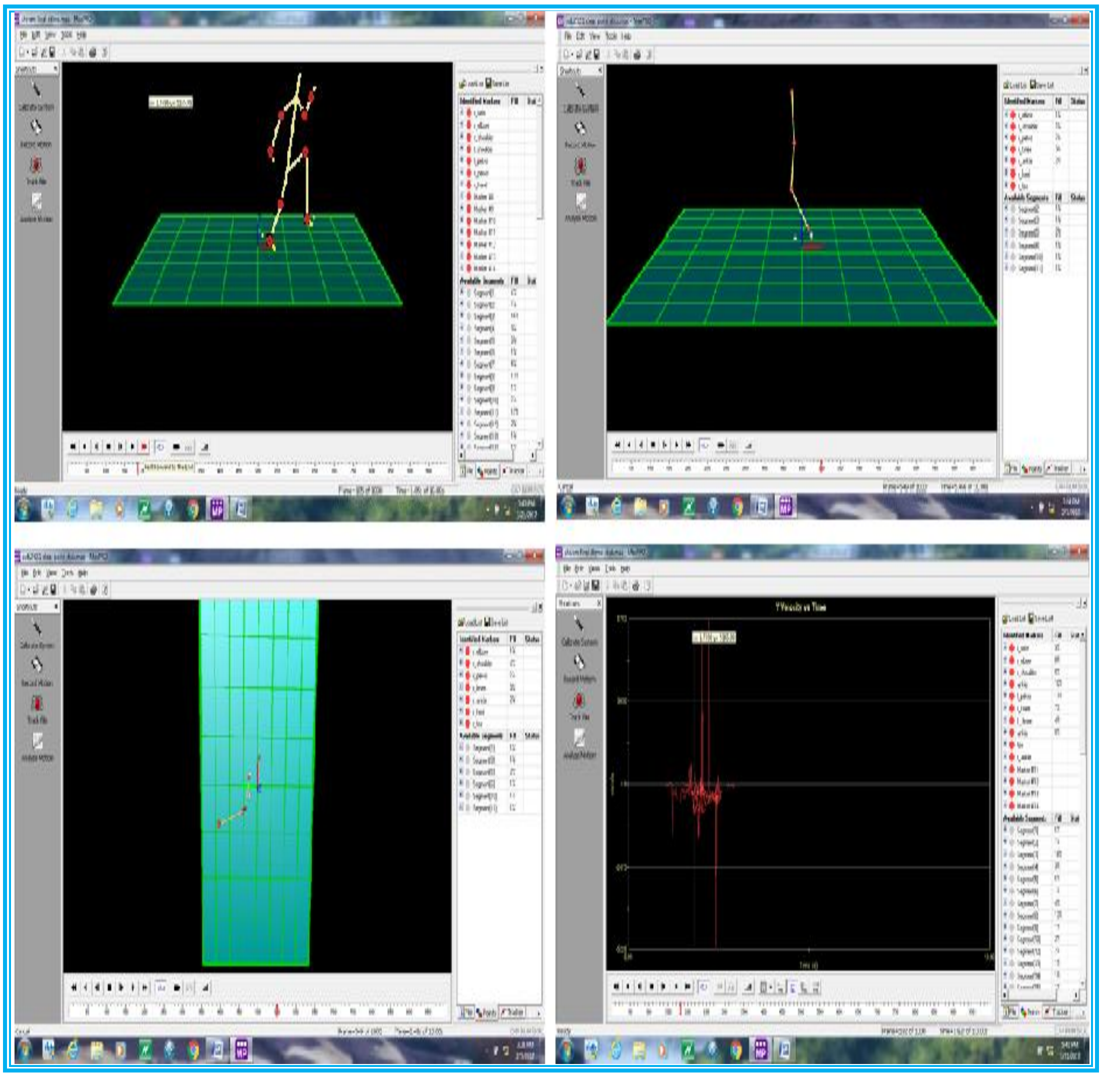
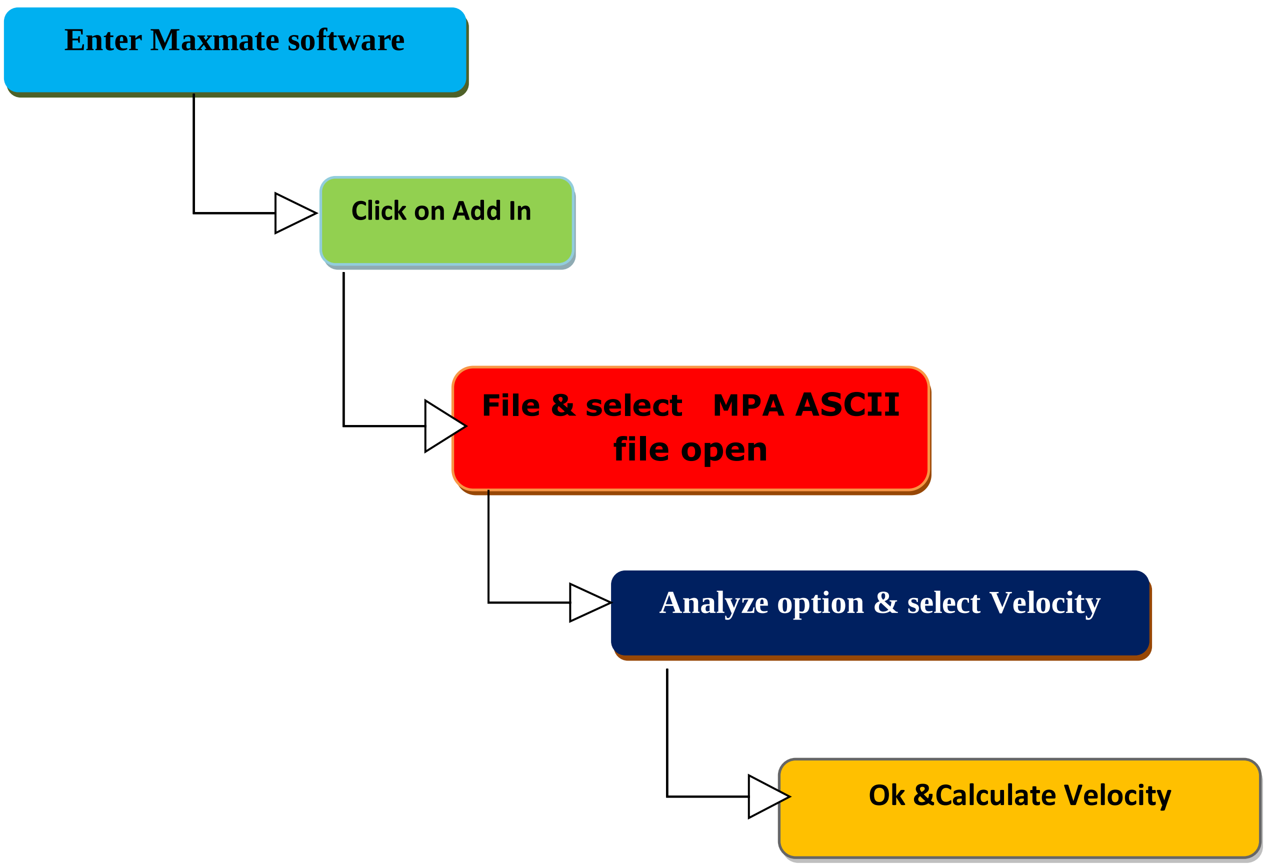


Fig.11.Developed Stick figure & three Dimensional Images at the time of moment of take off in Long Jump

Velocity: - the velocity of an object defines "the rate of change of position with respect to a frame of reference, and is a function of time". Velocity is equivalent to a specification of its speed and direction of motion. At the time of moment take off in Long jump Different Velocities i.e..horizontal Velocity, vertical velocity were around measures, whereas vertical velocities was represented by "*OY*" , and horizontal velocities by "OX" were developed by using Max pro software (3D Analyzer). To measure the velocity that file was simply saved in ASCII MPA file and then Maxmate software was opened and the file was selected and opened then after going to the analysis option and required type of velocity was selected and then value of starting time of movement came and finish time was put in time and OK option was clicked and Velocity came. The steps are as follows.[4]



[4]Retrieved from https://www.google.co.in/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=velocity&* on 25/02/2017

STATISTICAL TECHNIQUE

To find out the Relationship between selected kinematic variables of Long Jump Performance, Regression Analysis was used. For testing the hypothesis, the level of significance was set at 0.05.

Chapter - IV

ANALYSIS OF DATA AND RESULT OF THE STUDY

This chapter includes details of the findings and discussion therefore achieving the objectives of the research study. The main objective of the study was to investigate the kinematic analysis of take off in long jump. To achieve this objective the following research questions were investigated:

- What was the contribution of different kinematic variables in long jump performance?

The research questions were tested by using the Correlation Coefficient and Regression analysis.

Before investigating these research questions, the scholar had applied the descriptive analysis to know the nature of the data.

The whole analysis had been split into three sections. Section ‘A’ includes the descriptive analysis of the data of kinematic analysis of take off in long jump and Biomechanical variables during takeoff in long jump, Section ‘B’ including the analysis of the data using correlation coefficient and section ‘C’ include the analysis of the data using the Regression analysis.

Regression analysis was a statistical technique in which the value of dependent variable estimated on the basis of one or more variable. In this analysis, a regression equation developed between dependent and independent variables by means of least square method. This equation was used for estimating the value of dependent variables on the basis of R^2 which explain how much percentage of variance in the independence variable was explained by all the independent variables in the regression model.

Methods of Regression Analysis

While doing regression analysis, the independence variables were selected either on the basis of literature or some known information. In concluding the regression study, a large number of independent variables were selected, and, therefore, there was a need to identify only those independent variables which explain the maximum variation in the dependent variable. This could be done by following any of two methods, namely, “Stepwise regression “Enter” method in SPSS.

Stepwise Method

This method is used in exploratory regression analysis where the larger number of independent variables were investigated and the researcher does not have much idea about relationship of these variables with that of the dependent variable. In stepwise regression analysis, the independent variables were selected one by one depending upon the relative importance in the regression model. In other words, the first entered variable in the model had largest contribution in explaining variability in the dependence variables were including in the model if its regression coefficient was significant at 5% level. Thus, if the stepwise regression method was selected for regression analysis, the variables were selected one by one finally the regression coefficients of the retained variables were generated in the output. These regression coefficients were used to develop the required regression equation.

In using the linear regression method for developing regression model, the following assumptions were made:

1. Both dependent and independent variables were measured on either interval or ratio scale.
2. The linear relationship exists between dependent and independent variables.
3. The error in estimating the dependent variable was normally distributed.

In this section the results of the Regression analysis had been discussed to address research questions framed by the research scholar in this work. Regression analysis was used to investigate the kinematic analysis of take off in long jump.[1]

All independent variables were analyzed during the moment of take off in long jump.

[1] J.P. Verma “ statistical methods for sports and physical education “ Tata McGraw – Hill published by Tata McGraw Hill education private limited, 7 West Patel Nagar New Delhi 11008,2011 P. 75- 89.

There was one dependent variable in this analysis such as Linear& Angular kinematic analysis at the time of moment take off in Long Jump.

The scholar had chosen regression analysis to evaluate the parameters which were more important at the time of moment take-off in long jump.

Further, in using Regression analysis, one needs to check the assumption of normality appendix (A, C, D)

SECTION A: DESCRIPTIVE STATISTICS OF THE DATA

Descriptive analysis of the data was done by computing the statistics like mean and standard deviation:

TABLE - 1

MEAN AND STANDARD DEVIATION VALUE OF KINEMATIC ANALYSIS OF LONG JUMP

Descriptive Statistics			
	Mean	Std. Deviation	N
Performance	5.64	.124	30
Horizontal Velocity	6.83	1.33	30
Vertical Velocity	23.31	1.21	30
Centre of Mass	124.80	14.83	30
Right Angle	111.40	12.77	30
Right Ankle	130.93	16.72	30
Right Pelvis	117.53	15.26	30
Left Pelvis	179.43	4.818	30
Right Knee	76.66	4.611	30
Left knee	171.53	7.10	30
Right Shoulder	58.96	9.62	30
Left Shoulder	56.30	20.15	30
Right Elbow	114.70	45.09	30
Left Elbow	70.06	15.07	30

The values of mean and standard deviation for the all variables were shown in table-1. These values was be used for further analysis in the study.

