Chapter -V

Summary, Conclusions and Recommendations

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Summary

The purpose of this study was to investigate the relationship of different selected kinematic variables to success in high jump competitions. The high jump is a technical event. While most people feel that the bar clearance is only important aspect of high jumping, it is not. The run-up/approach is probably the most important aspect of this event (Dapena, 1995). Using the flop high jump technique (which is really the only technique used by the jumpers in these days); the jumper runs a curved approach towards the bar. The foot on the inside of the turn will be the take-off foot and the athlete will actually cross the bar with his back facing the bar (Tan & Yeadon, 2005).

Dick Fosbury, in 1968 Olympics won the gold medal in the high jump using a new and revolutionary technique which now bears his name Fosbury-flop (Whitney, 1992). Despite the initial skeptical reactions from the high jumping community, the new technique quickly gained popularity, and is almost exclusively used by modern high jumpers because this new technique could readily be learned by a new jumper in a few months, compared to the years of training needed to master the straddle style high jump (Hay, 2002 & Whitney, 1992). In the present day high jumping, the Fosbury-flop is the sole technique used by athletes at international as well as national and state level competitions (Hussain, Khan & Mohammad, 2011; Isolehto, Virmavirta, Kyrolainen and Komi, 2003).

Fosbury-flop high jump technique has been divided into three main parts a) run-up, b) take-off and c) flight means bar clearance (Hay, 1993). The run-up phase consists of a 'straight' run-up, perpendicular to the plane of the stands, followed by 'curved' section during the last some steps before take-off (Dapena, 2000). The run-up provides to athlete with optimum position for take-off, moving at a velocity consistent with the athlete's strength and skill (Hay, 1973). The take-off phase has been defined by Isolehto, Virmavirta, Kyrolainen and Komi, 2003 "as a period of time between the instant of take-off foot first touches the ground and the instant it loses contact with the ground". Mechanical aspect of the Fosbury-flop high jump are the peak height of center of mass during the flight over the bar, dependents on the height and vertical velocity of the center of mass at the toe-off instant (Isolehto, Virmavirta, Kyrolainen & Komi, 2003). The height of the jumper's center of mass at instant of toe-off depends on velocity and position at that instant (Dapena, McDonald & Cappert, 1990). A method of performing the flight phase for high jumpers is discussed by (Killing, 1989). This can be interpreted as a kind of preparatory movement introducing and facilitating the immediately following overextension. Correspondingly, within this variant, the hip area performs consecutive movements of extension, flexion, overextension and flexion.

When the researcher went through the literature he observed different studies are conducted on biomechanical analysis of other different phases of high jump as well as long jump technique at international level but none of researchers tried to study the Fosbury-flop high jump technique as a whole. In India, no researches have been undertaken till date in sports biomechanics. In the computer era, the motion analysis software and programming made biomechanical research especially in kinematics, possible to read the sports motion. For this the researcher had chosen this study with the following hypotheses.

The joints angles, linear velocity and angular velocity of different joints at different phases i.e. approach run phase, take-off preparation phase, take-off phase, flight phase, L-position phase and landing phase will influence significantly the high jump performance.

To work on the preceding hypotheses, fifty (50) elite male high jumpers were selected as the subject for the study. The jumpers who performed Fosbury-flop technique in All India and National competition were considered as subject, the selected subjects were initiated through concerned coaches and later direct contact were made the coaches provide names of the potential players who were free of any types of injury. To fulfill the purpose of the study two high speed video recording cameras were used to gather performance of the high jumpers. The video recordings of the jump performance for analysis were selected on the basis of clear jump at qualifying height. Three jumping performances of each jumper were recorded and loaded into the computer. Only one jump of each jumper was considered for further analysis. The filtering, calibration, digitizing, etc. was done with the help of Silicon Coach Pro-7 motion analysis software as well as manually. The basic statistical parameters of all variables were computed in the first phase of data analysis. In the second part Multiple Linear Regression was applied to know the existing relationship. All statistical functions were performed with the SPSS (v.18) software. In all statistical analyses, the significance threshold was set at $p < 0.05$ with 48 degree of freedom.

