The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2695 – 2703

# A Biomechanical Analysis of Long Jump Performance and Selected Kinematic Variables at the Landing of Hang Style Technique in Long Jump

**Mrs. Sangita Chakraborty,**
Research Scholar, Jiwaji University, Gwalior, MP, INDIA
**Dr. Arvind Singh Sajwan**,
Professor, Central University of Rajasthan, Ajmer, Rajasthan

**Abstract**
This study has aimed to find analysis of kinematical variables and the performance of the long jump during the landing of Hang style. Kinematical variables have been analyzed in this paper. Later, the standard deviation, mean value, and variable's scores in degree have been discussed in this paper. The primary quantitative research method has been performed in this article paper.

**Keywords:** biomechanical, kinematical variables, long jump, quantitative, hang style

## Introduction

The term biomechanics refers to a science that deals with the mechanical law's application for living particularly to the system of locomotors. On the other hand, biomechanics of sports is defined as a science as well that examines the external along with the internal force of the athlete. Implementation for the athletic movements is utilized and the forces produce the effects. This long-jumping event is known to be the only event of jumping in the original Olympics that has conducted in Ancient Greece. Mathematical processes along with scientific processes are applied during the conduction of the long jump. Long jump generally occurs during those moments when some streams, obstacles, ravines, and streams have come. In the case of the athletes, halters are carried by them that weight between 4.5 kg and 1 kg in their hand during the run to keep the momentum for the athletes; these weights help them as these weights swung forward during the jump. Swinging the weights back and down after the end of the jump changes the gravity of the jumper and also allows the jumper to stretch their legs in an outward position that increases the athlete's distance. The objective related to the study is to analyze the kinematical technique for the hanging style in the long jump. Another Here the angular kinematical variables are known as the independent variables, and the long jump performance is the dependent variable.

## Literature Review

The biomechanical mechanisms behind the long jump involve the things that have been done by the athlete. As an athlete, it is very important to keep him or, her methodological in every step of movement. The approach includes the process of take-off from the ground and the landing that shows the success of the long jump (Elfmark *et al.* 2021). An individual need to consider sessions for training in long jump for understand the techniques that are utilized for

The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2695 – 2703
the measurement of jump. The long jump is considered one of the most difficult events that is held at the games and a great skill is needed to perform this game. The long jumpers are recommended as the sprinter first and they are needed to control their speed after a smooth takeoff. In case the jumper steps over, it has been called disqualified.

**Biomechanical analysis of Long jump**

Different mathematical and scientific processes are involved in the long jump as there are methodological steps involved. The long jump performance is majorly dependent on the various dependent and independent variables (Maćkała *et al.* 2021). Proficiency of the motor influences the results that are achieved and also underestimates the explosive level of power. The standing performance of the long jump is affected by the countermovement level, muscle strength, and maximum joint. Jump distance is insensitive to the starting position that determines the knee flexion in an angle along with the take-off of the trunk's posterior position. The long jump often depends on successful performance and depends on coordination at a higher level for both the segments of the lower and upper body. As the movement of horizontal jumping requires coordination of complex motors, both the lower and upper segments suggest arm motion in the performance of long-jump. Different foot-setting effects are determined for the long jump position. Straddle position of foot placement therefore has started from the instant line for performing the activity. Well-maintained distances are attained for the long jump from the perspective straddle position. Various foot movements are affected throughout the countermovement such as the initial flight phase and the take-off phase. The reaction of the ground forces, take-off velocity, angle of the initial knee joint, and the improvement of the length during the jump is initiated. There are 3 selected activities of electromyography for muscle groups. The jumper needs to be harmonious in their movement to perform the complex flight, dash, and eventual landing. Women long jumpers are able to achieve a distance of jump between 7.5 meters to 6.5 meters (McCosker *et al.* 2019). On the other hand, men jump faster than women and achieve about 9 meters to 8 meters of distance. Common variables such as the velocity, angle of take-off, and resistance are affected generally for the athletes. Though the position of the Athlete does not matter in the case of taking a flight to realize the covered distance. The technique for the phase of the flight does not affect the performance and is dependent on the decision of the jumper. The jumper lands safely after preparing their body for the further extension of their legs, head, and chest.