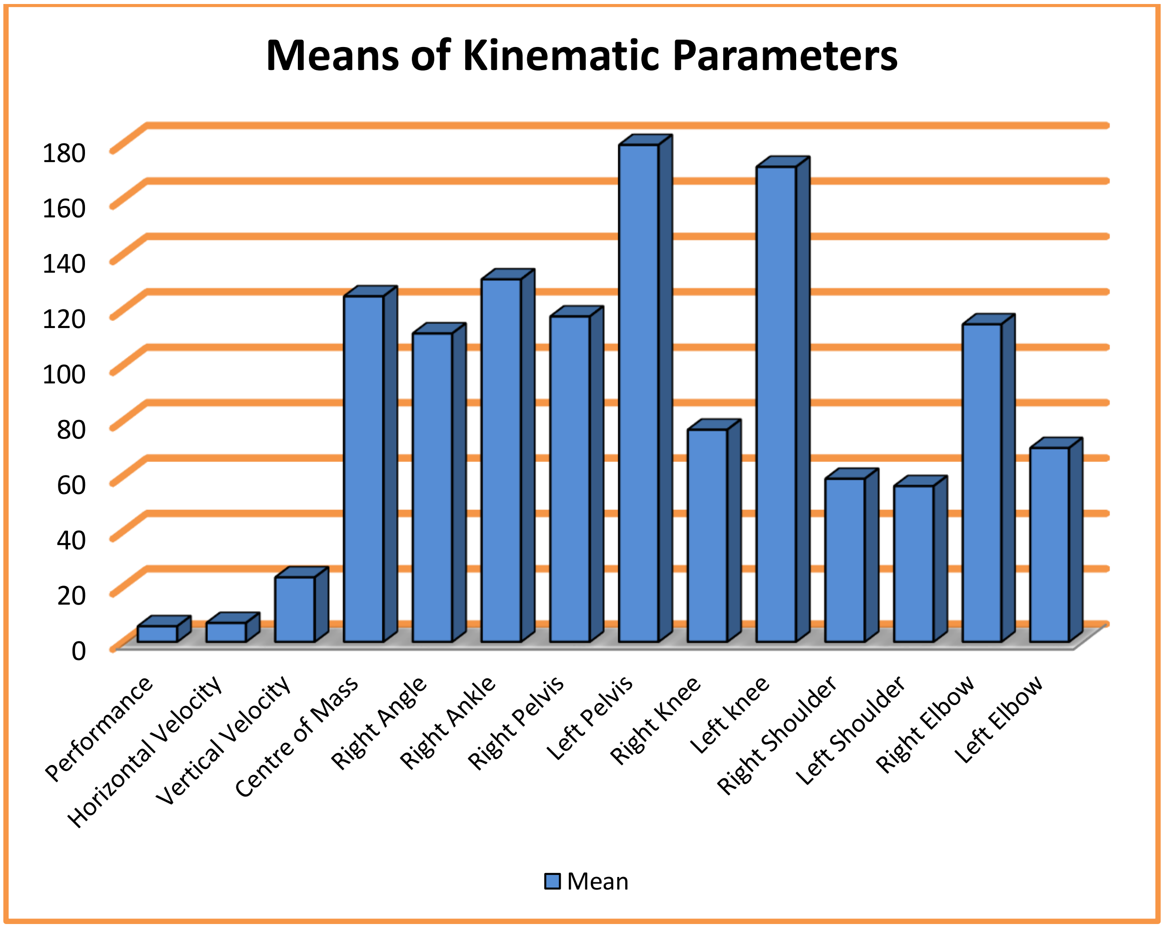


Fig. 12. Graphical Presentations Shows the Mean of the Kinematic Variables of Long Jump

SECTION B: CORRELATION

TABLE- 2

CORRELATION MATRIX FOR THE DATA ON DIFFERENT PRAMETER OF THE LONG JUMPER ALONG WITH SIGNIFICANCE LEVEL

Pearson Correlation		Performance	N
	Performance	1.000	30
	Horizontal Velocity	.114	30
	Vertical Velocity	.775*	30
	Centre of Gravity	-.231	30
	Right Angle	.206	30
	Right Ankle	.087	30
	Right Pelvis	.156	30
	Left pelvis	-.107	30
	Right Knee	.898*	30
	Left knee	-.081	30
	Right Shoulder	-.084	30
	Left Shoulder	-.172	30
	Right Elbow	.161	30
	Left Elbow	.020	30
Sig. (1-tailed)			
	Performance	.	30
	Horizontal Velocity	.275	30
	Vertical Velocity	.000	30
	Centre of Gravity	.110	30
	Right Angle	.138	30
	Right Ankle	.324	30
	Right Hip	.205	30
	Left Hip	.287	30
	Right Knee	.000	30
	Left knee	.336	30
	Right Shoulder	.330	30
	Left Shoulder	.182	30
	Right Elbow	.198	30
	Left Elbow	.459**	30

** Correlation is significance at 0.01(1- tailed).
* Correlation is significance at 0.05 (2- tailed).

This table shows the correlation coefficients along with their p- values and sample size. The correlation coefficient with Vertical Velocity and Right Knee (*) asterisk mark is significant at 5% level whereas with Left Elbow (**) asterisk mark significant at 1% level. In above table, correlation matrix including significance level at 0.05 had been shown.

Significance had been also tested for two–tailed test and for one tail test, significance value for the correlation coefficient at 0.01 level with 28(=N-2), df was 0.423 and level of significance set at 0.05 and 0.361. Thus all those correlation coefficients having values more than 0.423 and 0.361 were significant at 5% level.

SECTION C: REGRESSION ANALYSIS

TABLE – 3

MODEL SUMMARY ALONG WITH THE VALUES OF R AND R^2

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.898[a]	.806	.799	.05593	.806	116.343	1	28	.000
2	.920[b]	.846	.834	.05079	.040	6.951	1	27	.014
3	.937[c]	.878	.864	.04596	.033	6.971	1	26	.014

a. Predictors: (Constant), Right Knee

b. Predictors: (Constant), Right Knee, Vertical Velocity

c. Predictors: (Constant), Right Knee, Vertical Velocity, Right Pelvis

The three regression Models generated by the SPSS had been presented in Table 3 in the model, the values of R^2 was .878, which was maximum and, therefore, the model was used to develop the regression equation. It could be seen from the table 3 that model, three independent variables, namely, Right knee angle, Vertical Velocity and Right Pelvis had identified and, therefore, Regression equation shall be developed using these three variables only. The R^2 value for this model is 0.878, and, therefore, these three independence variables explain 87.8% variation in Right Pelvis angle for take-off of long jump performance. Thus, this Model could be considered appropriate to develop the regression equation.

TABLE -4

ANOVA TABLE SHOWING F- VALUES FOR ALL THE MODELS

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.364	1	.364	116.343	.000[b]
	Residual	.088	28	.003		
	Total	.451	29			
2	Regression	.382	2	.191	74.010	.000[c]
	Residual	.070	27	.003		
	Total	.451	29			
3	Regression	.397	3	.132	62.575	.000[d]
	Residual	.055	26	.002		
	Total	.451	29			

a. Dependent Variable: Performance

b. Predictors: (Constant), Right Knee

c. Predictors: (Constant), Right Knee, Vertical Velocity

d. Predictors: (Constant), Right Knee, Vertical Velocity, Right Pelvis

In table 4, F-value for the entire Model had been shown. Since F- value for the third model was highly significant, it might be concluded that the model selected was highly efficient also. Thus, it might be concluded that the above regression equation was reliable as the value of R^2 is 0.878. In other words, the three variable selected in this regression equation explain 87.8% of the total variability in Right Pelvis (all the three intendance variables) which was good. Since the F- value for this regression model was highly significant, the model reliable. At the same time, all the regression coefficient in this model were highly significant, and, therefore, it might be interpreted that all the three variables selected in the model, namely Right knee angle, Vertical Velocity and Right Pelvis had significant predictability in estimating value of Long Jump Performance.

TABLE -5

REGRESSION COEFFICIENT OF SELECTED VARIABLES IN DIFFERENT MODEL ALONG WITH t- VALUE AND PARTIAL CORRELATION

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	3.787	.173		21.892	.000			
	Right Knee	.024	.002	.898	10.786	.000	.898	.898	.898
2	(Constant)	3.527	.185		19.025	.000			
	Right Knee	.019	.003	.699	6.557	.000	.898	.784	.496
	Vertical Velocity	.029	.011	.281	2.636	.014	.775	.452	.199
3	(Constant)	3.336	.183		18.262	.000			
	Right Knee	.019	.003	.694	7.191	.000	.898	.816	.492
	Vertical Velocity	.030	.010	.293	3.032	.005	.775	.511	.207
	Right Pelvis	.001	.001	.181	2.640	.014	.156	.460	.181

a. Dependent Variable: Performance

The table 5 shows the unstandardized and standardized coefficient in all Models. unstandardized coefficient were also known as "B" coefficients and were used to develop the regression equation whereas standardized regression were denoted by "β" and were used to explain the relative importance of independence variables in terms of their contribution towards the dependence variable in the model. In third model, t- value for all three regression coefficient were significant as their significance values (p-values) were less than 0.05. Thus, it might concluded that the variables Right Knee angle Vertical Velocity and Right Pelvis significantly explain the variation in Long Jump performance.

Regression Equation: -Using regression coefficient (B) of the all three model shown in table 5 the regression equation could be developed which was as follow:

Performance of Long Jump = 3.336 +.019X (Right knee angle) + .030 X (Vertical Velocity) + .001 X (Right Pelvis Angle)

To conclude, it might be interpreted that the above regression equation was reliable as the value of R^2 was **.87.7.** In other words, the one variable selected in this regression equation explains **87.7%** of the total variability in the Right pelvis which was good. Since F- value for this regression model was highly significant & reliable. At the same time regression coefficient in this model was highly significant and therefore it might be interpreted that the one variable selected in the model viz.: performance of long jump quite valid in estimating the Right Knee Angle, Vertical velocity and Right pelvis of the Long jumper.

Discussion of Findings

The aims of this study were to conduct a three-dimensional analysis of take-off phase in the long jump and to explore the inter relationships between key variables.5 (Five) male long jumpers were filmed using three-dimensional methods various key variables for the long jump were used in a series of correlation and regression analysis. The relationships between key variables when correlated directly one-to-one were generally poor. However, when analyzed using a multiple regression approach, a series of variables was identified which supported the general principles outlined in the one model. These variables could be interpreted in terms of speed, technique and strength. We concluded that in the long jump, variables that were important to performance were interdependent and could only be identified by using appropriate statistical techniques. This has implications for a better understanding of the long jump event and it was likely that this finding could be generalized to other technical sports skills.

The kinematic variables revealed that significant relationship of Right knee angle, Vertical velocity y, right pelvis and Right Elbow angle with the performance in long jump also provides further insight into long jump performance, although not all variables associated with real jumping performance were studied the vertical speed was a maximum of the speed conveyed in from the keep running, and also the stature picked up from the push off the ground. Nearby the speed of the jumper, we additionally realize that the point of take off assumes an expansive part in the last separation of the hop. The take off point is typically somewhere close to 43 and 45 degrees, yet it changes on the competitor on the grounds that not all competitors are a similar stature, weight, and in this manner apply diverse strengths at take off. While these factors work autonomously to guarantee a maximal hop, they additionally had awesome importance to each other.

It is a mix of these factors that will permit our jumper to expand his separation. Keeping in mind the end goal to comprehend this, we had to begin with the powers utilized by the competitor to push off the ground. At the point when the competitor moves into the take off, his feet are applying weight on the ground, and on account of Newton's third law of movement, the Law of Action and Reaction, the ground pushes back on the competitor. This permits the competitor to utilize his body to make vertical speed from flat speed. by pushing off the ground and permitting the ground response compel to wind up plainly more prominent than that of the drive his foot was putting on the ground, the competitor can exchange some of his speed into the vertical bearing. Since the competitor had both types of speed, we should take a gander at how that would impact the separation he ventures. The vertical speed made by the push off decides the time that the competitor would spend noticeable all around, and in addition the most noteworthy stature he comes to. We could fore see and even figure these qualities because of the way that we know our competitor is experiencing consistently quickened movement, and accordingly gravity was influencing the jumper along the vertical pivot. When we had possessed the capacity to ascertain the time spent noticeable all around and the tallness of the competitor, we could then compute the separation the jumper would travel. Since even separation (the separation we need to expand) was a component of the level speed and the time the competitor spends noticeable all around, we could without much of a stretch anticipate how far the competitor would gone. Basically, the powers delivered by the competitor comfortable start of take off would bring through and affect the general separation and orientation of the force generated by the leg, i.e. the ground reaction force, was always identical to the leg angle.