Results of the study indicated that in the high jumping performance there was significant relationship exist between hip and shoulder joints angles with performance at approach run phase. Significant relationship existed between ankle joint angle and performance at take-off preparation phase. 36% variation in the performance was occurred due to this angle at take-off preparation phase, as well as 4% at approach run phase and 1% variation was documented at take-off, flight, L-position and landing phase. At approach run to take-off preparation, take-off preparation to take-off, take-off to flight and L-position to landing phase a significant relationship was exist between ankle joint linear velocity with performance, 17% variation in the performance was occurred due to ankle joint linear velocity at approach run to take-off preparation phase, 16% at take-off preparation to take-off phase, at take-off to flight phase 11%, at flight to L-position phase 1% and 12% variation in the L-postion to landing phase. The ankle joint angular velocity showed 0.1% variation in the performance at take-off phase, 1% variation at the flight, L-position and landing phase.

A positive insignificant relationship was exist between ankle joint angle and performance at approach run phase, L-position phase and landing phase and a negative insignificant relationship was found at take-off phase and flight phase.

When we see the relationship between stride length and performance, we found that there was a significant relationship exist between stride length and performance.

When we go through the results of this study, we found a significant relationship between knee joint angle with performance at take-off phase, and 4% variation in the performance occurred due to knee angle at approach run phase, 1% at take-off preparation phase, at take-off phase 14%, in flight phase 1%, at L-position phase 3% and 4% at landing phase. A significant relationship exist between knee joints linear velocity with performance at approach run to take-off preparation, take-off preparation to take-off, take-off to flight, flight to L-position and L-position to landing phase and 31% variation in the performance was occurred due to knee joint linear velocity at approach run to take-off preparation phase, 18% at take-off preparation to take-off phase, at take-off to flight phase 8%, in flight to L-position phase 25%, and 11% at l-position to landing phase. Angular velocity of the knee joint documented a significant relationship with performance at take-off and flight phase. Due to the knee joint angular velocity 9% variation observed in the performance at take-off phase, 2% at the flight phase, at the L-position phase 2% and 0% variation in the performance was recorded. A significant relationship was found between knee joint linear velocity and stride length at take-off phase and in the flight phase between knee joint angular velocity and stride length.

An insignificant relationship was observed between knee angle and performance at approach run, take-off preparation, flight, L-position and landing phase. Insignificant relationship was found between knee joint angular velocity and the performance in the L-position and landing phase. There was a significance relationship observed between hip joint angle with performance at approach run phase, significant relationship was depicted between hip joint linear velocity and performance at approach run to take-off preparation, take-off preparation to flight and and flight to L-position phase. At take-off phase significant relationship was exist between hip joint angular velocity and performance, 13% variation in the performance occurred due to hip angle at approach run phase, at take-off preparation phase 5%, at take-off phase 2%, in flight phase 1%, at L-position phase 4% and 0% at landing phase. 45% variation in the performance was observed due to hip joint linear velocity at approach run to take-off preparation phase, at take-off preparation to take-off phase 0.2%, at take-off to flight phase 38%, at flight to L-position phase 28% and 3% at l-position to landing phase. 11% variation in the performance was due to the hip joint angular velocity at take-off phase, at the flight phase 3%, at the L-position phase 6% and 4% at landing phase.

