Chapter -II

Review of Literature

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The review of related literature acts as a guideline for identify general trend in the research work already done in the concerned field or area. The review also helps the investigators in formulating the problem and in providing direction to the research undertaken. The present investigator has made sincere attempts to conduct a comprehensive and thorough survey of the related literature with respect to the variables under investigation. It is also necessary to acquaint oneself with the result of the research which helps the investigators to formulate his objectives and hypothesis.

In this chapter, the investigator has quoted some research studies which are important for understanding biomechanics of Fosbury-flop high jump technique. The careful review of related literature enlisted in this chapter based on various sources vis-a-vis journals, periodicals, encyclopaedia, unpublished thesis, etc. which were available in different libraries and net. The relevant literature pertaining to the present study has been abstracted in this chapter to provide the back ground material to evaluate the significance of this study as well as to interpret its findings.

Chen and Zhang (2001) carried out a research that focused on kinematic analysis on take-off technique of Chinese elite male high jumpers. The purpose of the study was to make an analysis on the take-off technique of some excellent male high jumpers through three-dimensional photographing. The result shows that there are significant differences in take-off technique between male Chinese high jumper and foreign one. The Chinese jumpers have a lower horizontal velocity in the last two steps and the fall in angle of their body range from big to small. During the take-off with the take-off leg touching the ground, they have a lower horizontal velocity and a shorter distance of vertical acceleration. The proportion of the buffer time to the stretch time of the take-off leg does not fully suit the laws of biomechanics. In addition, it is a common problem for our jumpers that the take-off leg does not fully stretch and swing leg has a lower swing speed and smaller amplitude.

Dapena (2002) conducted a research on the evolution of high jumping technique. High jumping technique has improved through changes in the run-up, the take-off and the bar clearance. The straddle technique used a fast run-up and strong free limb actions during the take-off to increase the generation of lift. The production of the angular momentum needed for the bar clearance in the Fosbury-flop technique is in conflict with the use of strong free limb actions during the take-off.

Fosbury-flop high jumpers compensate by using a faster run-up. Some athletes are able to generate more lift with the faster run-up and weaker free limb actions of the Fosbury-flop, while others can generate more lift with the slower run-up but stronger free limb actions of the straddle. Therefore, both techniques should be in use today. However, the straddle has disappeared because the Fosbury-flop is much easier to learn.

Frosio, Girlanda, Botton, Sibella and Borghese (2006) have studied on quantitative analysis of high jump styles. The purpose of the study was to investigate the relationship between the kinematics and the dynamics in the elite high jumpers. The analysis was based on a correct anthropometrical model of the body and on the kinematics data obtained through optical motion capture in indoor training sessions. The measure of the angular momentum has given suggestions on how to improve the efficiency of the movement. The analysis of the kinematics coordination and of the inter-trial variability suggests that athletes focus more either on the kinematics or the dynamics. From the result of this study, the angular momentum and the kinematics variability do not come out to be correlated.

Girouard, Dessureault, Ferland and Lafortune (1981) have studied on double approach was used to study high jumping: attention demands and biomechanics. The main goal of this study was to determine if the methodology used to measure the attention demands did hinder with high jumping performance. Two sub-goals were also aimed: (i) to find the main characteristics of the attention demands of high jumping; (ii) to find the main kinetic characteristics of high jumping. Two members were tested of the Canadian Olympic team. The results showed that the methodology using to measure the attention demands did not seem to hinder with subject's performance, the later being evaluated by means of force time variations during the take-off. The results also showed that: i) high jumping seems to require considerable amount of attention even for international caliber high jumpers, and ii) there were differences between Straddle and Fosbury-flop techniques as far as kinetic date were concerned.

Yuexin (1999) has studied on biomechanical analysis and technical characteristics of approach run in arc in Fosbury -flop. At present the speed in the approach run of Fosbury flop is increasing rapidly day by day. When the body is approaching in the arc, it attains a realistic and suitable inward obliquity. Thereby, the lift angle is increased, the approaching speed is accelerated and a good result of take-off is obtained, so as to achieve more perfect results of high jump. By applying biomechanical theory, the correlative factors of the inward obliquity of the body during approaching in the arc, the characteristics of that movement, the speed of the approach and the radius of the arc were analyzed and discussed. The internal relations of those correlative factors were found out in order to keep away from unilateral pursuing inward obliquity and acceleration, which is of great importance in practice.

Huang, Liu and Yuan (2007) have studied Chinese elite young male high jumpers', Jump-up technology in the last stage of the run-up process. With the 3-dimensional biomechanics analysis of seven Chinese elite young male high jumpers' jump-up technology in the last stage of the run-up process, the conclusions are drawn that the extent of support leg's buffer stage are too long and the extending velocity of swing leg are too small in the second step at the end of run-up process; that the horizontal velocity of body's center of gravity when the take-off leg access the ground are relatively high; that there are some large differences in the vertical velocity of the jump-up stages finish point which are not directly connected with the extent of jump-up leg's extension and are related with the jump-up time.

Hussain, Khan and Mohammad (2011) have studied the comparison of kinematical variables between successful and unsuccessful Fosbury-flop high jump technique. The aim of this study was to compare the selected kinematical variables of successful and unsuccessful Fosbury-flop high jump technique. For the success 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 21 years, 170.87 cm and 60.5 kg, respectively. To obtain kinematical data during the competition, one high speed Sony DCR SX 40E 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 of each athlete was selected for further analysis. The video footages were downloaded, slashed to desired footages and edited for biomechanical analysis. The 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 Pro-7 motion analysis software. All statistical process was conducted using the SPSS-16.0. A level of significance was set at 0.05. The obtained data of the variables were subjected to descriptive statistical analysis followed by t test. Results showed that insignificant differences were found between successful and unsuccessful jump on selected variables.

Zhiyu (2004) has studied the take-off technique of some elite Chinese men high jumpers. 3-dimension high speed photography has been used for a kinematical analysis of high jumper's techniques just before and after take-off. Some elite male Chinese high jumpers taking part in the trials are served as subjects. The results showed that Chinese jumpers H1 and H2 are lower than that of world level high jumpers. Their horizontal velocity of the last step is lower during the approach run at the moment of the swing leg taking off the ground, and Chinese jumper's inside incline of body is minus under the high speed of the approach run, the ability of finishing the take-off is weak the driving of the jumping leg is not sufficient, and their swing range and speed are smaller.

Kakihana and Suzuki (2001) carried out a research on the EMG activity and mechanics of the running jump as a function of take-off angle. To characterize the electromyographic (EMG) activity, ground reaction forces, and kinematics were used in the long jump with different take-off angles. Two male long jumpers volunteered to perform jumps at different approach speeds by varying the number of steps (from 3 to 9) in the run-up. Subject TM achieved a greater vertical velocity of the center of gravity (C.G.) at take-off for all approach distances. This jumping strategy was associated with greater backward trunk lean at touchdown and take-off, a lesser range of motion for the thigh during the support phase, more extended knee and ankle angles at touchdown, and a more flexed knee angle at take-off. Accompanying these differences in kinematics, TM experienced greater braking impulses and lesser propulsion impulses for the forward-backward component of the ground reaction force. Furthermore, TM activated mainly the rectus femoris, vastus medialis, lateral gastrocnemius and tibialis anterior, while if rarely activated the biceps femoris from just before contact to roughly the first two-third of the support phase. These results indicate that TM used a greater take-off angle in the running jump because he enabled and sustained a greater blocking effect via the coordination patterns of the muscles relative to the hip, knee and ankle joints. These findings also recommend that the muscle activities recorded in the present experiment are reflected in kinematics and kinetics. Further, the possible influence of these muscle activities on joint movements in the take-off leg, and their effect on the vertical or horizontal velocity of the jump are discussed.