Something else that we had to remember with the take off was the muscles force that was made as the jumper dispatches himself into the air. Since he should have the capacity to swing his feet underneath him. The jumpers take off would be the separation from his feet to his focal point of mass, which would be his pivot. In the sagittal plane the competitor would swing his feet underneath him and forward with a specific end goal to get ready for landing and trying to ensure that his feet hit the sand as far out as would be prudent. While this would be taken a gander at additional inside and out in the flight area, it was essential to realize that knee extensor muscles force was assumed to be fully activated and had a constant moment arm at the knee joint.

These factors would convey steady into the flight period of the hop, and was likewise be put into thought aimed the arrival stage. A projectile (the jumper) was launched into the air at an angle, θ, to the ground with a velocity, V_0. Their motion through the air was described by a parabola that was symmetric about its highest point. Once the jumper reaches this highest point they had zero velocity in the y-direction. Gravity then accelerates their motion back to the ground where they land a distance, R, from their take off point. Due to the symmetry, the velocity with which they land had the same magnitude, but opposite direction, to their take off velocity and at the time of moment take off leg behind the because of it's create vertical momentum and take off angle between 19 -21^0.

On the other hand other variable revealed the insignificant value obtained for all variables might be attributed to the improper technique of the subjects. Since the subjects chosen were of age ranged 17-25 college level, they were yet to require mastery of the skill in long jump.

Some other causes of insignificant result of selected kinematic variables at moment of take off in long jump might be due to the different patterns adopted by the athlete during training of long jump technique, further Arm moment was not purely in saggital plane due to which, measured arm Centre of Mass through the particular moment of Long jump performance was highly affected by force and take-off angle and these variables were out of the delimitation of the study. Majority of the biomechanical variables follow a non-linear relationship with performance which could have affected the findings. It might be due to the low level of performance of athlete, low sample size and use of different quality techniques by the athlete during the test.

The purpose of the study was to find out kinematic analysis of take off in long jump and what was the contribution of different kinematic variables in long jump performance. The kinematic variables revealed that significant relationship of Right knee angle, Vertical velocity (y), right pelvis and Right Elbow angle with the performance in long jump also provides further insight into long jump performance, although not all variables associated with real jumping performance were studied. (**Alexander's 1990)**.

They found that jump performance was enhanced by a high approach speed, a high knee angle at touch-down and high (concentric and eccentric) muscle strength. Factors which did not have a great influence on jump distance were tendon compliance, muscle fibre contraction speed and some aspects of muscle architecture. Thus it appears that the important factors identified could also be clearly related to speed, technique and strength, and were closely related to those identified from the present regression analysis. Knee extensors, Peak knee flexion velocity but also in the hip abductors and extensors. This insight would be of value to coaches who should ensure that as an athlete develops, attention was paid to not just the development of speed but also to the development of technique and strength **(Seyfarth 2011).**

The angle of the take-off leg placement in the frontal plane was correlated with the frontal torso inclination during the take-off phase from the board. The rapid plantar flexion of the ankle joint towards the end of the take-off, contributes very little to upward velocity. Long jumpers spend a lot of time on exercises to strengthen the muscles of their take-off leg. Greater eccentric muscular leg strength gives the athlete a greater ability to resist flexion of the take-off leg, which enhances mechanical pivot mechanism during the take-off and hence, produces a greater take-off velocity **Nicholas P. Linthorn (2011).**

Similar study conducted on series of jumps by an experienced female athlete was recorded with a force platform and a high-speed video camera. We obtained a wide range of run-up velocities by using direct intervention to set the length of the athlete’s run-up. In all jumps the horizontal take-off force was predominantly a backwards braking force and so the athlete’s horizontal velocity was substantially reduced during the take-off. The athlete’s breaking impulse increased with increasing run-up velocity, but not so much as to neglected the increase in run-up velocity. The optimum long jump take-off technique was a compromise between the conflicting desires of generating vertical impulse and minimizing the horizontal braking impulse. We currently had no firm recommendation as to the usefulness of a force Platform in improving an Athlete’s take-off technique. braking impulse. **(Nicholas P. Linthorneet al. 2011)**

Conclusion: the present study has increased our knowledge of the relationships between run-up velocity, Angles of different joint, Centre of Mass, take-off technique, and jump distance.

However, we were not able to provide scientifically rigorous advice to the individual athlete on how to optimize their take-off impulses and take-off technique so as to maximize their jump distance.

Determination of Sample Size and power Analysis with G* power software

A Researcher Interested in the developing the multiple regression model for estimating performance of long jump on the basis of three predictors namely: Right Knee, Vertical Velocity and Right Pelvis how much sample size should be taken to have at least 80% power to test whether these three predictors significantly predict the outcome variables.

TABLE – 6

Values of R^2 in different situations

Association between other covariates and main predictor	R	R^2
Low	0.2	0.04
Medium	0.5	0.25
High	0.9	0.81

Exact test: Multiple Regression – random Model

In multiple regression analyses, the relation of a dependent variable Y to m independent factors X = (X1, Xm) was studied. The present procedure refers to the so-called unconditional or random factors model of multiple regression (Gatsonis & Sampson, 1989; Sampson, 1974), that was, it was assumed that Y and X1, . . . , X were random variables, where(Y, X1, . . . , Xm) had a joint multivariate normal distribution with a positive definite covariance matrix: the regression coefficient vector *g*, the analog of *b* in the fixed model, by *g* = S- 1 X SYX. The maximum likelihood estimates of the regression coefficient vector and the residuals were the same under both the fixed and the random model (see theorem in Sampson (1974)); the models differ, however, with respect to power. The present procedure allows power analyses for the test that the population squared correlations coefficient µ2YX has

The value µ2 0 the null and alternate hypotheses are:

$$H0: \mu 1 = \mu 2$$

$$H1: \mu 1 \neq \mu 2$$

Power and sample size

We replicate an example given for the procedure for the fixed model, but now under the Assumption that the predictors were not fixed but random samples: We assume that a dependent variable Y was predicted by asset B of 3 predictors and that $r2$ Y X was 0.25, was that the 3 predictors account for 87.8% of the variance of Y. The sample size is N = 30 subjects. What was the power of the F test that $r2$Y X = 0 at a = 0.05? We choose the following settings in **G* Power** to calculate the power:

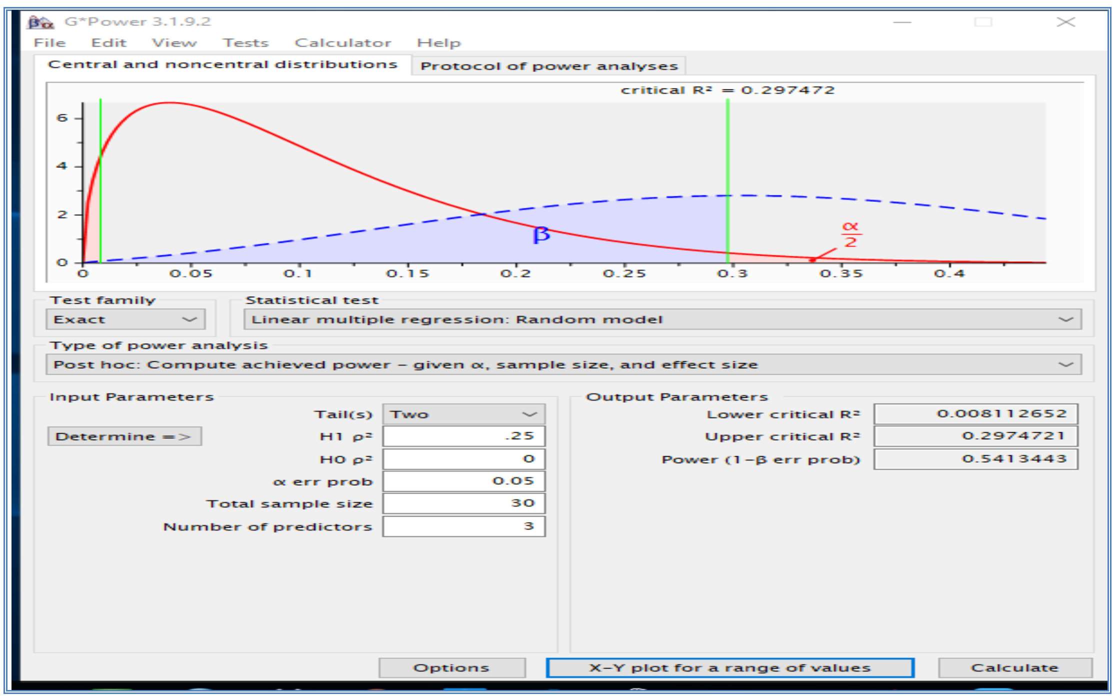


Fig. 13. Compute Achieved power- given α, sample size and effect size

• **Select**

Type of power analysis: Post hoc

• **Input**

Tail(s): Two

H1 $p2$: 0.25

H0 $p2$: 0.0

a err prob: 0.05

Total sample size: 30

Number of predictors: 3

Output

Lower critical R^2: 0.008112652

Upper critical R^2: 0.2974721

Power ($1 - \beta$ *err prob*): 0.5413443

The output shows that the power of this test was about 0.541 which was less than the power 0.80 found in the fixed model. This observation holds in general: The power in the random model was never larger than that found for the same scenario in the fixed model. In linear regression analysis model with 3 predictors there are 54.13% chance correctly rejecting the null hypothesis that the multiple correlation R^2 values equal to zero with 30 sample size.[2]

[2] J.P. verma and priyam verma "Sample Size Determination and power Analysis with G* power software ISBN : 978-93-5279-158-3 Lakhmibai National Institute Of Physical Education Gwalior www. Jp.org 2007 July P. 87-91.

Discussion of Hypothesis

It was hypothesized that selected kinematic variables were in significant relationship with performance, however in the present findings the researcher has failed to reject the hypothesis at 0.05 level as for all the relationship of Right knee angle, Vertical Velocity, Left elbow and Right pelvis p-value was less than 0.05. The null hypothesis was rejected and some other kinematic variables were in insignificant relationship with performance, however in the pretext of present findings the researcher have failed to accept the hypothesis at 0.05 level as for all the relationship Horizontal Velocity ankle joint (right& left) angle at Pelvis joint (left), angle at knee joint (left) and angle at shoulder joint (right, left), angle at elbow joint (right) and height of center of mass p-value was greater than 0.05. The null hypothesis was not rejected.

Chapter - V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The Detailed Summary of the dissertation on the topic "A three Dimensional kinematic of analysis of Long Jump" is given below:

Summary

There were several research studies, which exit having completed the kinematic analysis of Long Lump. Five long jumpers were selected who studied in Lakshmibai National Institute of Physical Education, Gwalior. The subjects were having their age ranging from 17-25 years. To obtain reliable measurement, standard and calibrated equipments like camera steel tape were used, and the study was conducted under controlled conditions. The subjects were filmed in three planes. The camera used for analysis was Canon- 70D. After taking the video, the photos were taken by pausing or stopping the video at the desired moment with the help of Kinovea software Version - 08.25. And video graphs camera used in study were filmed at 100 F/s with three max 100 with Max pro software Version 1.5.1.0 (3D Analyzer). The study was filmed by a professional researcher and on the basis of the reliability ensured by the manufacturers various measurement values were obtained for the study and was considered reliable. Participants in the men's Long jump trials were filmed by using 3D photogrammetric techniques with two synchronized high-speed video cameras at 100 F/s and focal length 8mm. The cameras were placed perpendicular to the runway, about 5 meter away in line with the take off board, to obtain sufficient number of frames after TO so as to calculate the take off parameters. Judges were asked to place themselves in order to have clear view of all sequential movements and also that they were not in the view field of the camera to obstruct analysis. The film was analyzed by using a segment Biochemical model which is defined by 14 (Marker) points using calibrating through Software. For analysis purposes, the camera used for capturing the sequential movements was Canon-70D and at the time of moment take off in Long jump expected all various joints angles(Angular), Different Velocities i.e. horizontal Velocity, vertical velocity, linear velocities "*OY",* and angular velocities "OX" were obtained by using Max pro software (3D Analyzer). After taking the video, the photos were taken by Pausing the video at the desired moment with the help of Kinovea Software Version-08.25. For referencing purpose, the take off board to long jump distance was taken to find out the actual height of center of Mass of each subject at selected moment. The width of takeoff board &plasticine indicator board was 30 cm, vertical height of the camera was 1.25 meter and horizontal distance of the camera was 5.00 meter. The subjects were filmed at Lakshmibai National Institute of Physical Education, Gwalior. The Vediography sequence was taken under controlled condition. The subjects performed the technique six times. And also used the G*Power is a tool to compute statistical power analysis for many different *t* tests, *F* tests, $\chi 2$ tests, *z* tests and some exact tests. G*Power can also be used to compute effect sizes, sample size and to display graphically the results of power analysis. The output shows that the power of this test was about 0.541 which was less than the power 0.80 found in the fixed model. This observation holds in general: The power in the random model was never larger than that found for the same scenario in the fixed model. In linear regression analysis model with 3 predictors there are 54.13% chance correctly rejecting the null hypothesis that the multiple correlation R^2 values equal to zero with 30 sample size

Therefore, the objective of the study was:

- What was the contribution of different kinematic variables in long jump performance?