There was insignificant relationship observed between hip joint angle with performance at take-off preparation, take-off, flight, L-position and at landing phase. Insignificant relationship was observed between hip joints linear velocity and performance at take-off preparation to take-off and at L-position to landing phase. Insignificant relationship was documented between hip joint angular velocity with performance at flight, L-position and at landing phase. There was a significant relationship exist between shoulder joint angle and performance at approach run, take-off preparation, take-off and L-position phase. 14% variation in the performance occurred due to shoulder joint angle at approach run phase, at take-off preparation phase 8%, at take-off phase 12%, in flight phase 1%, at L-position phase 20% and 0.3% at landing phase. There was significant relationship exist between shoulder joint linear velocity and performance at approach run to take-off preparation, take-off preparation to take-off, take-off to flight and flight to L-Position. 44% variation in the performance was occurred due to shoulder joint linear velocity at approach run to take-off preparation phase, at take-off preparation to take-off phase 36%, at take-off to flight 27%, in flight to L-position phase 7% and1% variation in the L-position to landing phase.

There was significant relationship exist between shoulder joint angular velocity with performance at flight phase and landing phase and 12% variation in the performance is due to the shoulder joint angular velocity at take-off phase, In the flight phase 23%, at the L-position 5% and 10% variation at landing phase.

Insignificance relationship was found between shoulder joint angle and performance at the flight and at landing phase. At L-position to landing phase insignificance relationship was obtained between shoulder joint linear velocity and performance. In the L-position phase insignificant relationship was found between shoulder joint angular velocity and the performance.

There was significant relationship exist between elbow joint angle with performance at take-off preparation and flight phase and 1% variation in the performance occurred due to elbow joint angle at approach run phase, at take-off preparation phase 13%, at take-off phase 4%, flight phase 11%, at L-position phase 3% and due to elbow angle 0% at landing phase. There was significant relationship exist between elbow joint linear velocity and performance at approach run to take-off preparation, take-off preparation to take-off, at take-off to flight, flight to L-Position and at l-position to landing phase. 28% variation in the performance was occurred due to elbow joint linear velocity at approach run to take-off preparation phase, at take-off phase 44%, at the take-off to flight phase 7%, in flight to L-position phase 13%, and 15% at L-position to landing phase. There was significant relationship exist between elbow joint angular velocity and performance at flight phase and L-position phase. 6% variation in the performance was found due to the elbow joint angular velocity at take-off phase, in the flight phase 7%, at L-position phase 14% and 3% at landing phase.

Insignificant relationship was exist in between elbow joint angle with performance at approach run, take-off, at L-position and landing phase. An insignificant relationship was evident between elbow joint angular velocity and performance at take-off phase and landing phase. There was an insignificant relationship also observed in between elbow joint angle and stride length at take-off, flight, L-position phase and landing phase.

Conclusions

From the obtained results following conclusions drawn:-

- At approach run phase hip and shoulder joints angles have a negative significant relationship with the performance.
- At take-off preparation phase ankle and shoulder angles have positive significant relationship with the performance whereas elbow angle has negative significant relationship.
- Knee and shoulder angles have a positive significant relationship with the performance at take-off phase.
- In the flight phase elbow angle has a positive significant relationship with the performance.
- Shoulder angle has a negative significant relationship with the performance at L-position phase.

- Stride length has a positive significant significant relationship with the performance.
- Ankle, knee, hip, shoulder and elbow joints linear velocity have a positive significant relationship with the performance at approach run to take-off preparation phase.
- Ankle, knee, shoulder and elbow joints linear velocity have a positive significant relationship with the performance at take-off preparation to take-off phase.
- In the take-off to flight phase ankle, knee, hip, shoulder and elbow joints linear velocity have a positive significant relationship with the performance.
- Knee, hip, shoulder and elbow joints linear velocity have a positive significant relationship with the performance at flight to L-position phase.
- In the L-position to landing phase ankle and knee joints linear velocity have a positive significant relationship with the performance whereas elbow joint has negative relationship.
- Knee, hip and shoulder joints angular velocity have a negative significant relationship with the performance at take-off preparation to take-off phase.
- In the take-off to flight phase knee and shoulder joints angular velocity have a positive significant relationship with the

performance and elbow joint angular velocity has negative relationship.