Greig (2004) has studied the applications in sports biomechanics: sensitivity of optimum performance. This study considers the sensitivity of optimum high jumping performance and the potential for sub-maximal jumping. Practical implications are clear in both performance enhancement and injury prevention, the central research foci of sports biomechanics. A single elite male high jumper performed sixteen jumps in the training environment. Direct intervention was used to modify the length of the approach-run, thus inducing a change in approach speed. The peak height of the centre of mass was defined as jump height (h), with the horizontal velocity of the centre of mass over the final approach stride defined as approach speed (v). Quadratic regression analysis enabled calculation of optimum approach speed, and a predictive equation with which to investigate the potential for sub-maximal jumping. The regression equation h = - 0.836 + 0.845v - 0.059v2 (r2 = 0.73, pv = 0.04, pv2 = 0.06) elicits an optimum approach speed of 7.22 $m.s^{-1}$, resulting in a predicted maximal jump height of 2.20 mts. The same predicted jump height is achieved from an approach speed of 7.00 $m.s^{-1}$. Jump height performance at 95% of maximum requires an approach speed of 5.78 $m.s^{-1}$, equivalent to 80% of optimum approach speed. Sub-maximal approach speeds have been shown to elicit jump heights approximating maximal performance. The reduced approach speed is likely to result in reduced loading, with insinuations for injury prevention. At sub-maximal speeds more jumps may be performed with insinuations for enhanced technical refinement. Whilst it is not possible to generalize the result to all high jumpers, the rationale for the study suggests an application of sports biomechanics with many practical implications for the athlete and coach. Optimum technique, as a theoretical constrict, might be disputed to have little direct relevance to the performer. The potential for sub-maximal performance might also be investigated in the influence of approach speed on long jump performance, and on the phase ratio obtained in triple jump.

Arabatzi and Kellis (2009) carried out a research biomechanical analysis of snatch movement and vertical jump: similarities and differences. The aim of this research was the investigation of the relationship of kinematic and kinetic characteristics of movement snatch with the vertical jump. Eight elite weight lifters performed snatch and vertical jump (CMJ) movements. Kinematic, electromyographic (EMG) and ground reaction force data were simultaneously collected. Results showed non-statistical differences ($p > 0.05$) in all kinematic variables between the two movements. Any differences that were examined in certain phases were not statistically significant and did not after the examination that there was a resemblance of the two movements in angle and angular velocity values. A high relationship was examined between the two movements in the vertical GRFs and the EMG activity of rectus femoris. The present study showed that the second pull of the snatch movement could resemble a vertical jump with extra load and may be beneficial in improving power.

Blazevic, Antekolovic and Mejovsek (2006) have studied on the variability of high jump kinematic parameters in longitudinal follow-up. The aim of the study was to determine the basic kinematic parameters of the high jump as well as the impact of changes in kinematic parameters on the height of the jump, and finally to determine the variability of kinematic variables in longitudinal research. By means of kinematic analysis 25 kinematic variables were obtained for seven jumps performed in the time span of three years by an elite Croatian female high jumper. By analysis of the kinematic variables and the height of the jump the variables which correlated the most with the height of the jump were acquired. Those were: height of the flight of CG (H2), vertical velocity of C.G. at the end of the take-off, height of the hips above the bar, take-off angle, take-off duration, angle at the moment of entering the take-off, maximal height of C.G. at the moment of crossing the bar, horizontal velocity of C.G. in the penultimate stride in the run-up. The values of certain kinematic variables increased with the increase in the height of the jump, while values of other kinematic variables decreased with the increase in the height of the jump. Basic kinematic variables that increased with the height of the jump were height of the flight of C.G. (H2), vertical velocity of C.G. at the end of the take-off, height of the hips above the bar, take-off angle, maximal height of C.G. at the moment of crossing the bar as well as horizontal velocity of C.G. in the penultimate stride in the run-up, while the values of kinematic variables take-off duration and angle at the moment of entering the take-off decreased with the increase in the height of the jump. By analyzing the kinematic variables of all the observed jumps it was determined that all the parameters varied with the increase in the height of the jump. Variables that had the highest variability with regard to the height of the jump were: length of the penultimate stride in the run-up (SD = 18.90), distance between C.G. and bar projection at the moment of the take-off leg positioning (SD = 15.24), distance between take-off point and the bar projection (SD = 11.78) and the length of the last stride during the run-up (SD = 11.11). The lowest variability was observed in the variable take-off duration, which is the duration of contact between the take-off leg and the surface, indicated by the 0.007 value of standard deviation (SD).

Dapena and Chung (1988) have studied the vertical and radial motions of the body during the take-off phase of high jumping. Film analysis of seven high jumpers showed that the radial velocity of the center of mass (COM) with respect to the supporting foot was more negative or less positive than the vertical velocity throughout the take-off phase. This favored faster eccentric or slower concentric conditions of the leg muscles. The radial distance from the hip of the take-off leg to the center of mass (RG/H) first decreased by 0.030 m, due to negative radial motions of the arms and swinging leg. This contributed to a smaller negative radial velocity of the hip (VRH) and thus to slower eccentric conditions of the muscles of the take-off leg. Therefore, it may have helped to cushion the first impact with the ground. Subsequently, RG/H increased by 0.120 m, due to positive radial velocities of the arms, the swinging leg and the head and trunk. This contributed first to larger negative (and later to smaller positive) VRH values and thus to faster eccentric and slower concentric conditions of the muscles of the take-off leg.

Dapena (2001) has studied on mechanisms responsible for under twisting in the bar clearance of high jumping. A high jumper's airborne motion is a twisting somersault. The twist is the combined result of angular momentum acquired prior to take-off and of action and reaction rotation in the air. Some athletes are under twisted at the peak of the jump, with the hip of the lead leg lower than the hip of the take-off leg. This decreases the effectiveness of the bar clearance. This project compared 10 under twisted high jumpers (5 male and 5 female) with 10 normal high jumpers (5 male and 5 female) to find the causes of the under twisting. 3-dimensional coordinates of 21 body landmarks were obtained for the airborne phase using the DLT method. The catting rotation was separated from the rotation produced by the angular momentum through the use of a rotating reference frame RH that somersaulted with longitudinal axis of the athlete, and twisted about the longitudinal axis at angular velocity produced by the twisting component of angular momentum. The twisting angular velocity of hips relative to RH indicated the angular velocity of catting. Its value was integrated between take-off and the peak of the jump to compute the cumulative twist angle change due to catting. The results showed that under twisting was not due to problems in the twist orientation of the hips at the take-off, but to deficiencies in the subsequent rotation in the air. In four of the five men, the under twisting was due to decreased catting. In four of the five women, it was due to insufficiency in the twist rotation produced by angular momentum, ultimately traced to an excessive backward lean at the end of the take-off. The results of the project suggest that in many cases the correction of under twisting may be attained in men through the improvement of catting, and in women through the attainment of a more vertical position at the end of the take-off.

Dapena (1980) has studied the mechanics of the translations involved in the Fosbury-flop technique of high jumping were examined in the light of appropriate experimental data, generated using a three-dimensional cinematographical method. The curved run-up was found to cause the athletes to lean toward the center of the curve at the start of the take-off phase (TD). The center of gravity (C.G.) of all the jumpers had a negative vertical velocity at TI). The lateral deviation of the path of the

C.G. during take-off phase was small, implying small centripetal forces. The initial trajectory of the parabolic path of the C.G. after the take-off made an angle of between 40 and 48 degrees with the horizontal plane. During the take-off phase the take-off leg was found to flex at least as much as previously reported for athletes using the straddle style. One of the subject in the study was able to clear the bar although the peak height of the parabolic path followed by his C.G. was at the same level as the bar.

Kobayashi (1982) has studied the take-off in running high jump. According to the figures calculated from the photogrammetric data of take-off in running high jump, the mechanical energy (potential energy plus kinetic energy) of the center of gravity of the body and the distance from the center of gravity (C.G.) of the body to the contacting point of the take-off foot with the ground, when plotted against time, showed concaved curves in which the minimum values were reached at about 0.05 to 0.07 second after the contact of the take-off foot with the ground. The smoothed curve of ground reaction was recorded by the force plate showed a convexed curve with its maximum at about 0.05 to 0.07 second. It was possible to understand the relationship among these changes by the model of spring-mass system in which the center of gravity of the body is connected by a spring to the contacting point of the take-off foot with the ground. In order to satisfy the condition that the spring constant of the model used in the study is positive and the model is to keep the physical effectiveness. The correlations between the height of the bar cleared and each of the spring constant, the proper period of the model and take-off time were not significant. However, in most of the cases, the significant correlation was observed between the height cleared and the 'take-off ratio' of the same subject. In agreement with the rise of height cleared, some subjects showed a decreasing pattern of the 'take-off ratio,' while the others showed an increasing pattern. In case of the subject whose record reached 2.20 mts, a highly significant positive correlation (r =0.968) was observed between the height cleared and the 'take-off ratio'. For the height above 1.90 mts, the take-off ratios of this particular subject (0.303 - 0.331) were larger than those (0.248 - 0.313) of the three other subjects whose best record reached only to 2.00 mts.