Before investigating this research question, the scholar applied the descriptive analysis to know the nature of the data.

The whole analysis has been split into three sections. Section ‘A’ includes the descriptive analysis of the data of kinematic analysis of take off in Long Jump and Biomechanical variables during take-off in Long Jump, Section ‘B’ including the analysis of the data using correlation coefficient and section ‘C’ include the analysis of the data using the Regression analysis.

The values of the mean, standard deviation and standard error of the mean for long jump and jumper were given in the table 4 and it was observed that the mean of right elbow angle of the long jumper was larger than that of the jumper However, whether that difference was significant or not that was tested by using the Regression Analysis.

Correlation coefficient was employed to check relationship between the variable was used. Table 2 shows the correlation coefficients along with their p- values and the sample size. The correlation coefficient with Vertical Velocity and Right Knee (*) asterisk mark was significant at 5% level whereas with Left Elbow (**) asterisk mark was significant at 1% level. In the above table, correlation matrix including significance level at 0.05 has been shown.

Significance has also been tested for two–tailed test and for one tail test, significance value for the correlation coefficient at 0.01 level with 28(=N-2), df was 0.423 and that of at 0.05 was 0.361. Thus all those correlation coefficients having values more than 0.423 and 0.361 were significant at 5% level.

It could be seen from the table 4 that the value of Regression Model value was .87.8. This value was significant as the p- value was less than 0.05. Thus, the null hypothesis of Regression model of population means of subject was rejected and it could be concluded that the Right Knee Angle, vertical velocity and Right pelvis of Long Jumper varies significant among the (Contribution of different kinematic variables) jumpers during takeoff. In this example only two – tail test was used and, therefore, only conclusion which drawn was that the right knee angle vertical velocity and Right pelvis of long jumper were not and no further conclusion could be drawn.

The three regression Models generated by the SPSS have been presented in Table 3 in the model, the values of R^2 was .878, which was maximum and, therefore, the model develop was used to develop the regression equation. It could be seen from the table 3 that in third model, three independent variables, namely, Right knee angle, Vertical Velocity and Right Pelvis were identified and, therefore, Regression equation was developed using these three variables only. The R^2 value for this model was 0.878, and, therefore, these three independence variables explain 87.8% variation in Right Pelvis angle for take-off of Long Jump performance. Thus, this Model could be considered appropriate to develop the regression equation. The entire model had been shown. Since

F- value for the third model was highly significant, it might be concluded that the model selected was highly efficient also.

Thus, it might be concluded that the above regression equation was reliable as the value of R^2 was 0.878. In other words, the three variable selected in this regression equation explain 87.8% of the total variability in Right Pelvis (all the three intendance variables) which was good Model. Since the F- value for this regression model was highly significant, the model reliable. At the same time, all the regression coefficient in this model were highly significant, and, therefore, it may be interpreted that all the three variables selected in the model, namely Right knee angle, Vertical Velocity and Right Pelvis had significant predictability in estimating value of Long Jump Performance.

The unstandardized and standardized coefficient in all models. unstandardized coefficient also known as "B" coefficients was used to develop the regression equation whereas standardized regression were denoted by "β" and was used to explain the relative importance of independence variables in terms of their contribution towards the dependence variable in the model. In third model, t- value for all three regression coefficient are significant as their significance values (p values) were less than 0.05. Thus, it may concluded that the variables Right Knee angle, Vertical Velocity and Right Pelvis significantly explain the variation in long jump performance.

Regression Equation: -Using regression coefficient (B) of the all three model shown in table 5 the regression equation could be developed which was as follow:

Performance of Long Jump = 3.336 +.019X (Right knee angle) + .030 X (Vertical Velocity) + .001 X (Right Pelvis angle)

To conclude, it might be interpreted that the above regression equation was reliable as the value of R^2 was **.87.7.** In other words, the one variable selected in this regression equation explains **87.7%** of the total variability in the Right pelvis which was good. Since F- value for this regression model was highly significant, reliable. At the same time regression coefficient in this model was highly significant and therefore it may be interpreted that the one variable selected in the model viz.: performance of long jump quite valid in estimating the Right Knee Angle, Vertical velocity and Right pelvis of the Long jumper.

The purpose of the study was to find out kinematic analysis of Long jump and what was the contribution of different kinematic variables in long jump performance. The kinematic variables revealed that significant relationship of Right knee angle, Vertical velocity y, right pelvis and Right elbow angle with the performance in long jump also provides further insight into long jump performance, although not all variables associated with real jumping performance were studied the vertical speed is a mix of the speed conveyed in from the keep running, and also the stature picked up from the push off the ground. Nearby the speed of the jumper, we additionally realized that the point of take off assumes an expansive part in the last separation of the hop. The take off point was typically somewhere close to 43 and 45 degrees, yet it changes on the competitor on the grounds that not all competitors are a similar stature, weight, and in this manner apply diverse strengths at take off. While these factors work autonomously to guarantee a maximal hop, they additionally have awesome importance to each other.

It is a mix of these factors that would permit our jumper to expand his separation. Keeping in mind the end goal to comprehend this, we had to begin with the powers utilized by the competitor to push off the ground. At the point when the competitor moves into the take –off remove, his feet apply weight on the ground, and on account of Newton's third law of movement, the Law of Action and Reaction, the ground pushes back the competitor . This permits the competitor to utilize his body to make vertical speed from flat speed. By pushing off the ground and permitting the ground response compel to wind up plainly more prominent than that of the drive his foot was putting on the ground, the competitor exchanges some of his speed into the vertical bearing. Since the competitor has both types of speed, we should take a gander at how that would impact the separation he ventures. The vertical speed made by the push off decides the time that the competitor would spend noticeable all around, and in addition the most noteworthy stature he comes to. We could for see and even figure these qualities because of the way that we know our competitor is experiencing consistently quickened movement, and accordingly gravity is influencing the jumper along the vertical pivot. When we had possessed the capacity to ascertain the time spent noticeable all around and the tallness of the competitor, we could then compute the separation the jumper were travel. Since even separation voyaged (the separation we need to expand) is a component of the level speed and the time the competitor spends noticeable all around, we could without much of a stretch anticipate how far the competitor will go. Basically, the powers delivered by the competitor comfortable start of take off would bring through and affect the general take off action.

Something else that we had to remember with the take off was the muscles force that was made as the jumper dispatches himself into the air. Since, he should have the capacity to swing his feet underneath him. The jumpers take off would be the separation from his feet to his focal point of mass, which would be his pivot. In the sagittal plane the competitor would swing his feet underneath him and forward with a specific end goal to get ready for landing and trying to ensure that his feet hit the sand as far out as would be prudent. While this would be taken a gander at additional inside and out in the flight area, it is essential to realize that muscles force were made at take off and was then preserved all through the rest of the bounce.

On the other hand other variable revealed the insignificant value obtained for all variables might be attributed to the improper technique of the subjects. Since the subjects chosen were of age ranging 17-25 college level, they were yet to require mastery of the skill in long jump.

Some other causes of insignificant result of selected kinematic variables at moment of take off in long jump may be due to the different patterns adopted by the athlete during training of long jump technique, further Arm moment was not purely in saggital plane due to which, measured arm Centre mass through the particular moment of Long jump performance was highly affected by force and takeoff angle and these variables were out of the delimitation of the study. Majority of the biomechanical variables follow a non-liner relationship with performance which could have affected the findings. It might also be due to the low level of performance of athlete, low sample size and use of different quality techniques by the athlete during test.

These factors would convey steady into the flight period of the hop, and would likewise be put into thought amid the arrival stage. A projectile (the jumper) was launched into the air at an angle, θ, to the ground with a velocity, V_0. Their motion through the air was described by a parabola that is symmetric about its highest point. Once the jumper reaches this highest point they had zero velocity in the y-direction. Gravity then accelerates their motion back to the ground where they land a distance, R, from their take off point. Due to the symmetry, the velocity with which they land had the same magnitude, but opposite direction, to their take off velocity.

Conclusion

Based on the analysis and within the limitations of the present study, the following conclusion may be drawn:

- The angular kinematic variables i.e. ankle joint (right, left), knee joint (left), Pelvis joint (left), shoulder joint (right, left), and elbow joint, (Right, left), has no significant relationship with performance of Long Jump.
- The angular kinematic variables i.e. Right knee angle and Right Pelvis angle had significant relationship with performance.
- The Linear kinematic variables i.e. Horizontal velocity and center of Mass had no significant relationship with performance of Long Jump.
- The Linear kinematic variables i.e., Vertical velocity at the time of moment takeoff in Long jump has significant relationship with performance of Long Jump.
- The present study had increased our knowledge of the relationships between run-up velocity, Angles of different joint, Centre of Mass, take-off technique, and jump distance.
- However, we were not yet able to provide scientifically rigorous advice to the individual athlete on how to optimize their take-off impulses and take-off technique so as to maximize their jump distance.

Recommendations

Recommendations for Athletes

Based on the conclusion drawn in this study, the following recommendation has been made:

- The present study may be conducted on athletes of national and international levels. Such studies will help in the development of biomechanical model of the technique in long jump.
- This study may help the Athlete of national or international level for about parameters accounting for decrement (Low & high) performance in Long Jump.
- This study may help the Athlete of international level to know the contribution of different kinematic variables in long jump performance.

Recommendations for Coaches and Physical Education Teachers

- The result of the study may be helpful to the physical education teachers and coaches to evaluate the performance of long jumper.
- The result of the study may be helpful to the physical education teachers and coaches to find out most contributing factor to enhance performance of Long jump.

Recommendations for Researchers

- The result of the present study may utilize to analyze the kinematic analysis of the performance of long jumpers.
- The same study may be replicated with the use of much more sophisticated equipments in order to have more objective and accurate data for the purpose of kinematic analysis.
- Similar studies may be undertaken to analyze other events of track and field athletes and other games and sports.
- Researchers may develop approaches and carry out a full cost–benefit analysis of public involvement in research would be beneficial. Although methodologically challenging, it would be very useful to conduct some longer-term studies which

sought to quantify the impact of public involvement on such key indicators as participant recruitment and retention in clinical trials.

- Payment for public involvement in research remains a contested issue with strongly held positions for and against; it would be helpful to further explore the value research partners and researchers place on payment and its effectiveness for enhancing involvement in and impact on research.

APPENDIX –A

ASSUMPTION FULFILLED THROUGH TESTS OF NORMALITY

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Performance	.197	30	.004	.851	30	.001
Horizontal Velocity	.162	30	.043	.966	30	.442
Vertical Velocity	.162	30	.042	.955	30	.235
Centre of Mass	.152	30	.077	.925	30	.037
Right Angle	.197	30	.004	.896	30	.007
Right Ankle	.135	30	.172	.927	30	.040
Right Pelvis	.256	30	.000	.875	30	.002
Left Pelvis	.170	30	.028	.935	30	.068
Right Knee	.091	30	.200*	.981	30	.856
Left knee	.169	30	.028	.880	30	.003
Right Shoulder	.157	30	.057	.891	30	.005
Left Shoulder	.192	30	.006	.889	30	.005
Right Elbow	.134	30	.176	.906	30	.012
Left Elbow	.140	30	.136	.902	30	.009

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

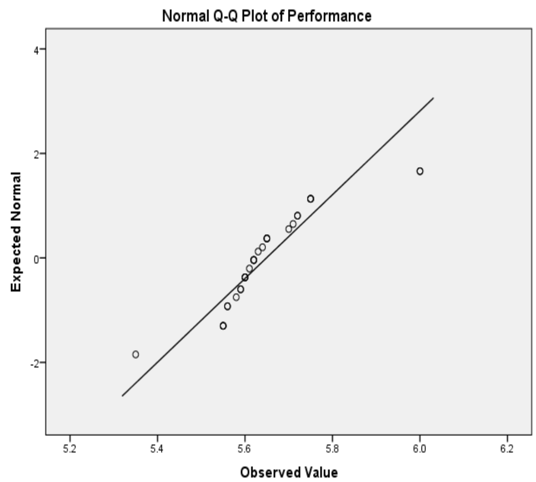
APPENDIX –B
VARIABLES ENTERED/REMOVED

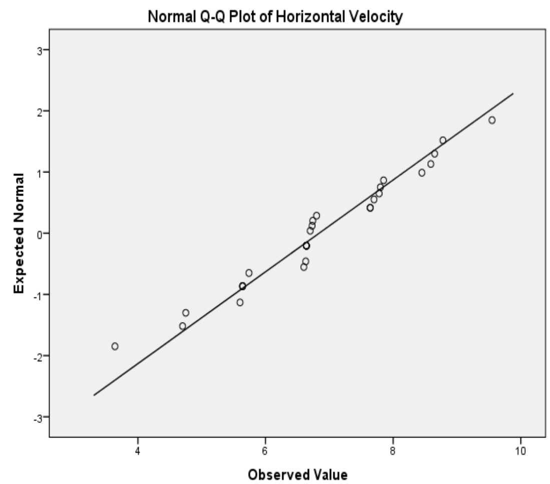
Model	Variables Entered	Variables Removed	Method
1	Right Knee	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	Vertical Velocity	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	Right Pelvis	.	Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