There are several 4 phases during the procedure of the long jump and these phases deliver the biomechanical analysis for the related jumper (Westermann *et al.* 2020). Every phase related to the jump and its techniques is utilized for defining the performance level. The phase of dashing need to be ample for the athletes for gains the phase of take-off at the utmost velocity. Vertical along with horizontal velocity is measured for the determination of the athlete's mass center along with the angle for taking-off. The long jumper's total traveled distance is calculated during the landing of the jumper. After the landing, the jumper is able to stabilize them to counter the reaction force from the ground. The final jump performance is affected by the landing and flight during the implementation of the technique. Vertical velocity is gained during the phase of take-off and is primarily achieved during the pivoting of the body (Nishimura *et al.* 2019). The impact of vertical force acted to accelerate the body vertically and that leads the body to gain velocity vertically. Hip extension along with the strength of the leg, and abduction strength is strong enough for resisting the impact of the fore hugely on the body during the phase of takeoff. The motion of the trunk is specific for the long jump, especially for the phase of takeoff. In order to maintain the straight position of the trunk, the takeoff for the legs makes it essential for effective pivoting during the phase of takeoff. Compression of the lumber spine can occur due to this takeoff posture. Inclusion of parameters for non-correlated techniques, the takeoff angle is correlated with a remarkable distance and that is also included in the predictive equation. Gender difference in the sector of the long jump refers to a decisive factor. Men as compared to women have attained a higher velocity and that is remarkably modified for the parameters of the steps (Panoutsakopoulos *et al.* 2021). In order to attain a maximum speed with control, the approach is required for the length of the steps consistently. Female sub-elite athletes are shown a remarkable asymmetry in the inter-limb for their steps and set temporal parameters for their last step.

**Analysis of kinematics during long jump**

There are different three approaches to perform for the athlete such as the requirement for accuracy, the requirement for velocity, and the requirement for the position. Long jumpers adjust the position of the body for preparing the take-off during the penultimate stride. The penultimate stride increases the length of the stride and lowers the body-centered mass (BCM). The gained velocity for BCM is generally achieved by the moving action of the body. The further forces that are applied to the foot upwardly help the body to move forward for the run. According to the words of Reddy and Singh (2021), there are several variables such as the kinematic and anthropometrical variables have been selected for the smooth conduction of the study. Variables of anthropometry include the weight, length of the hand, height, length of the upper arm, length of the forearm, length of the foot, and length of the upper leg (Azuma and Matsui, 2021).Kinematical variables refer to the center of gravity of the body during the hanging style of flight technique in the long jump. This also includes the subject's highest performance in the technique of hang-style during the long jump and the subject's speed. Here the subject's speed ranges between the landing and take-off for the long jump related to the technique of hang-style. Variables related to kinematics include the knee joint, ankle joint, joint of the hip, joint elbow, joint of shoulder, joint of the wrist, head inclination angle, and trunk inclination angle. There are mainly four styles used related to the take-off for the jumpers such as the style of kick, the style of double-arm, the take-off sprint, and the power of sprint (Jia *et al.* 2022). Variables of kinematics related to the study have the speed approach, length of stride, foot planting angle, knee angle, and the last stride velocity. Biomechanical studies are shown the technique for the long jump after studying the characteristics of kinematics. Long jumpers also have the dynamic characteristics of take-off that refer to the most important part and generator of the result of the long jump.

The parameters of kinematics are obtained with the ARIEL system of 3-D kinematics (Zhang *et al.* 2022). Initially, two cameras are set with an angle of 90 degrees to film the predicted object. Particular approaches for the strides along with the takeoff are filmed with the landing and the other two flights. The long jump hang technique involves body stretching and it

The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2695 – 2703
makes it possible to airborne for the long jumper. There are different three-dimensional methods used by athletes in the field. Different key variables are utilized for the long jump in a series of multiple regression and correlation analyses (Burhaein *et al.* 2020). Some relationships among the major variables that are directly correlated individually are generally poor. A series related to the variables are identified with the general principles. These kinematical variables are interpreted in terms of technique, speed, and strength. The performances are interdependent with having variables of the long jump and are identified for the statistical techniques. It has better implications and understandings related to the event of the long jump and are generalized to the skills of other sports.