Kersting, Arampatzis and Bruggemann (1998) have studied on biomechanical analysis of the high jump at the sixth WCA in Athens. The data were gathered for the study during the men's high jump final competition at the 1997 Track & Field World Championships. A total of 26 successful jumps by twelve athletes were analyzed. The data was collected using four synchronized video cameras (50 Hz). On the basis of the total initial center of mass (COM) energy and the take-off characteristics, two relatively homogeneous groups could be identified. The take-off phase characteristics which are determined by loss of COM energy during take-off and from the transformation of approach energy to jump energy are very important for determining jump height. The initial energy of the COM determines the height an athlete can achieve. The actual jump height is strongly influenced by the take-off characteristics of the athlete. Both groups achieved the same jump height. Group (II) produced higher initial energy values. Group (I) demonstrated more efficient take-off characteristics. It was established that many athletes did not use their initial conditions optimally.

Lees, Rojas, Cepero, Soto and Guttierrez (2000) have studied how elite high jumpers used their free limbs, in a competitive high jump and to estimate the contribution that these made to vertical take-off velocity. This was achieved by analyzing the competitive performances of six elite male high jumpers using 3-D motion analysis and assessing limb function using the relative momentum method. The mean peak relative momentum of the arm nearest to the bar at take-off was 9.4 kg ms^{-1}, while that of the arm furthest away from the bar was 11.3 kg ms^{-1} and these did not differ significantly. The free leg-reached a mean peak relative momentum of 20.9 kg ms^{-1}. At touch-down the free leg and a large positive relative momentum that was offset by the negative relative momentum of the arms, although their combined value still remained positive. The mean combined free limb's relative momentum at touch-down was 13.8 kg ms^{-1} and reached a peak of 37.6 kg ms^{-1}. The difference between these two values amounted to 7.1% of whole body momentum, which was judged to be the amount by which the free limbs contributed to the performance. The arms had a greater influence on performance than had the lead leg. This was because the lead leg increased its relative momentum little during the contact period at the same time as the arms had an initial negative momentum little during the contact period while the arms had an initial negative value that increased markedly after touch-down. The compressive force exerted by the motion of the free limbs, estimated by the change in the combined free limb's relative momentum, reached a mean peak of 366 N and was greatest at 37% of the contact period. It was concluded that to maximum the contribution the free limbs can make to performance, the arms should have a vigorous downward motion at touch-down to make the most use of the high relative momentum of the free (lead) leg.

Linthorne and Kemble (1998) have studied on take-off technique in the high jump. The mathematical model incorporates the geometry of the athlete's legs and the properties of leg extensor muscles. In this model, the leg angle is the angle between the ground and the line joining the foot to the hip and the knee angle is the angle included between the thigh and shank. The model's anthropometric values were adjusted to be representative of elite male and female athletes, and many jumps were then simulated with various run-up speeds and angles of the leg and the knee at touchdown. Because of their longer legs and greater leg strength male athletes should use a faster run-up and have a greater leg angle at touchdown than female athletes. For an individual athlete jumping performance is only moderately sensitive to deviations from the optimum take-off technique. As training increases the athlete's leg strength, the optimum jump performance increases, but the run-up speed must be faster, and leg angle at touchdown must be increased. The simulations also predict the observed changes in jump performance, leg angle and knee angle as an athlete uses a progressively faster run-up (Greig and Yeadon, 1997). This relatively simple model accurately predicts the observed relationships between performance parameters in elite high jumpers.

Nolan and Patritti (2008) have studied the take-off phase in transtibial amputee high jump. The present study was performed on two athletes (both using intact limb take-off) competing in the high jump finals of the 2004 Paralympics Games. Two digital video cameras were used to film the event with the data later digitized and reconstructed using standard 3-D direct linear transformation procedures. Some similarities with non-amputee high jump technique were noted in that centre of mass (COM) height was low at touch-down, there was a similar magnitude of negative vertical velocity at touch-down, and most of the vertical velocity generated occurred in the first half of take-off phase. However, both transtibial amputee athletes exhibited a slower horizontal approach velocity, a lower positive vertical take-off velocity, a more upright position at touch-down and a greater range of motion of the hip throughout the take-off phase compared to what is known about non-amputee high jump technique. These differences may be associated with constraints of take-off from the prosthetic limb on the previous step, resulting in having to adopt a different posture at touch-down compared to non-amputees. Understanding transtibial amputee high jump technique and the differences compared to what is known about non-amputee technique has implications for coaching and improving performance in prosthetic sports.

Papadopoulos, Glavroglou, Groulos and Tsarouchas (1995) have studied on a biomechanical analysis of the support phase during the preparation and take-off in long and high jumping. The purpose of the study was twofold: i) to describe the support phases during the penultimate and last stride in the long and high jumping, in order to define those characteristics which underline a purposeful preparation for the take-off phase) to compare kinematically and determine the technical characteristics which are being demonstrated by top level jumpers in their effort to achieve high performances in the long and high jumping, respectively. For this reason, the performances of a long and high jumper, during competition were recorded by two synchronized video-cameras. A subsequent 3-D analysis was performed by a video-motion analysis. The motion analysis of the kinematics chain of the upper and lower extremities with regard to the technique pattern of the take-off phase shows that, in general, the take-off pattern in both the long and the high jump performances look similar. Moreover, it was clearly demonstrated that in the supporting phase prior to the take-off, a vertical acceleration of the centre of gravity (C.G.) took place during the amortization, as well as, during the extension of the supported leg.

Song and Peng (2003) have studied the technique of high jump by Wang Zhouzhou. In this research they carried out a comparison analysis of the technique parameter of the National Track & Field Championship in Shanghai in 1999, and the champion of 6th World Track & Field Championship. They find out the last step to the jumping leg landing, the horizontal speed is lower, the jumper's inside gradient of body is minus when the swing leg landing and take-off the ground. Before the take-off and the beginning of the take-off, the horizontal speed is lower and their driving of ankle and knee is lower at the moment of take-off. In Addition to the above all the bar clearance technique is not economical and efficient are all the fields that he should try the best to improve.

Tan and Yeadon (2005) have studied on why do high jumpers use a curved approach? At present all elite high jumpers use the Fosbury-flop technique with a curved approach. This suggests that the curved approach presents some clear advantage, although there is no general accordance upon the mechanism or the mechanics. This study aimed to determine the characteristics of the approach curve and to investigate how it contributes to generation of somersault rotation. A simple theoretical model was used to show that a tightening approach curve would change the inward lean towards the centre of the curve into outwards lean. 3-D video analysis was used to record the performances of two elite male high jumpers in competition. It was establish that in each case the radius of the approach curve and the inward lean angle both decreased towards the end of the approach. The amount of outward lean angular velocity generated was shown to be a major proportion of the required somersault angular velocity for a jump. It was concluded that the main advantage of a curved approach was that it resulted in the generation of somersault velocity providing the curve tightened towards the end of approach.

Zhang and Li (2008) have studied on a kinematical analysis on Huang Hai-qiang's take-off technique when clearing the height of 2.32m during the 11th IAAF World Junior Championship. The purpose of the study was to study the men's high jump champion, Huang Hai-qiang's take-off technique during the 11th IAAF World Junior Championship from the point of view of 3-D kinematics. The result shows that Huang's three joints of take-off leg hip, knee and ankle are fully pedaled and stretched at the finishing point of his take-off, but the swinging velocity of his two arms and a swinging leg is rather low and the swinging range is relatively small, the absolute value of his horizontal velocity and vertical velocity is relatively low in the instant of take-off and the low vertical speed is the main reason to hamper his athletic improvement; there is no obvious difference from international elite high jumpers on the time of take-off, the highest point of his body's center of gravity (C.G.) is at the back of the horizontal pole and the length of his last step is relatively short.

Ashby and Delp (2006) have studied on optimal control simulations reveal mechanisms by which arm movement improves standing long jump performance. Optimal control simulations of the standing long jump were developed to gain insight into the mechanisms of improved performance due to arm motion. The activations that maximize standing long jump distance of a joint torque activated 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 mts) than when it was restricted (1.60 mts). 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 (C.G.). Some of the performance improvement in the free arm jump was attributable to the ability of the jumper to swing the arms backwards during flight phase to alleviate excessive forward rotation and position the body segments appropriately for landing. In restricted arm jumps, the excessive forward rotation was avoided by ‘holding back’ during 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 the free arm movement.