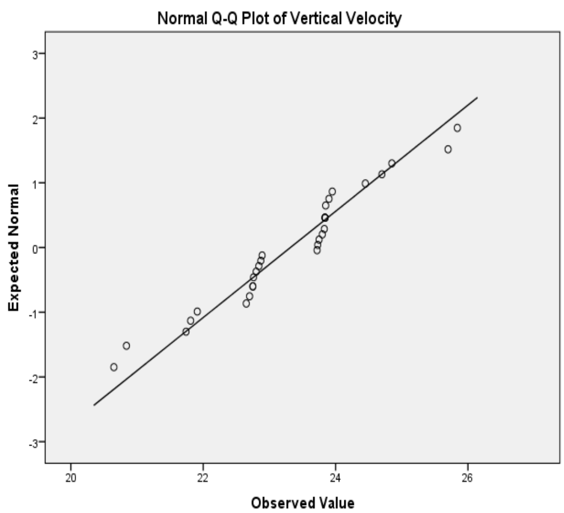
a. Dependent Variable: Performance

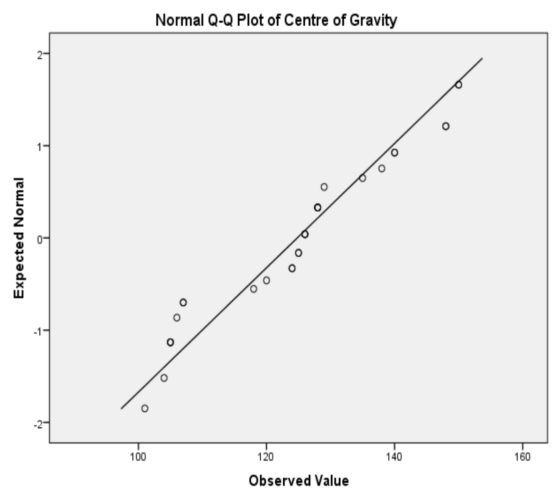
APPENDIX –C

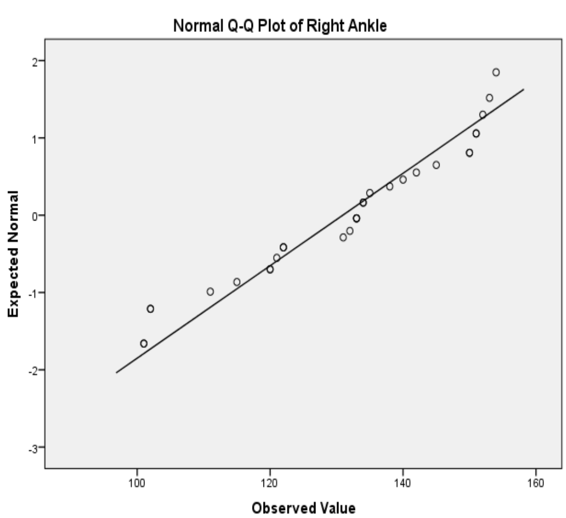
ASSUMPTION FULFILLED THROUGH NORMAL Q-Q PLOTS