- At the flight to L-position phase only elbow joint angular velocity has a positive significant relationship with the performance.
- Shoulder joint angular velocity has a negative significant relationship with the performance at L-position to landing phase.
- At approach run phase 13% variation in the performance was occurred due to the hip joint angle and 14% due to the shoulder joint angle.
- At take-off preparation phase 36% variation in the performance was reported due to ankle joint angle, 8% due to shoulder joint angle and 13% due to elbow joint angle.
- 14% variation in the performance was documented due to knee joint angle and 12% due to shoulder joint angle at take-off phase.
- In flight phase 11% variation in the performance was evident due to elbow joint angle and very minor variations were documented due to other joints angles.
- At L-position phase it was exhibit that 20% variation in the performance was recorded due to shoulder joint angle.
- 17% variation in the performance was found due to the ankle joint linear velocity, 31% due to knee joint linear velocity, 45% due to hip joint, 44% due to shoulder joint and 28% due to elbow joint linear velocity at approach run to take-off preparation phase.

- 16% variation in the performance was occurred due to ankle joint linear velocity, 18% due to knee joint, 36% due to shoulder joint and 44% due to elbow at take-off preparation to take-off phase.
- In the take-off to flight phase it was found that there was 11% variation in the performance due to ankle joint linear velocity, 38% due to hip joint and 27% due to shoulder joint linear velocity.
- At flight to L-position phase 25% variation in the performance was evident due to knee, 28% due to hip joint and 13% due to elbow joint linear velocity.
- It was exhibit that 12% variation in the performance was recorded due to ankle joint linear velocity, 11% due to knee joint and 15% due to elbow joint linear velocity at L-position to landing phase.
- 11% variation in the performance was occurred due to hip joint angular velocity and 12% due to shoulder joint angular velocity at take-off preparation to take-off phase.
- In the take-off to flight phase there was 29% variation found in the performance due to knee joint and 23% due to shoulder joint angular velocity.
- When we go through at the flight to L-position phase only elbow joint angular velocity showed 14% variation in the performance.

- At L-position to landing phase it was exhibit that 10% variation in the performance was recorded due to shoulder joint angular velocity.

Recommendations

Researches and explorations are not the end in itself, but merely open the way for future investigations. Similarly, the present work is not the end in this area. In fact, all the variables can never be studied in a single research. So the present study was confined to study the biomechanical variables only. The results of the present investigation led to certain possibilities for further researches.

- A similar study may be conducted in consideration both kinetics and kinematics variables.
- A similar study may be conducted on female high jumpers.
- A similar study may be conducted on comparison of male and female high jumpers.
- A similar study may be conducted on International level high jumpers.
- A similar study may be conducted on state level as well as collegiate level male and female long jumpers.
- A similar study may be conducted in 3D analysis instead of 2D analysis with higher degree of freedom.

- A similar study may be conducted to compare considering Indian international to the foreign counterparts. This would provide invariant parameters for the study.
- A similar study may be conducted in different population, sex, and age group at a different skill levels.
- A similar study may be conducted on biomechanical parameters with physiological parameters.
- A similar study may be conducted to investigate the others techniques (Eastern cut-off, the Straddle and the Scissors).
- A similar study may be conducted to the high jumpers with decathlons.
- The similar study may be conducted on other biomechanical parameters.
- A similar study of high jumping may be conducted on a sample of school level subjects from a variety of skill level.
- A longitudinal study may be conducted with college high jumpers comparing to the other.
- A future investigation may have subjects perform multiple jumps with varying approach velocities.

- A future investigation may be conducted varying the approach velocities of high jumpers at different skill levels to predict the optimal approach velocity for each skill level.
- A future investigation may be conducted to see if the lower extremity muscle strength of the plant leg is a predictor of success in high jump.
- A future investigation may be conducted with the camera placed at different angles to the bar looking at the variable of trunk tilt at plant and take-off horizontal velocity, vertical velocity and center of mass at plant expressed as a percentage of body height.
- A future research may be conducted on the single phase of the jump, like approach phase, take-off phase etc.