Ashby and Heegaard (2002) have studied on the role of arm motion on the performance of the standing long jump. 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 the landing (TD) positions. The subjects jumped 21.2% further on an average with the arm movement (2.09 ± 0.03m) than without (1.72 ± 0.03m). Seventy-one percent of the increase in performance in JFA was attributable to a 12.7% increase in the take-off velocity of the center of gravity (C.G.). Increases in the horizontal displacement of the centre of gravity (C.G.) before take-off and in the horizontal position of the toe with respect to the centre of gravity (C.G.) 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 centre of gravity (C.G.) by swinging the arms backwards during the flight phase. Without freedom to swing the arms during flight, the subjects had to eliminate any excessive forward rotation while still in contact with the ground. This tendency in JRA was manifest in the premature decline in the vertical ground reaction force and the development of a counterproductive backward rotating moment about the centre of gravity (C.G.).

Bridgett and Linthorne (2006) have studied on changes in long jump take-off technique with increasing run-up speed. The aim of the study was to determine the influence of run-up speed on take-off technique in the long jump. Seventy-one jumps by an elite male long jumper were recorded in the sagittal plane by a high speed video camera. A wide range of run-up speed was attained using direct intervention to set the length of the athlete's run-up. As the athlete's run-up speed increased the jump distance and take-off speed increased, the leg angle at touchdown remained almost unchanged, and the take-off angle and take-off duration steadily decreased.

Bridgett, Galloway and Linthorne (2002) have studied on the effect of run-up on long jump performance**.** A male long jumper with a personal best performance of 8.25 mts was recruited for the study. The athlete jumped for maximum distance a number of times using his normal competition run-up speed and then several more times using shorter and slower run-ups. The jump distances were measured with a fiberglass tape and the jumps were recorded in the sagittal plane with a high-speed video camera operating at 100 Hz. An Ariel Performance Analysis System was then used to determine the horizontal speed of the athlete's centre of mass (COM) in the last stride before take-off. The relation between run-up speed and jump distance obtained using technique intervention study was clearly different from that for the cross-sectional study of Hay (1993). A difference is to be anticipated because of the different aims and designs of two studies. The cross-sectional study considered many jumpers of different ability, from mediocre high school athletes (lower left) through to elite male athletes (upper right). These athletes were trying to achieve their maximum possible distance. That is, the data points are maximum (or near-maximum) performances, where the athlete has used a self-selected jumping technique that was intended to be close to the optimum for athlete's physical capabilities. (In long jumping, the optimum technique is usually to use the fastest possible run-up and to spring upwards as much as possible at take-off). Run-up speed has a strong influence on long jump performance and so speed training and strength training are necessary components of a long jumper's training program. The use of results from cross-sectional studies may lead to unsuitable or inaccurate conclusions for the individual athlete.

Chow and Hay (2005) have studied on computer simulation of the last support phase of the long jump. The purpose of this research was to observe the interacting roles played by the approach velocity, the explosive strength (represented by vertical ground reaction force) and the change in angular momentum about a transverse axis through the jumper's center of mass (δHzz) during last support phase of the long jump, using a computer simulation technique. A 2-D inverted-pendulum-plus-foot segment model was developed to simulate the last support phase. Using a reference jump derived from a jump performance reported in the literature. The effects of varying individual parameters were studied using sensitivity analyses. In each sensitivity analysis, the kinematic characteristics of the longest jumps with the δHzz considered and not considered when the parameter of interest was altered, were noted. A sensitivity analysis examining the influence of altering both approach velocity and VGRF at same time was also conducted. The major findings were that i) the jump distance was more sensitive to changes in approach velocity (e.g., a 10% increase yielded a 10.0% increase in jump distance) than to changes in the VGRF (e.g., a 10% increase yielded a 7.2% increase in jump distance); ii) the relatively large change in jump distance when both the approach velocity and VGRF were altered (e.g., a 10% increase in both parameters yielded a 20.4% increase in jump distance), suggesting that these two parameters are not independent factors in determining the jump distance; and iii) the jump distance was overestimated if the δHzz was not considered in the analysis.

Georgios, Moscha, Georgios, Thomas and Kollias (2009) have studied angular momentum and landing efficiency in the long jump. The purpose of the study was to compare the 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 2-D 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 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 $kg{\cdot}m^2{\cdot}s^{-1}$; hitch kick: -22.69 $kg{\cdot}m^2{\cdot}s^{-1}$; $P<0.001$) 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 the 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 two arms during take-off.

Graham and Lees (2005) have studied on 3-D kinematic analysis of the long jump take-off. Two models exist in the study which defines the relationship between selected variables that affect performance. Fourteen male long jumpers were filmed using 3-D 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 the 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 two models. These variables could be interpreted in terms of the speed, technique and strength. We concluded that in the long jump, variables that are essential to performance are interdependent and can only be identified by using appropriate statistical techniques. This has implications for a better understanding of long jump event and it is likely that this finding can be generalized to other technical sports skills.

Hay (1986) has studied on biomechanics of the long jump. The important aspects have received relatively little attention on the accuracy of the approach, the technique used during the final strides of the approach, the role of elastic energy in the take-off, the initiation and control of the jumper's angular momentum and the techniques used in the landing. The methods used to gather data in the studies reviewed have been rather unimaginative. 2-D cinematography has been used in the vast majority of the studies and force platforms in a few. Other data-gathering procedures like 3-D cinematography, electromyography and accelerometry 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 the study by Ballreich, few papers have involved anything more sophisticated than means, standard deviations (SD), correlation coefficients and an occasional multiple regression equation. Given these facts, it is hard to avoid the conclusion that our knowledge of the 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 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 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, the future progress in this area of sports biomechanics is likely to be very slow.

Hay and Nohara (1990) have studied on techniques used by elite long jumpers in preparation for take-off. It was hypothesized that some characteristics of the positions adopted by long jumpers during 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 touch-down and/or the vertical velocity at take-off. Trials by twenty male and twenty six female long jumpers were recorded cinematographically and subsequently analyzed. The take-off distance for the fourth-last stride, the landing distance for the last stride, and the height of the center of gravity (C.G.) at take-off into 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 C.G. at take-off into the jump. Considered alone, they were not influential in determining the distance of jump.

Hay, Miller and Canterna (1986) have studied on the techniques of elite male long jumpers. A model was developed to identify the characteristics of the long jumping technique that determine the distance of the jump. The performances of the finalists in the TAC (U.S. National) Championships were recorded cinematographically and the best trials analyzed. The results indicated that the relative lengths of last two strides of the approach are poor indicators of success in the event. Maximum horizontal velocities were usually achieved at take-off into the third or second last stride and not exclusively during the second last stride, as previously reported. None of the subjects had either a zero or upward vertical velocity of the center of gravity (C.G.) at touchdown of the foot for take-off into the jump, contrary to an argument occasionally advanced. The greatest percentages of the variance in the distance of the jump were accounted for by the horizontal velocity at take-off into the fourth last stride, the change in horizontal velocity during the next support phase, the horizontal and resultant velocities at take-off and the flight distance.

Hussain, Khan, Mohammad, Bari and Ahmad (2011) have studied on the kinematical parameters of male and female intervarsity long jumpers. The purpose of this research was to compare selected kinematical parameters of male and female long jumpers. A total twelve (six male and six female) All India Intervarsity level long jumpers were randomly selected from the All India Intervarsity Athletic Championship, held at Chennai, India as subject. To obtain kinematical data two digital Sony DCR SX40E video recording cameras, operating at 1/2000 with a frame rate of 60 f/s, were used during the event. The selected kinematics variables for this research were approach speed, last stride length, velocity of last stride, angle of foot planting, knee angle at take-off and total covered distance. For capturing movement and motion of the athlete, one camera was placed at a distance of ten meter right side of the run way mounted at a height of three feet used to capture approach run, other camera was used to capture the last stride, foot planting and take-off of the jumpers which was placed perpendicular at a distance of seven meters on the right side of the take-off board, the height of the camera was set four feet from the ground. All jumps performed by the selected jumpers during competition were recorded and best valid jump for each athlete was selected for further analysis. The recorded video footages were downloaded, slashed and edited by using downloaded version of

STHVCD55 software. Digitization, smoothing and analysis were conducted using the Silicon Coach Pro7 motion analysis software. Obtained data were subjected to an independent sample t test for the comparison of the kinematics parameters between male and female jumpers. All statistical procedures were conducted using the SPSS (16.0) software. A level of significance was set at 0.05. Results of the study revealed that, there were significant differences found between male and female intervarsity level long jumpers in their last stride length, velocity of last stride, take-off leg knee angle and total covered distance, where as insignificant differences were examined between male and female intervarsity level long jumpers in their approach run speed and angle of foot planting. On the basis of the results it is concluded that the male and female both exhibited same approach run speed and angle of foot planting but the male athlete yielded good result as their total covered distance was more than female, this is just because of males possesses greater muscles strength than females.