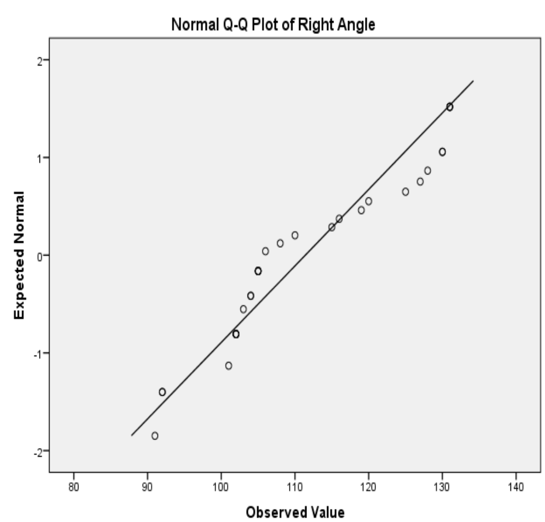




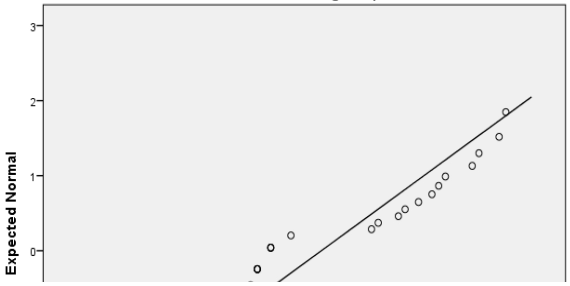




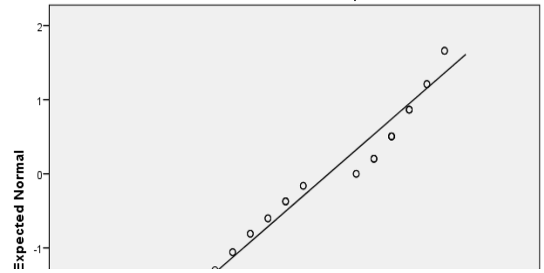




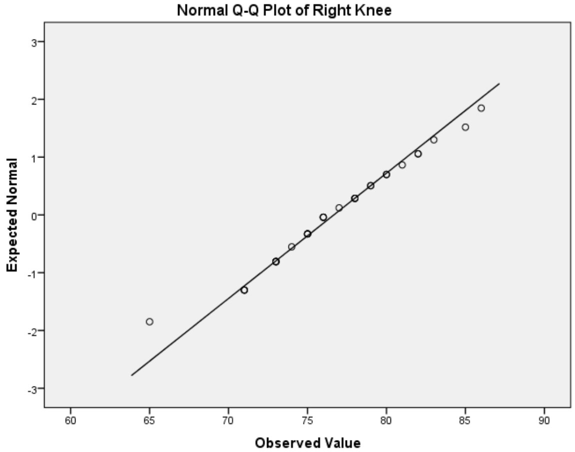
Normal Q-Q Plot of Right Hip



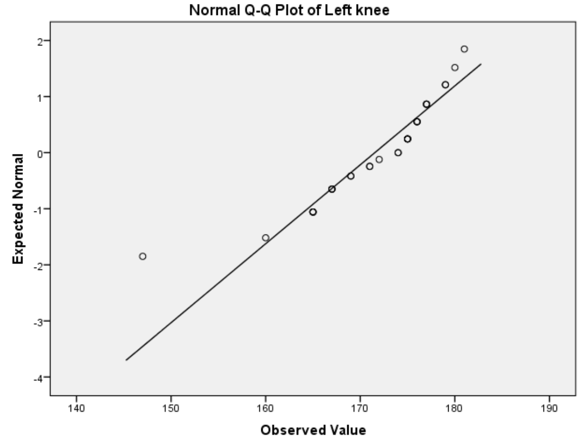
Normal Q-Q Plot of Left Hip



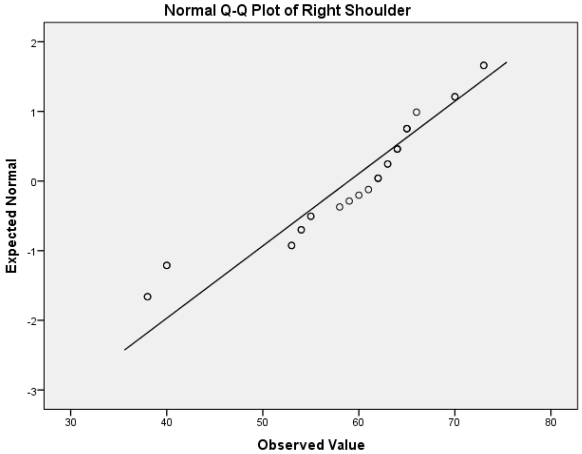
Normal Q-Q Plot of Right Knee



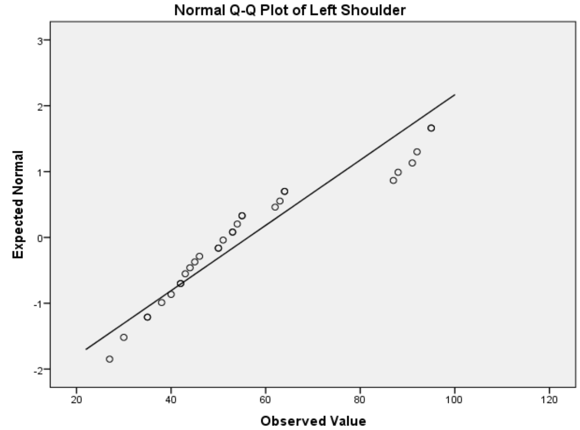
Normal Q-Q Plot of Left knee



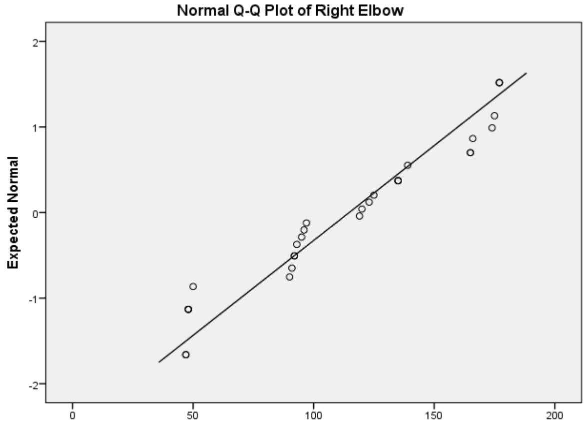
Normal Q-Q Plot of Right Shoulder



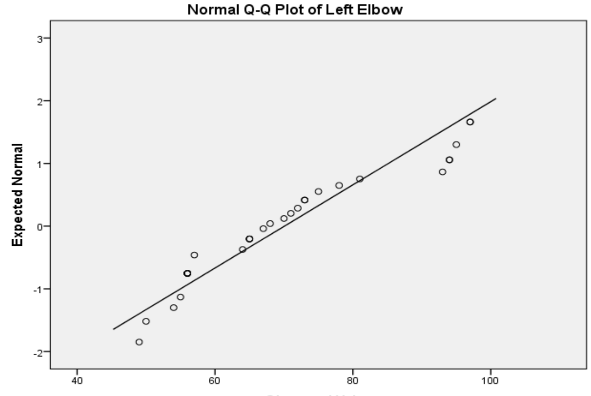
Normal Q-Q Plot of Left Shoulder



Normal Q-Q Plot of Right Elbow

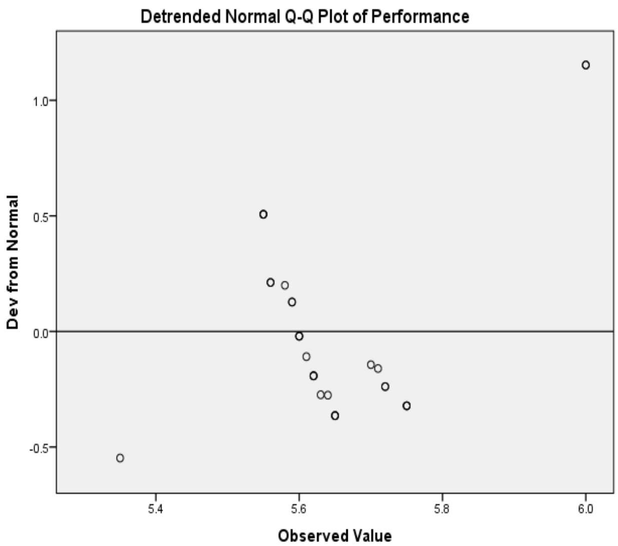


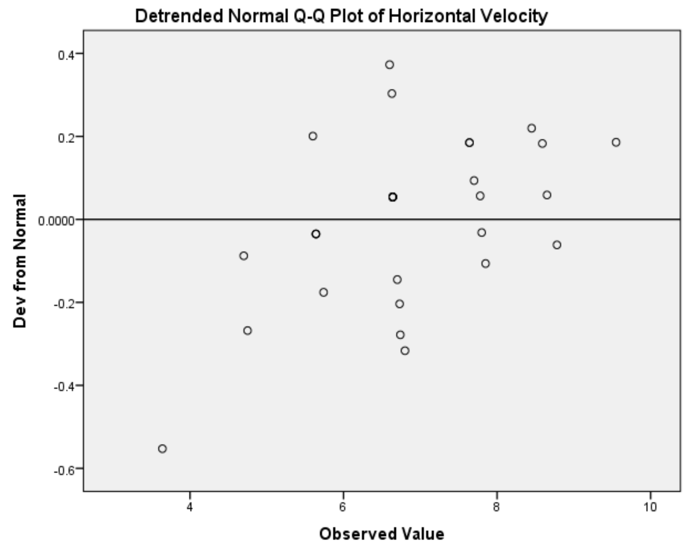
Normal Q-Q Plot of Left Elbow

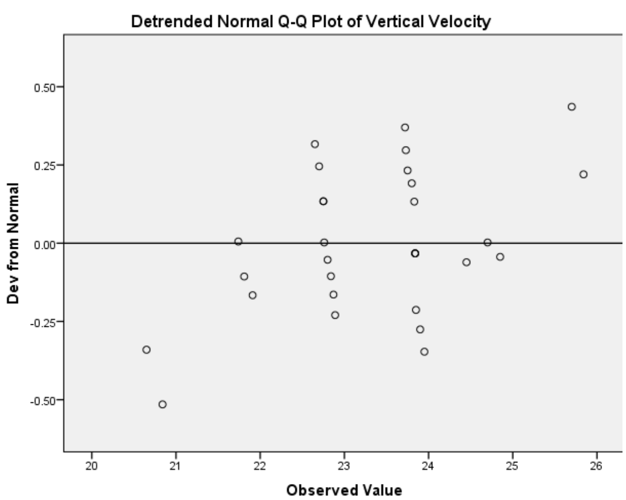


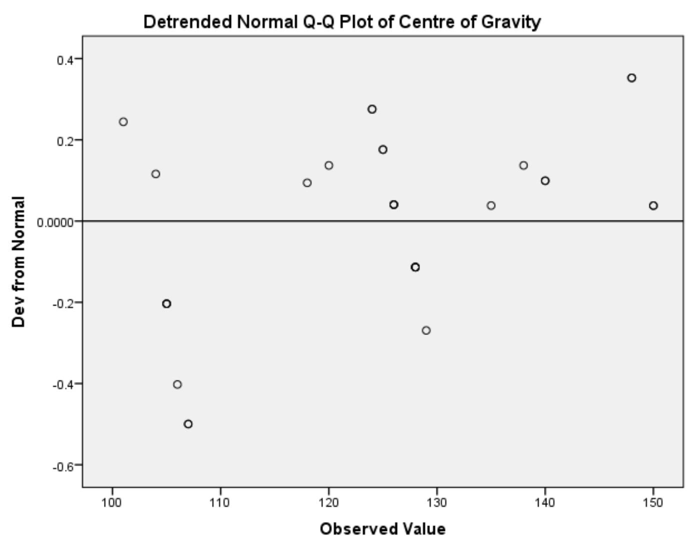
APPENDIX-D

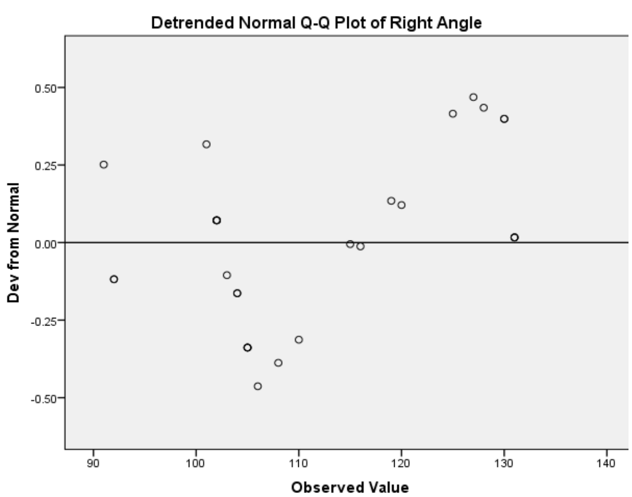
ASSUMPTION FULFILLED THROUGH DETRENDED NORMALQ-Q PLOTS

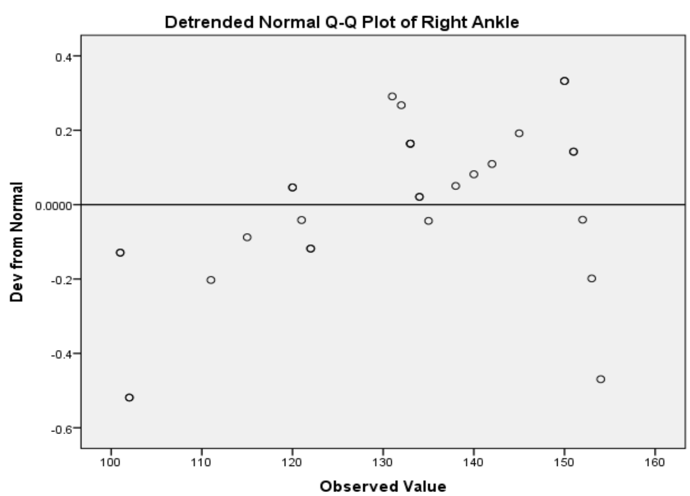


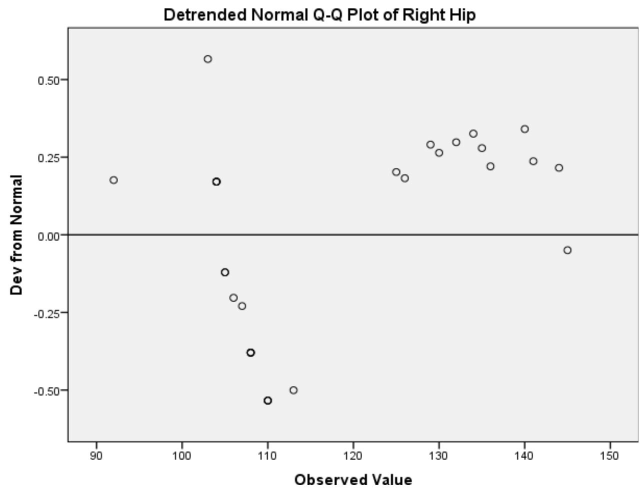


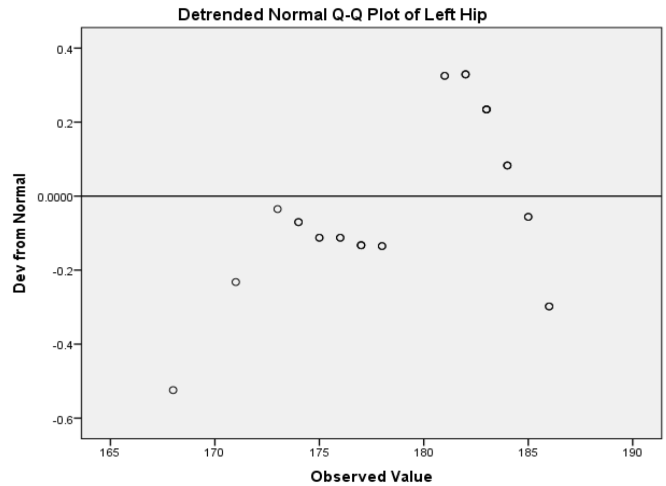


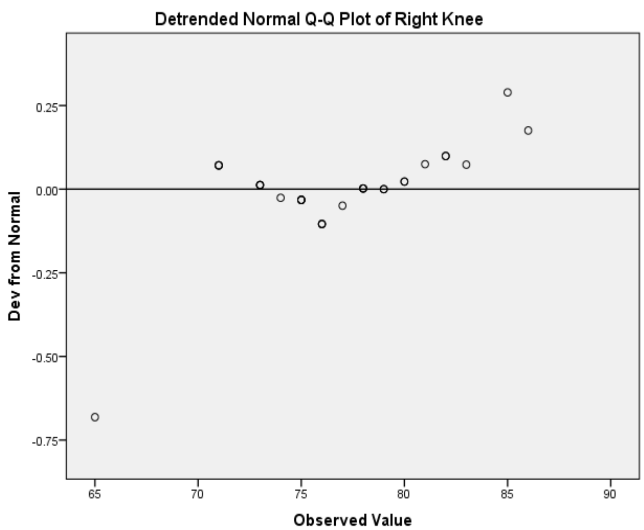


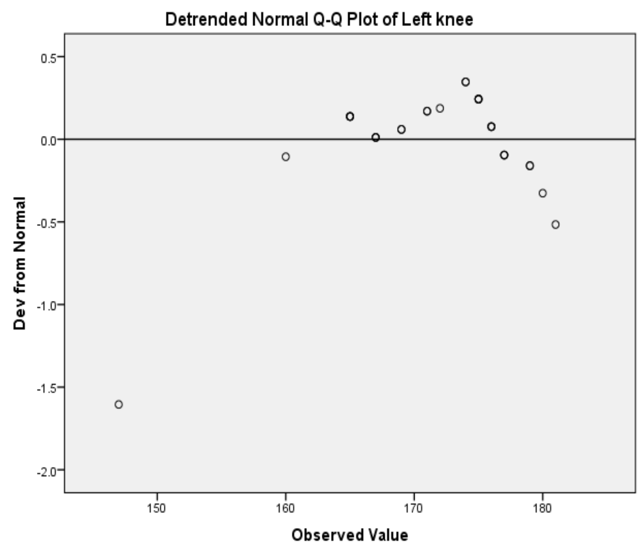


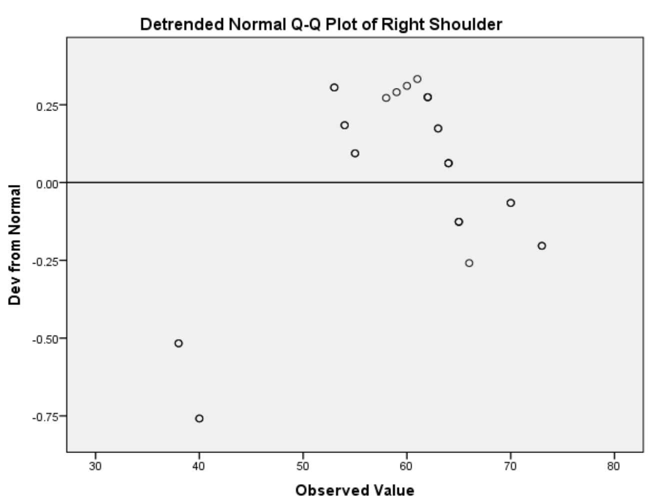


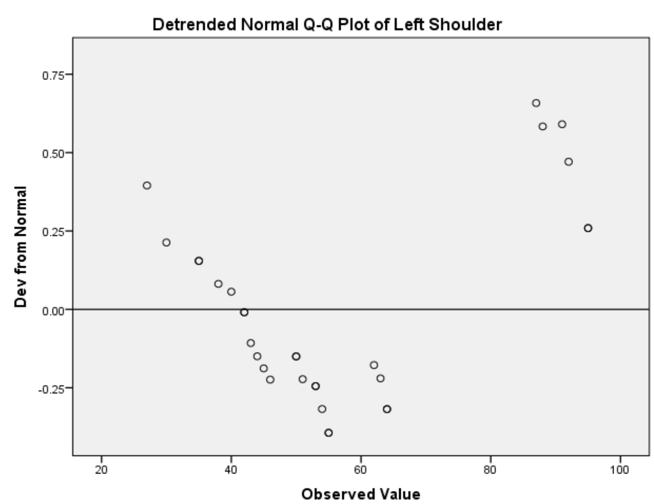

Detrended Normal Q-Q Plot of Right Hip
Dev from Normal
Observed Value
0.50
0.25
0.00
-0.25
-0.50
90
100
110
120
130
140
150