Hussain, Khan and Mohammad (2011) have studied on the analysis of selected kinemetical parameters of two different level male long jumpers. The purpose of this article was to compare the selected kinematical variables of intervarsity and interschool level long jumpers. A total of twelve (6 intervarsity and 6 interschool level) long jumpers were selected for the study as subjects. To acquire kinematical data two digital Sony DCR SX40E video recording cameras, operating at 1/2000 with a frame rate of 60 frames per second, were used during the respected events. The selected kinematics variables for this research were approach speed, last stride length, velocity of last stride, angle of foot planting, knee angle at take-off and total covered distance. For capturing the movement and motion of the athlete, one camera was placed at a distance of ten meters right side of the run way mounted at a height of five feet used to capture approach-run, second camera was used to capture the last stride, foot planting and take-off of the jumpers which was placed perpendicular at a distance of seven meters on the right side of the take-off board, the height of the camera was set five feet from the ground. All jumps performed by the selected jumpers during competition were recorded and best valid jump for each athlete was selected for further analysis. The recorded video footages were downloaded, slashed and edited by using the downloaded version of the STHVCD55 software. Digitization, smoothing and analysis were conducted using the Silicon Coach Pro-7 motion analysis software. Acquired data were subjected to an independent sample t-test for the comparison of the kinematics variables between intervarsity and interschool male long jumpers. All statistical procedures were conducted using the SPSS (16.0) software. A level of significance was set at 0.05. Results of the study revealed that there were significant differences between intervarsity and interschool level long jumpers in their approach run speed, velocity of last stride and total covered distance where as insignificant differences were examined between intervarsity and interschool level long jumpers in their last stride length, take-off leg knee angle and angle of foot planting. On the basis of the results it is concluded that intervarsity and interschool level long jumpers both exhibited almost same angle of foot planting. Intervarsity athlete yielded good result as their approach-run speed velocity of last stride and total covered distance than interschool level jumpers. This might be due to the reason that training age of the intervarsity jumpers was higher than the interschool level long jumpers.

Nolan, Patritti and Simpson (2004) have studied on a biomechanical analysis of the long jump technique of elite female amputee athletes. The purpose of this study was to investigate whether female lower limb amputees conform to established long jump model and to compare the kinematics of the approach-run and take-off phases for elite female transfemoral and transtibial amputee long jumpers. Eight female transfemoral and nine female transtibial amputee athletes were videotaped (sagittal plane movements at 50 Hz) from third-to-last step to take-off during the 2004 Paralympic Games long jump finals. After digitizing and reconstruction of 2-D coordinates, key variables were calculated at each stride and during contact with take-off board. Additionally, approach speed during the run-up of each jump was recorded (100 Hz) using a laser Doppler device (LDM 300 C Sport, Jenoptik Laser, Jena, Germany). The transfemoral amputees had a consistently higher center of mass (COM) 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 (COM) 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 touch-down and may have inversely affected their jump performances. 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 touch-down onto the take-off board. It is recommended that coaches and athletes continued with caution when trying to replicate techniques used by able-bodied athletes because adaptations to the constraints of prosthesis should be considered.

Lees, Fowler and Derby (1993) have studied on a biomechanical analysis of the last stride, touch-down and take-off characteristics of the women's long jump. This research was concerned with the measurement of a selection of performance variables from competitors in the women's long jump final of the World Student Games held in Sheffield, UK in July, 1991. Several performances of each of six finalists were recorded on cine film at 100 Hz. Resulting planar kinematic data were achieved for the last stride, touch-down and take-off. For 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 calculate 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 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 the 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 the evidence for mechanical, biomechanical and muscular mechanisms. The former relates to the generation of vertical velocity by body riding over the base of support; second is the elastic re-utilization of energy; and third is the contribution by concentric muscular contraction.

Linthorne, Bridgett and Guzman (2005) have studied on optimum take-off angle in the long jump. In this study, they establish that the optimum take-off angle for a long jumper may be predicted by combining the equation for the range of a projectile in free flight with the measured relations between take-off speed, take-off height and take-off angle for the jumper. The prediction method was evaluated using video measurements of three experienced male long jumpers who performed maximum effort jumps over a wide range of take-off angles. To produce low take-off angles the jumpers used a long and fast run-up, whereas higher take-off angles were produced using a progressively shorter and slower run-up. For all three jumpers, the take-off speed decreased and the take-off height increased as the athlete jumped with a higher take-off angle. The calculated optimum take-off angles were in good agreement with the jumpers' competition take-off angles.

Luhtanen and Komi (1979) have studied on mechanical power and segmental contribution to force impulses in long jump take-off. Changes in total mechanical work, it’s partitioning into different energy states, mechanical power, force time characteristics, force impulses of body segments and mass center's pathway characteristics during long jump take-off were investigated on four national and six ordinary level jumpers. Both cinematographic and force platform techniques were used. The data showed that the national level jumpers had higher run-up and higher take-off (release) velocities in horizontal and vertical directions. In addition, they were able to utilize efficiently the elastic energy stored in leg extensor muscles at take-off impact. This was seen in high support leg eccentric and concentric forces, which were produced in short contact times. The ordinary level jumpers had greater variability in the investigated attributes, and they reached their maximum length of jumps in numerous different ways. Cinematically the greatest difference between the subject groups was examined in the timing of the various body segment movements. In better athletes all the body parts (arms, trunk and legs) had decelerating horizontal impulses, but in all ordinary level jumpers the horizontal impulse of the swing leg was accelerating during take-off.

Panoutsakopoulos and Kollias (2009) have studied on biomechanical analysis of the last strides, the touchdown and the take-off of top Greek male and female long jumpers. The purpose of this study was to compare the technique of top Greek male and female long jumpers and to examine their technique using as reference biomechanical characteristics of the elite international jumpers. 2-D kinematic data from top ten Greek male (25.4 ± 3.0 years) and top twelve Greek female (25.5 ± 4.3 years) long jumpers were video recorded while participating in the 2007-Greek National Championships finals. A qualitative assessment of the long jump technique was also conducted. Application of Principal Components Analysis did not reveal a solid 'speed' or 'vertical impulse' dependency of performance. However, the top three jumpers were clearly identified as the 'faster and stronger' jumpers ($p < 0.05$). The attained values suggested that top Greek long jumpers were inferior compared to corresponding values reported for elite international jumpers. However, the examined jumpers performed their jumps without any obvious technical mistakes. Track and field coaches of elite Greek athletes should modify training so that the athletes can better utilize their velocity at take-off during long jumping.

Ricardo, Barros, Mercadante, Lara, Sakalauskas, Sergio, Tiago and Milton (2007) have studied on 3-D kinematical analysis of long jump in the 'Gold Meeting Rio of Athletics 2007'. The study was based on the 3-D kinematical analysis of long jump in an official competition of the International Association of Athletics Federation. A six camera kinematical analysis system was used to reconstruct the 3-D coordinates of eighteen points, modeling the athlete's body with the follow segments: head, trunk, arms, forearms, thighs, calves and feet. Several performance variables concerning the center of mass (COM) trajectories and velocities were used to characterize and compare the individual jumps. Descriptive statistics was used to compare the results obtained with those found in the literature.

Seyfarth, Friedrichs, Wank and Blickhan (1999) have studied on dynamics of the long jump. A mechanical model is proposed which quantitatively describes the dynamics of 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 explain the active peak of the force time curve and a distal mass coupled with non-linear visco-elastic elements to explain the passive peak. The influence of the positions and velocities of the supported body and the jumper's leg as well as of systemic parameters such as leg stiffness and the mass distribution on the jumping distance were investigated. The techniques for optimum operation are identified: (i) There is a minimum stiffness for optimum performance. Further increase of the stiffness does not lead to longer jumps. (ii) For any given stiffness there is always an optimum angle of attack. (iii) The same distance can be achieved by different techniques. (iv) 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. (v)

Thus, increasing the touch-down velocity of the jumper's supporting leg increases the jumping distance.

Seyfarth, Blickhan and Van (2000) have studied on optimum take-off techniques and muscle design for long jump. A two-segment model based on Alexander (1990; Phil. Trans. R. Soc. Lond. B 329, 3-10) was used to investigate the action of the knee extensor muscles during long jumps. A more realistic representation of the muscle and tendon properties than implemented previously was necessary to demonstrate the advantages of eccentric force enhancement and the non-linear tendon properties. During the take-off phase of long jump, highly stretched leg extensor muscles are able to generate required vertical momentum. Thereby, serially arranged elastic structures may increase the duration of muscle lengthening and dissipative operation, resulting in an enhanced force generation of muscle-tendon complex. To attain maximum performance, athletes run at maximum speed and have a net loss in mechanical energy during the take-off phase. The positive work done by the concentrically operating muscle is clearly less than the work done by the surrounding system on the muscle during the eccentric phase. Jumping performance was insensitive to changes in tendon compliance and muscle speed, but was greatly influenced by the muscle strength and eccentric force enhancement. In agreement with a variety of experimental jumping performances, the optimal jumping technique (angle of attack) was insensitive to the approach speed and to muscle properties (muscle mass, the ratio of muscle fiber to tendon cross-sectional area, relative length of fibers and tendon). The muscle properties also restrict the predicted range of angle of the velocity vector at take-off.

Stefanyshyn and Nigg (1998) have studied the contribution of the lower extremity joints to mechanical energy in running vertical jumps and running long jumps. The energy contribution of lower extremity joints to vertical jumping and long jumping from a standing position has previously been investigated. However, the resultant joint moment contributions to the vertical and the long jumps performed with a running approach are unknown. Also, the contribution of the metatarsophalangeal joint to these activities has not been examined. The objective of this research was to determine the mechanical energy contributions of the hip, knee, ankle and metatarsophalangeal joints to running long jumps and running vertical jumps. A sagittal plane analysis was performed on five male university basketball players while performing running vertical jumps and four male long jumpers while performing running the long jumps. The resultant joint moment and power patterns at the ankle, knee and hip were similar to those reported in the literature for the standing jumps. It appears that the movement pattern of the jumps is not influenced by an increase in horizontal velocity before take-off. The metatarsophalangeal 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 the long jumping as the energy contribution of the hip increased.

Thomas, Luis and Wolfgang (2001) have studied the analysis of the long jump technique in the transition from approach to take-off based on time-continuous kinematic data. In this investigation, a pattern recognition approach was applied to analyze the movement structure during the last strides of the approach run and the jump. Time-continuous kinematic data of 57 trials (4.45 – 6.84 m) was analyzed. Cluster analysis identified at coarse level different movement patterns for each flight and the support phase. Above these structural differences, individual movement patterns were diagnosed, especially for jump. Further, the contribution of single variables on the differences of the complex movement patterns was determined by discriminant analysis. Based on the results, conclusions were drawn concerning the long jump and individuality in training. Overall, the applied pattern recognition method allows for the identification of structural changes of the movement patterns as well as the individual movement styles.

Vega, Aguilera, Puzzella and Mallamaci (2007) have studied on an alternative strategy to teach Biomechanics: The long jump. The work develops an alternative methodology to teach the Physics principles of Parabolic Cannon Shot in the career of Bioengineering using instead the physic-biological relationship of long jump performed in Athletics. This is a closer-to-reality example for this discipline, and it is a field and computer laboratory reproducible practice that is simple to do by using affordable technology, because practice can be filmed by the students in a real setting for future analysis off classroom hours. The data extracted from the film can be analyzed and used to learn the physics of motion of the participating athletes and to draw conclusions from their hands-on experience. As a main factor of the proposal, this latter characteristic aims at motivating the students to work and participate within a collaborative framework so as to motivate them to reason and respond the questionnaire issues that stems from a real experience. A significant improvement of knowledge transference is thus achieved by promoting teaching through reality-based perception, analysis and learning. This work is undergoing its first stage, and its conclusions arise from the observations on team-work dynamics.

Wakai and Linthorne (2005) have studied on optimum take-off angle in the standing long jump. The aim of this study was 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 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.

Wang and Wei (2005) have studied on biomechanical study on the muscles specific abiuties of take-off in long jump. Through using the method of biomechanical theory and experimental research, the paper studied the specific ability characteristics of take-off leg muscles in the long jump. Seven male long jumpers were required to complete the running long jump. Kinematics and dynamics data were from the biomechanical investigation. The Inverse Dynamics' method was used to calculate the muscles moment of hip, knee and ankle of the take-off leg. The result showed that the ability of quick eccentric contraction of hip was important in the take-off. The knee was shown the characteristics of fore-support push in take-off. The ability of concentric contraction of knee's extensors played a very important part in getting vertical velocity. The larger peak of knee f1exion moment emerged in earlier take-off phase that indicated the knee flexion muscles actively contracted in this period.

Wu, Wu, Lin and Wang (2003) have studied on biomechanical analysis of the standing long jump. The purposes of the study were to (i) investigate the effects of arm movement and initial knee joint angle employed in the standing long jump by the ground reaction force analysis and 3-D motion analysis; and (ii) investigate how the jump performance of the female gender related to body configuration. Thirty four healthy adult females performed standing long jump on a force platform with full effort. Body segment and joint angles were analyzed by 3-D motion analysis system. Using kinetic and kinematic data, the trajectories on mass center of body, knee joint angle, magnitude of peak take-off force, and impulse generation in the preparing phase were calculated. Average standing long jump performances with free arm motion were +1.5 times above performance with restricted arm motion the in both knee initial angles. The performances with knee 90^{o} initial flexion were +1.2 times above performance with knee 45^{o} initial flexion in free and restricted arm motions. Judging by trajectories of the center mass of body (COM), free arm motion improves jump distance by anterior displacement of the COM in the starting position. The take-off velocity with 90^{o} knee initial angle was as much as 11% higher than in with 45^{o} knee initial angle. However, the take-off angles on the COM trajectory showed no significant differences between each other. It was found that starting jump from 90^{o} bend knee relatively extended the time that the force is applied by the leg muscles. To compare the body configurations and jumping scores, there were no significant correlations between jump scores and the anthropometry data. The greater muscle mass or longer leg did not correlated well with superior jumping performance.

Gutierrez, Campos and Navarro (2009) have studied on a comparison of two landing styles in a two-foot vertical jump. The aim of this study was to identify the differences between the two styles. Twenty-three subjects participated in the study, of whom fourteen were volleyball players and nine were basketball players. The jumping performances were video recorded and synchronized with two force platforms at 250

Hz. Two temporal periods of the take-off were defined according to reduction or increase in the radial distance between the center of gravity (C.G.) and the foot support (T - RD_{CG} and T + RD_{CG}, respectively). The findings produced no specific advantages when both styles were compared with respect to take-off velocity and consequently, to jump height, but take-off time was significantly shorter ($p < 0.001$) in the hop style take-off. However, this reduction was compensated for by greater time employed in the last step of the approach run ($p < 0.001$). When the step-close style was used, the vertical velocity of C.G. at the beginning of the take-off is significantly lower. Moreover, the mean vertical force developed during T - RD_{CG} was reduced by -627.7 ± 251.1 N, thus lessening impact on the landing. Horizontal velocity at the end of the take-off is less when the step-close style is used ($p < 0.005$), suggesting that this style is better for jumps where it is necessary to move horizontally during the flight against an opponent.

Ham, Knez and Young (2007) have studied on a deterministic model of the vertical jump. In an attempt to understand the factors that influence vertical jump performance, an extensive analysis was undertaken using deterministic model. Once identified, practical training strategies enabling improvement in these factors were explicated. Our analysis showed that a successful vertical jump performance was the result of a complex interplay of run-up speed, reactive strength, concentric action power of the take-off leg(s), hip flexors, shoulders, body position, body mass and take-off time. Our analysis showed that the concentric action power of the legs was critical factor affecting stationary double leg vertical jumps, whereas reactive strength was critical component for a single leg jump from a run-up.