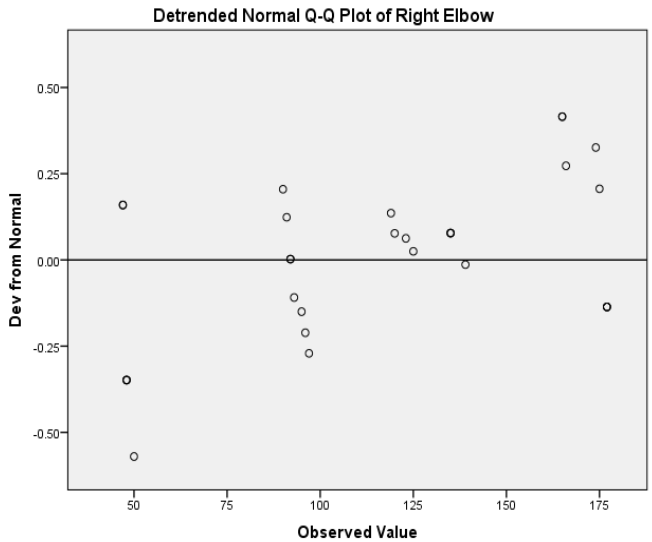

Detrended Normal Q-Q Plot of Left Hip
Dev from Normal
Observed Value
0.4
0.2
0.0000
-0.2
-0.4
-0.6
165
170
175
180
185
190

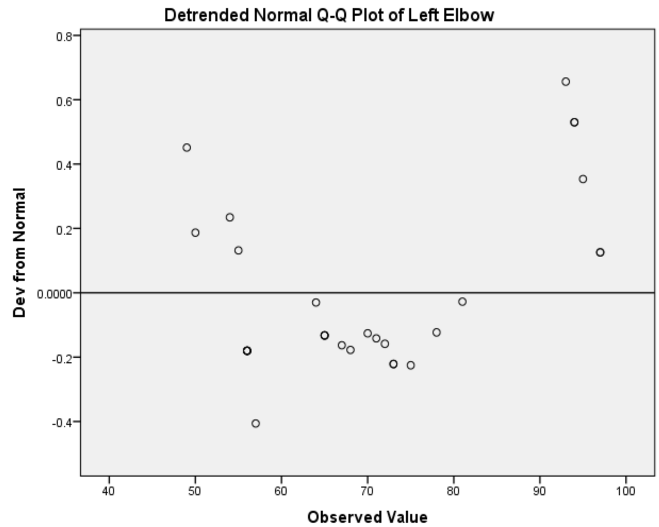

Detrended Normal Q-Q Plot of Right Knee
Dev from Normal
Observed Value
0.25
0.00
-0.25
-0.50
-0.75
65
70
75
80
85
90


Detrended Normal Q-Q Plot of Left knee
Dev from Normal
Observed Value
0.5
0.0
-0.5
-1.0
-1.5
-2.0
150
160
170
180


Detrended Normal Q-Q Plot of Right Shoulder
Dev from Normal
Observed Value
0.25
0.00
-0.25
-0.50
-0.75
30
40
50
60
70
80

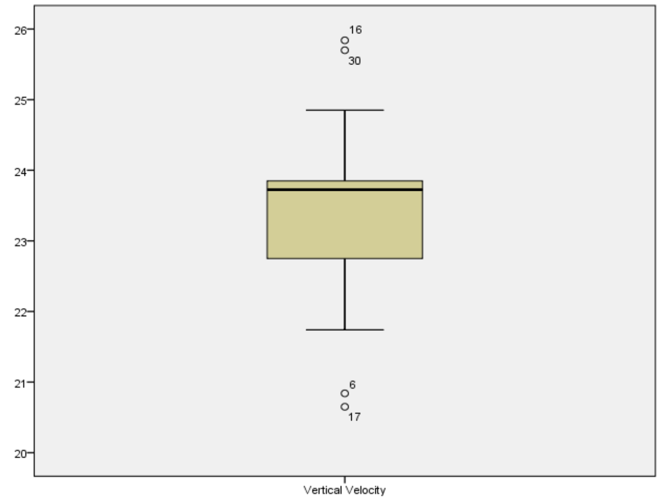

Detrended Normal Q-Q Plot of Left Shoulder
Dev from Normal
Observed Value
0.75
0.50
0.25
0.00
-0.25
20
40
60
80
100

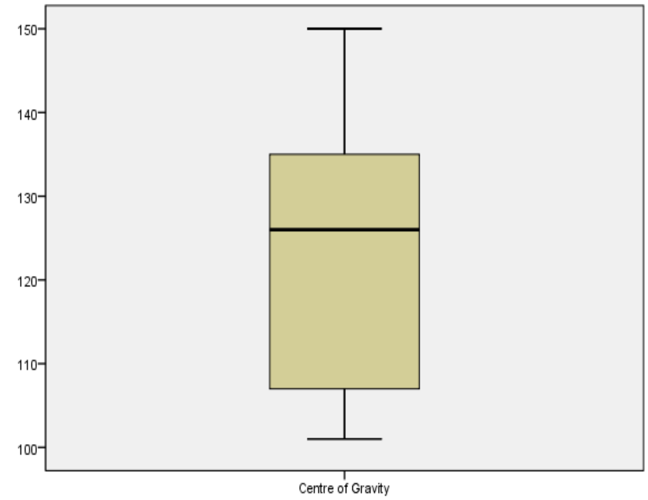

Detrended Normal Q-Q Plot of Right Elbow
Dev from Normal
0.50
0.25
0.00
-0.25
-0.50
50
75
100
125
150
175
Observed Value

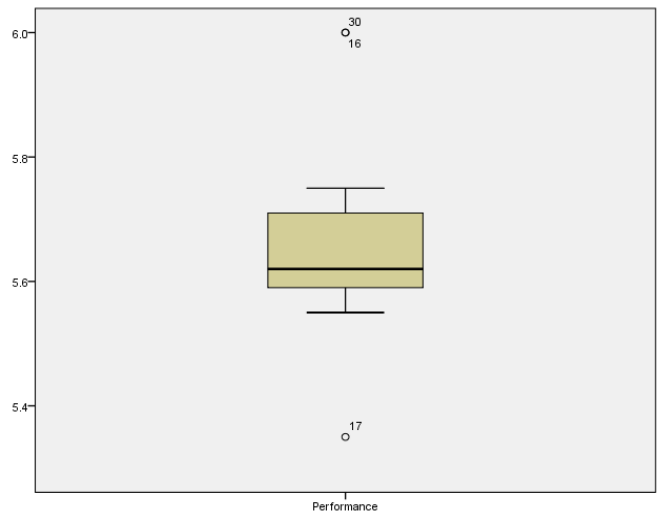

Detrended Normal Q-Q Plot of Left Elbow
Dev from Normal
0.8
0.6
0.4
0.2
0.0000
-0.2
-0.4
40
50
60
70
80
90
100
Observed Value