Harman, Rosenstein, Frykman, and Ricard (1990) have studied on the effects of arms and countermovement on vertical jumping. For determination of their effects and interaction, 18 males jumped for the maximal height from a force platform in all four combinations of the arm-swing/no-arm-swing and countermovement/no-countermovement. For all jumps, vertical velocity peaked 0.03 sec before and dropped 6-7% by take-off. Peak positive power averaged over 3,000 W and occurred about 0.07 sec before the take-off, shortly after peak vertical ground reaction force (VGRF) and just before peak vertical velocity. Both countermovement and arm-swing significantly ($P < 0.05$) improved the jump height, but the effect of arm-swing's was greater, enhancing peak total body center of mass (TBCOM) rise both pre and post take-off. Countermovement only affected the post-take-off rise. The arm-swing resulted in higher peak VGRF and peak positive power. During the countermovement, the use of arms resulted in less unweighting, slower and the less extensive TBCM drop, and less negative power. Countermovement increased pre take-off jump duration by 71-76%, increased average positive power and yielded large positive and negative impulses. High test-retest reliability was shown for the jump descriptive variables. Body weight together with peak post take-off TBCM rise effectively predicted peak power (multiple R2 = 0.89, standard error of estimate = 243 W). The results lend insight into which jumping techniques are most appropriate for given sports situations and indicate that a jump test can effectively be used to estimate peak power output.

Holcomb, Lander, Rutland, Wilson and Dennis (1996) have studied on biomechanical analysis of the vertical jump and three modified plyometric depth jumps. The plyometric depth jump (DJ involves hip extensors far less than the countermovement jump (CM), thus DJ may not sufficiently train the hip extensors. This research sought to develop a DJ that would demand more from hip extensors. Specific jumps were also developed for the ankle and knee extensors. Subjects, eleven college-age men, performed CMJ and DJ from a height of 50 cm. Data was collected to determine the net joint moments, power, and work about the joints. Variables were calculated during the down and the up phases and for the entire jump. Maximum moment and power values were calculated for each joint. ANOVAs were used to compare the selected variables from

DJ to the corresponding variables in CMJ. All the variables from the selected joints were greater with DJ and 29 of the 33 comparisons were significantly different ($p <= 0.05$). The corresponding joint moments for ankle, knee and hip depth jumps were significantly greater than for CMJ. The modified plyometric jumps were shown to enhance the contribution of the muscles that extend ankle, knee, and hip.

Lees, Vanrenterghem and Clercq (2004) have studied on how an arm swing enhances performance in the vertical jump. This research was conducted to examine the various theories that have been proposed to explain the enhancement of jumping performance when using an arm swing compared to when no arm swing is used. Twenty adult male athletes were asked to perform a series of maximal vertical jumps while using an arm swing and again while holding their arms by their sides. Force, motion and the electromyographical data were recorded during each performance. Participants jumped higher (0.086 m) in the arm swing compared to the no-arm swing condition and was due to increased height (28%) and velocity (72%) of the center of mass (COM) at take-off. The increased height at take-off was due to the elevation of the arm segments. The increased velocity of take-off stemmed from a complex series of events which allowed arms to build up energy early in the jump and transfer it to the rest of the body during the later stages of the jump. This energy came from the shoulder and elbow joints as well as from the extra work done at the hip. This energy was used to (a) increase the kinetic and potential energy of the arms at take-off, (b) store and release energy from the muscles and tendons around the ankle, knee and hip joint, and (c) 'pull' on the body through an upward force acting on the trunk at shoulder. It was concluded that none of the prevailing theories exclusively explains the enhanced performance in the arm swing jump, but rather the enhanced the performance is based on several mechanisms operating together.

McCaulley, Cormie, Cavill, Nuzzo, Urbiztondo and McBride (2007) have studied on mechanical efficiency during repetitive vertical jumping. The purpose of this investigation was to compare mechanical efficiency between repeated static jumps (SJ), countermovement jumps (CMJ), drop jumps from 75% of maximum CMJ jump height (75DJ) and drop jumps from 125% of maximum CMJ height (125DJ). The subjects included eight jump-trained males. All subjects completed 30 continuous repetitions in the SJ, CMJ, 75DJ, and 125DJ. Oxygen consumption, peak force and center of mass (COM) displacement for each repetition during the four jumping patterns were measured. M.E. was calculated from a combination of force-time curves, displacement-time curves and lactate-corrected oxygen consumption values. In addition, muscle activity was recorded from the vastus medialis, vastus lateralis and biceps femoris using the surface electromyography (EMG). 125DJ and 75DJ resulted in significantly (P < or = 0.05) greater M.E. in comparison to CMJ and SJ. CMJ resulted in significantly greater M.E. in comparison to SJ. In addition, braking phase muscle activity was significantly greater in 125DJ and 75DJ in comparison to CMJ. Negative work was significantly different between 125DJ, 75DJ and CMJ (125DJ > 75DJ > CMJ). There was a significant positive correlation (r = 0.68) between M.E. and negative work performed across 125DJ, 75DJ and CMJ. These findings suggest that stretch-shortening cycle movements, which include a strenuous braking phase combined with the simultaneous high muscle activity, increase M.E. This may be due to the optimal muscle-tendon unit kinetics and usage of stored elastic energy.

Nolan and Lees (2000) have studied on touch-down and take-off characteristics of the long jump performance of world level above and below-knee amputee athletes The aims of this research were to establish the take-off characteristics of long jump performance of disabled amputee athletes and to establish to what extent amputee athletes conform to a model of performance defined for elite able-bodied athletes. The jumps of eight male below-knee (trans-tibial) and eight male above-knee (trans-femoral) amputee athletes who competed in the finals of long jump at the

1998 World Disabled Championships were recorded in the sagittal plane on video (50 Hz). Approach speed was measured using a Laser Doppler System. The best jump for each athlete was digitized and kinematic data from the key instants of touch-down (TD), maximum knee flexion (MKF) and take-off (TO) were obtained. Amputees demonstrated a lower approach speed and jumped less far than able-bodied athletes although below-knee amputees performed better than above-knee amputees. For each amputee group there was a significant ($p < 0.05$) linear relationship between approach speed and distance jumped. With exception of their slower horizontal speed and greater negative vertical speed at touch-down, below-knee amputees demonstrated characteristics of technique that were similar to elite able-bodied long jumpers. Above-knee amputees at touch-down had a more upright trunk, smaller hip and the knee angles and consequently a smaller leg angle. This was attributed to the difficulty of taking off on the last stride on prosthetic limb. Consequently, above-knee amputees were less able to gain vertical velocity during compression (TD-MKF) phase, but were able to compensate for this by using a greater hip range of motion during the extension (MKF-TO) phase. It was concluded that below-knee amputees displayed the same basic jumping technique as elite able-bodied long jumpers but above-knee amputees did not. These findings have implications for the training and technical preparation of the amputee long jumpers.

Robertson and Fleming (1987) have studied on kinetics of standing broad and vertical jumping. The purpose of this research was to determine the contributions made by the leg muscle groups to the external mechanical work done in the standing broad and the vertical jumping. Six subjects were filmed jumping from a force platform. Linked-segment analysis and inverse dynamics methods were used to calculate the muscle moments of force and power and work output created by these moments of force. The results support the principle that all three extensor moments of force summate in both types of the jumping but that the sequence of contractions was not from proximal muscles to distal as is stated by the continuity principle. Instead all three extensor moments act simultaneously to produce the leg extension. The contributions made by the three muscle groups were not the same for two types of jumps. For the propulsive phase of the standing broad jump the contributions of the hip, knee and ankle muscles were 45.9%, 3.9%, and 50.2%, respectively, whereas, for the vertical jump the contributions were 40.0%, 24.2%, and 35.8%, respectively. These results indicate that broad jumping utilizes the muscle groups differently than vertical jumping and show importance of the hip and ankle musculature in the production of external work in the jumping.

Vanezis and Lees (2005) have studied on a biomechanical analysis of good and poor performers of the vertical jump. The aim of this research 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 the 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 the hip were computed from these data for the joint moments and power. Generally, better jumpers 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 the greater muscle capability in terms of strength and rate of strength development in the 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 main determinant of vertical jump performance with technique playing a smaller role.