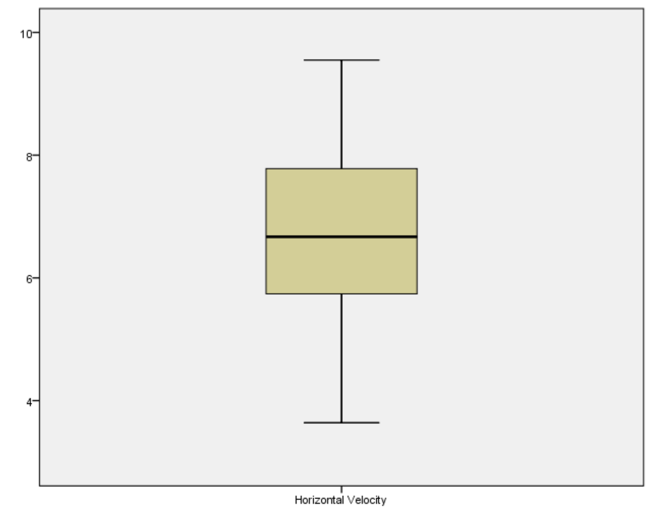
APPENDIX- E

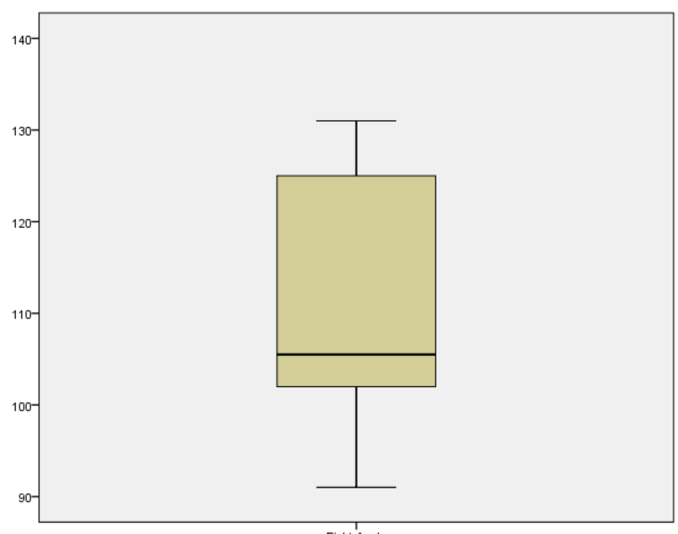
OUTLEIR CHECHED THRUOGH BOXPLOT TEST

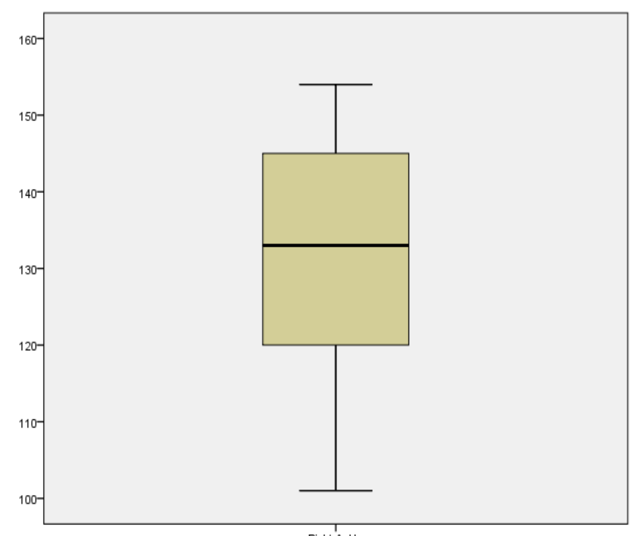


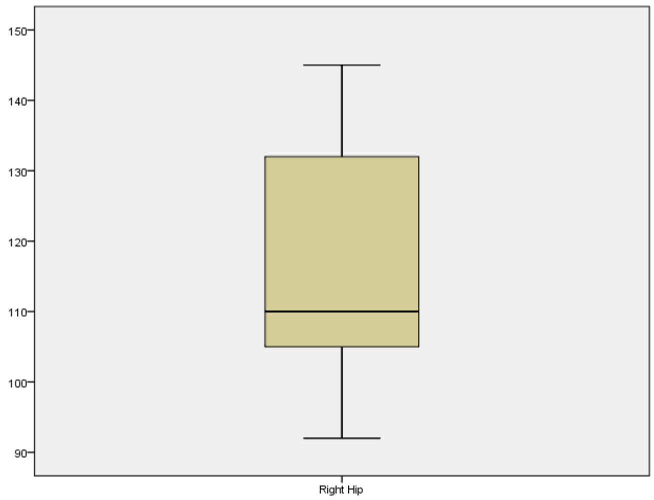


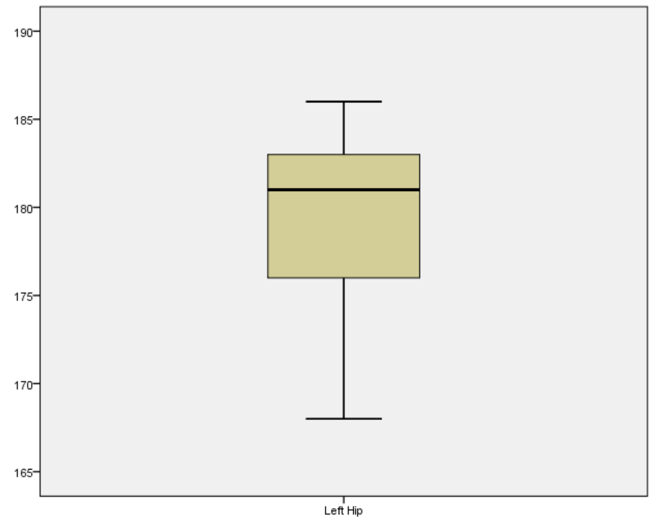


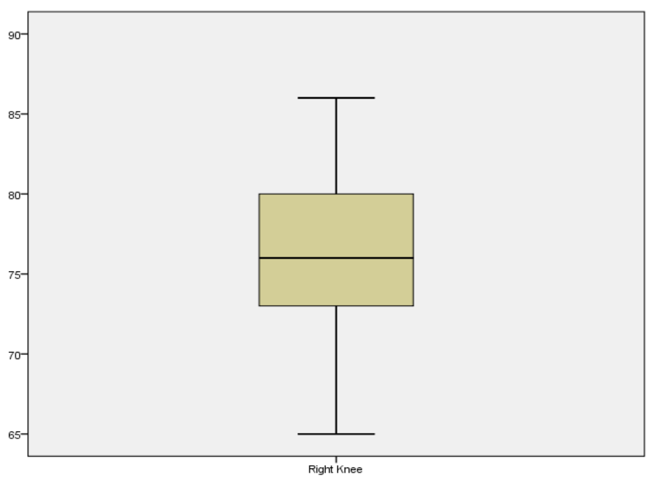


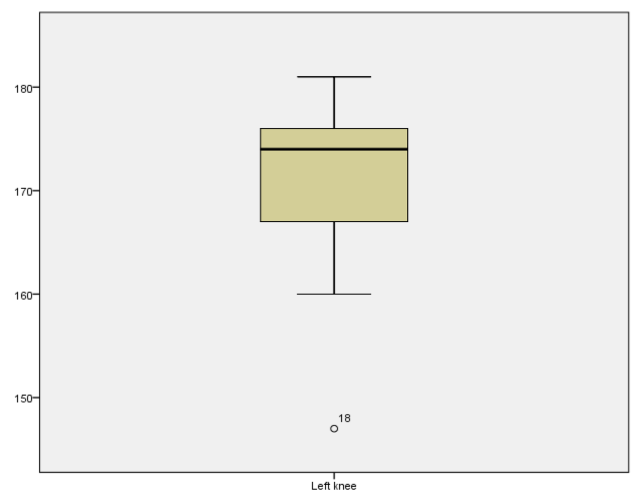


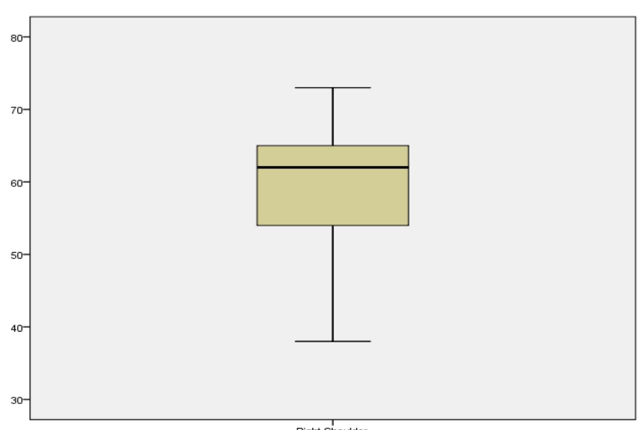


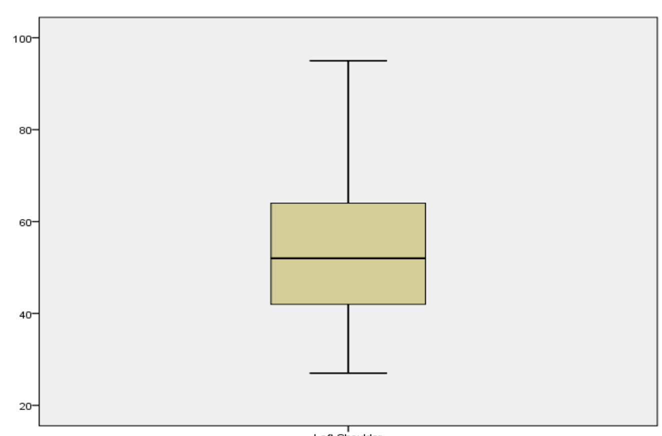

150
140
130
120
110
100
90
Right Hip

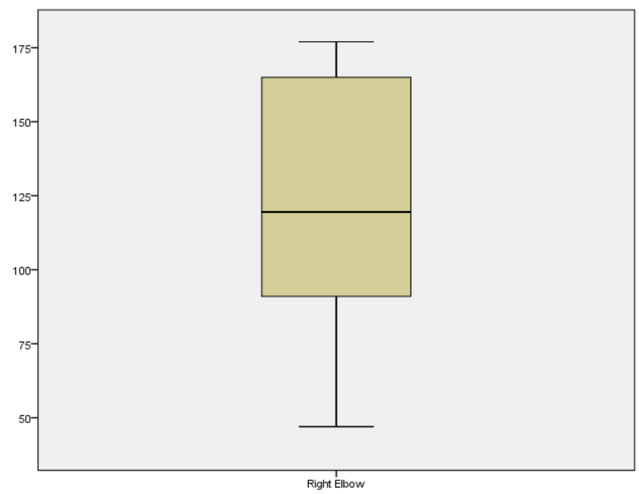

190
185
180
175
170
165
Left Hip

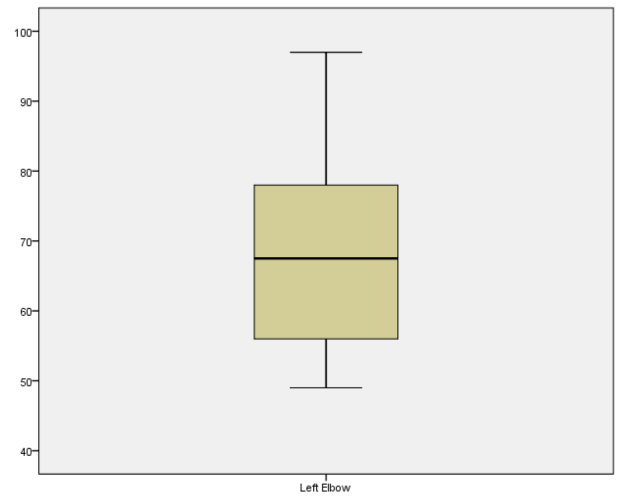

90
85
80
75
70
65
Right Knee


180
170
160
150
18
Left knee


80
70
60
50
40
30
Right Shoulder

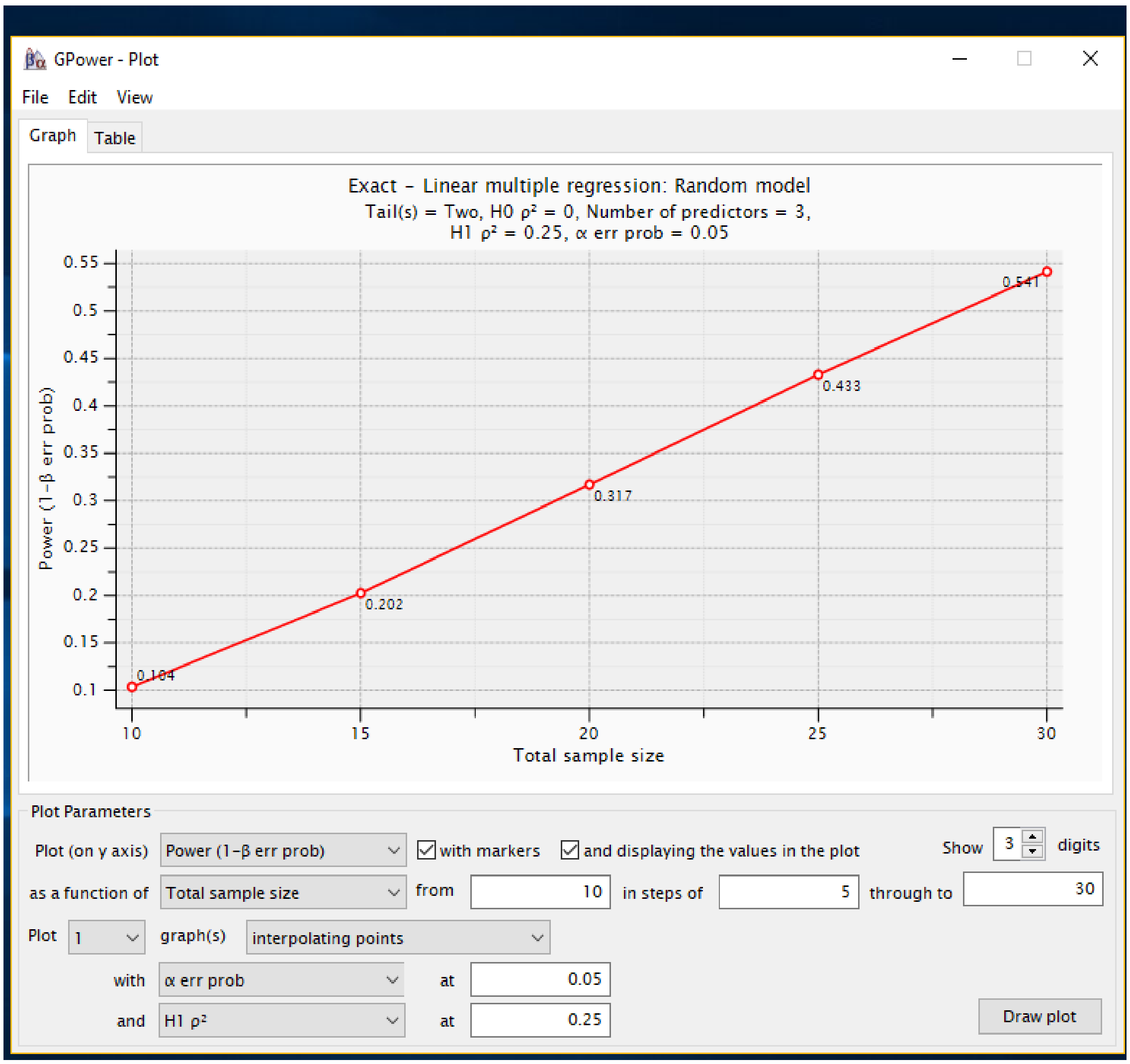

100
80
60
40
20
Left Shoulder


175
150
125
100
75
50
Right Elbow


100
90
80
70
60
50
40
Left Elbow

APPENDIX-F

G* POWER – PLOT TO SHOWS THE ACHIEVED POWER- GIVEN α, SAMPLE SIZE AND EFFECT SIZE



APPENDIX-G

CONSENT FORM OF SUBJECTS

Lakshmibai National Institute of Physical Education, Gwalior
Deemed to be University
(Declared vide Government of India, Ministry of Human Resource Development Notification No.F.9-14/92-U.3 dated 21.09.1995 under section 3 of UGC Act, 1956)
Government of India, Ministry of Youth Affairs and Sports

Consent to Subject in a Research Study

Title of Study: A THREE DIMENSIONAL KINEMATIC ANALYSIS OF LONG JUMP

Investigators/ Researchers:

Name: Bhanu Pratap **Dept:** Sports Biomechanics **Mob:** 08236044418

Objective of the Study

- To find out which kinematic variables is most contributing in the enhancement of the performance of Long Jump.

Research Question

- What is the contribution of different kinematic variables in Long Jump Performance?

Risks and discomforts

There are no known risks associated with this research. OR there are certain risks or discomforts associated with this research. They include (describe any reasonably foreseeable risks or discomforts to the participant. You may also describe the measures you will take to minimize these risks and discomforts.)

Potential benefits

There are no known benefits to you that would result from your participation in this research. OR (Describe any benefits to the participant and to others that may reasonably be expected from the research.) This research may help us to understand (brief statement, if appropriate).

Significances of the Study

The study was significant in the following ways-

- The result of the study may help coaches and trainees to train players.
- This study was help the coaches, athletes and exercise scientists were in great need of an additional investigation of this problem.
- The result of the study may be used as a screening tool in assessing the quality of Long Jumper on the basis of kinematic variables.
- This study may help the physical education teacher and coaches to develop training program for the Long Jumper to achieve excellence.
- The finding of this study may give certain guidelines based on kinematic parameter for selecting the proper Long Jumper for a particular position.
- It may be helpful for giving conditioning program and selecting scientific training methods according to level of Long Jumper.

Protection of confidentiality

(Describe the extent to which confidentiality of records identifying the participant will be maintained. If appropriate, precede the description with: We will do everything we can to protect your privacy. If appropriate, follow the description with: Your identity will not be revealed in any publication resulting from this study.)

Voluntary participation

Your participation in this research study is voluntary. You may choose not to participate and you may withdraw your consent to participate at any time. You will not be penalized in any way should you decide not to participate or to withdraw from this study.

Contact information

If you have any questions or concerns about this study or if any problems arise, Please contact (Supervisor, Prof. A.S. Sajwan, Co- supervisor, Assit. Prof. Pushpendra Purashwani and Research Scholar Mr. Bhanu Pratap) at LNIPE, Gwalior If you have any questions or concerns about your rights as a research participant, please contact the LNIPE, Gwalior Review Board at Department of Sports Biomechanics.

Consent

I have read this consent form and have been given the opportunity to ask questions. I give my consent to participate in this study.

Subject's signature________________________________ Date: ________________

A copy of this consent form should be given to you.

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