Bing (1999) has studied on horizontal-to-vertical velocity conversion in the triple jump. The aim of this investigation was to determine the effects of selected factors on horizontal-to-vertical velocity conversion in triple jump. An understanding of this conversion is important not only for studies on the techniques of triple jump, but also for the other jumping events. Ten elite jumpers were studied in this investigation. 3-D kinematic data were collected for at least four complete trials in the same competition for each athlete. The loss in horizontal velocity and the gain in the vertical velocity during each support phase were calculated for each trial. The loss in horizontal velocity was found to be a linear function of gain in vertical velocity. The slope of this linear function, A**1**, is referred to as the horizontal-to-vertical velocity conversion coefficient. The loss in horizontal velocity increased as gain in vertical velocity increased. The sensitivity of loss in horizontal velocity to the gain in vertical velocity increased as magnitude of A**1** increased.

Fukashiro, Senshi, Timoto, Yuji, Kobayashi, Hirokazu, Miyashita and Mitsumasa (1981) have studied on the triple jump. The purpose of this investigation was to investigate the triple jump from the viewpoint of the velocity of the center of gravity (C.G.) and the mechanical energy. Eight 16 mm cameras were used to film the whole motion of fifteen triple jumpers from the end of the run-up to the landing of the jump. The horizontal velocity decreased during the first half of each take-off and increased during second half. However, the absolute value of the velocity decreased from hop-to-step and from step-to-jump. The vertical velocity increased at an almost constant rate during each take-off. The maximum height of the center of gravity (C.G.) was similar during the flights in the hop and the jump and in the step it was approximately 10% lower than in the hop and the jump. The mechanical energy decreased after each take-off. Four percent of mechanical energy acquired during the run-up was lost during take-off for the hop. The maintenance ratio was much lower (approximately 85%) for the step and the jump.

Hay (1992) has studied on the biomechanics of the triple jump. The purpose of this research was to review the published opinions of coaches and the findings of scientists concerning the techniques used in the triple jump and to identify promising avenues for future research on subject. A model is developed to identify those factors that have a causal role in determining official distance of a triple jump. This model is then used as a basis for the subsequent review. The review itself considers each of biomechanical factors identified in the model, some additional factors reported in literature and selected characteristics of triple jumping techniques. It is concluded that the research on triple jump techniques has been sparse and has had little impact on the practice. Identification of the individual attributes that determine the optimum ratio of the phase distances for the given athlete, the loads to which the supporting legs are subjected and the control of balance during the triple jump are seen as challenging and potentially useful topics of the future research.

Bobbert, Mackay, Schinkelshoek, Huijing, Ingen and Van (1986) have biomechanically analyzed the drop and countermovement jumps. For this study thirteen subject's performance of drop jumps from a height of 40 cm (DJ) and of countermovement jumps (CMJ) was analyzed and compared. From force plate and cine data biomechanical variables including forces, moments, power output and amount of work done were calculated for the hip, knee and the ankle joints. In addition, electromyograms were recorded from five muscles in the lower extremity. The results attained for DJ appeared to depend on jumping style. In a subgroup of subjects making a movement of large amplitude (i. e. bending their hips and knees considerably before pushing off) the push-off phase of DJ closely resembled that of CMJ. In a subgroup of subjects making a movement of the small amplitude, however, the duration of the push-off phase was shorter, values for moments and mean power output at the knees and the ankles were larger, and the mean EMG activity of gastrocnemius was higher in DJ than in CMJ. The findings are attributed to the influences of the rapid pre-stretch of the knee extensors and plantar flexors after the touch-down in DJ. In both subgroups, larger peak resultant reaction forces were found at the knee and the ankle joints, and larger peak forces were calculated for the Achilles tendon in DJ than in CMJ.

Bobbert, Peter, Huijing, Gerrit and Van (1987) have studied on Drop jumping. The influence of jumping technique on the biomechanics of jumping. In the literature, drop jumping is advocated as an effective exercise for the athletes who prepare themselves for explosive activities. When executing the drop jumps, different jumping techniques can be used. In this research, the influence of jumping technique on the biomechanics of the jumping is investigated. Ten subjects executed drop jumps from a height of 20 cm and the counter-movement jumps. For the execution of the drop jumps, two different techniques were adopted. The first technique, referred to as bounce drop jump, required the subjects to reverse the downward velocity into an upward one as soon as possible after the landing. Second technique, referred to as counter-movement drop jump, required them to do this more gradually by making a larger downward movement. During jumping, the subjects were filmed, ground reaction forces were registered and electromyograms were recorded. Results of a biomechanical analysis show that moments and power output about the knee and the ankle joints reach larger values during the drop jumps than during counter-movement jumps. The largest values were achieved during bounce drop jumps. Based on this finding, it was hypothesized that bounce drop jump is better suited than counter-movement drop jump for the athletes who seek to improve the mechanical output of the knee extensors and plantar flexors. Researchers are, therefore, advised to control the jumping technique when investigating the training effects of executing drop jumps.

Bohm, Cole, Bruggemann and Ruder (2006) have studied on contribution of muscle series elasticity to maximum performance in drop jumping. The contribution of the muscle in-series compliance on maximum performance of the muscle tendon complex was investigated using a forward dynamic computer simulation. The model of the human body contains eight Hill-type muscles of the lower extremities. The muscle activation is optimized as a function of time, so that maximum drop jump height is attained by the model. It is shown that the muscle series elastic energy stored in downward phase provides a considerable contribution (32%) to the total muscle energy in the push-off phase. Furthermore, by the return of stored elastic energy all muscle contractile elements can reduce their shortening velocity up to 63% during the push-off to develop a higher force due to their force velocity properties. The additional stretch taken up by the muscle series elastic element allows only rectus femoris to work closer to its optimal length, due to its force length properties. Therefore the contribution of the series elastic element to the muscle performance in maximum height drop jumping is to store and return energy, and at the same time to increase the force producing ability of the contractile elements during push-off.

Kovacs, Istvan, Tihanyi, Jozsef, Devita, Paul, Racz, Levente, Barrier, Jason, Hortobagyi and Tibor (1999) have studied on foot placement modifies kinematics and kinetics during drop jumping. The purpose of this study was to compare lower extremity kinematics and kinetics and muscle activation patterns between drop vertical jumps performed with the heel-toe (HTL) and forefoot (FFL) landings. Ten healthy male university students performed two types of drop jump from a 0.4m high box placed 1.0m from the center of the force plate. They were instructed to either land first on the ball of the feet without heels touching the ground during the subsequent vertical jump, i.e., forefoot landing jump (FFL), or to land on the heels followed by depression of metatarsals, i.e., heel-toe landing jump (HTL). Three successfully performed trials per jump type were included in the analysis. The criteria for selection of the correct jumps was proper foot position at contact as judged from video records and the shape of the force-time curve. The first peak and the second peak determined from the vertical force-time curves were 3.4 times greater and 1.4 times lower for HTL compared with those with FFL ($P < 0.05$). In the flexion phase of HTL, the hip and the knee joints contributed 40% and 45% to the total torque, whereas during FFL the greatest torque contributions were 37% for both the knee and the ankle joints. During the extension phase, the greatest torque contributions to the total torque were 41% and 45% by the knee and the ankle joints during HTL and 34% and 55% during FFL. During the flexion phase, power production was 20% greater ($P < 0.05$) in HTL than in FFL, whereas during the extension phase power production was 40% greater in FFL than in HTL. In the flexion phase of HTL the hip and the knee joints produced the greatest power, and during the extension phase the knee and the ankle joints produced the greatest power. In contrast, during both the flexion and extension phases of FFL, the knee and the ankle joints produced the greatest power. The EMG activity of gluteus, vastus lateralis, and the plantar flexor muscles was similar between HTL and FFL in most cases except for the greater vastus lateralis EMG activity during the pre-contact phase in HTL than in FFL and the greater gastrocnemius activity in FFL than in HTL. Foot placement strategy modifies the individual joint contributions to the total power during the drop jumping.

Yoshinori, Tadao and Shingo (2001) have studied on biomechanical study of human jumping with different take-off angles and jump heights. In this researtch, they investigated the way in which human control the take-off angles and the strength in counter movement jumps, using a high-speed video camera, a force platform and EMG recordings. five university male athletes were selected as the subjects. The joint works and time integrals of EMG of lower limbs were calculated. Close negative correlations were seen between take-off angles and the hip joint work and between the take-off angles and the IEMG of the biceps femoris. This suggests that the forward propulsion needs the hip joint work and activity of the biceps femoris. Close positive correlations were seen between the jump heights and the contribution of the hip joint work to the total work and between the jump heights and the IEMG of the gluteus maximus. This suggests that the upward propulsion needs the hip joint work and the activity of the gluteus maximus.