## Methodology

Research methodology is an individual section of the research that mainly helps to define and elaborate an appropriate approach that needs to adopt in this study of research. In other words, it can be said that research methodology assists to get a better and deeper knowledge and analysis of the related study paper. However, two types of research methods are being procedure used for gathering and collecting the required data. The two important kinds of research methods are quantitative research procedure and qualitative research procedure (Dawadi *et al.* 2021). Quantitative research primarily includes utilizing numbers and surveys for collecting relevant data regarding the research paper. This particular method could further utilize statistical analysis for finding out the adequate meaning and connection of the data for the research paper.

### Subject selection

In this study, all the participants are between 16 years and 28 years. About 21 participants are taken for this analysis. The age group of these participants taken in this study is 18-20, 21-23, 24-26, and 27-28. There are male and female and other gender jumpers are chosen for this study, specially the male jumpers.

### Variable selection

This study focuses on the different kinematical (Angular) variables. Such variables are the angle of right ankle joint, angle of left ankle joint, angle of left knee joint, angle of right knee joint, angle of left hip joint, angle of right hip joint, angle of right shoulder joint, and angle of left shoulder joint, angle of left elbow joint, angle of right elbow joint, angle of left wrist joint, angle of right wrist joint, angle of trunk head inclination and angle of trunk inclination.

### Statistical Technique

In order to analyze the kinematical technique, descriptive statistics has been used related to the technique of hang style in long jump. It will find out the performance of long jump that is dependent variable, and the independent variables at the landing technique of hang-style in long jump.

## Discussion

The age group of the participants is as follows: 18-20, 21-23, 24-26, and 27-28 years. There has 13 male, 5 female and 3 other gender participants been participated in this research and the descriptive data analysis is given below.

The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2695 – 2703

| R | S | T | U | V | W | X | Y | Z | AA |
|---|---|---|---|---|---|---|---|---|---|
| *Age group* | | *Gender* | | *Performance of long jumpers in hang-style technique depends on left ankle angle* | | *Performance of long jumpers in hang-style technique depends on right ankle angle* | | *Performance of long jumpers in hang-style technique depends on left knee angle* | |
| | | | | | | | | | |
| Mean | 1.80952381 | Mean | 0.619047619 | Mean | 1.3809524 | Mean | 1.857142857 | Mean | 1.571428571 |
| Standard Error | 0.235220744 | Standard Error | 0.175610371 | Standard Error | 0.24374255 | Standard Error | 0.231822123 | Standard Error | 0.254216149 |
| Median | 2 | Median | 0 | Median | 1 | Median | 2 | Median | 2 |
| Mode | 3 | Mode | 0 | Mode | 1 | Mode | 2 | Mode | 2 |
| Standard Deviation | 1.077916862 | Standard Deviation | 0.804747816 | Standard Deviation | 1.11696869 | Standard Deviation | 1.062342425 | Standard Deviation | 1.164964745 |
| Sample Variance | 1.161904762 | Sample Variance | 0.647619048 | Sample Variance | 1.24761905 | Sample Variance | 1.128571429 | Sample Variance | 1.357142857 |
| Kurtosis | -1.088257967 | Kurtosis | -0.865279548 | Kurtosis | -1.2024511 | Kurtosis | -0.868366237 | Kurtosis | -1.385644166 |
| Skewness | -0.378410201 | Skewness | 0.844446608 | Skewness | 0.33001994 | Skewness | -0.519260299 | Skewness | -0.295325951 |
| Range | 3 | Range | 2 | Range | 3 | Range | 3 | Range | 3 |
| Minimum | 0 | Minimum | 0 | Minimum | 0 | Minimum | 0 | Minimum | 0 |
| Maximum | 3 | Maximum | 2 | Maximum | 3 | Maximum | 3 | Maximum | 3 |
| Sum | 38 | Sum | 13 | Sum | 29 | Sum | 39 | Sum | 33 |
| Count | 21 | Count | 21 | Count | 21 | Count | 21 | Count | 21 |

| AB | AC | AD | AE | AF | AG | AH | AI | AJ | AK |
|---|---|---|---|---|---|---|---|---|---|
| *Performance of long jumpers in hang-style technique depends on right knee angle* | | *Performance of long jumpers in hang-style technique depends on left hip angle* | | *Performance of long jumpers in hang-style technique depends on right hip angle* | | *Performance of long jumpers in hang-style technique depends on left shoulder angle* | | *Performance of long jumpers in hang-style technique depends on right shoulder angle* | |
| | | | | | | | | | |
| Mean | 1.714285714 | Mean | 1.857142857 | Mean | 1.333333333 | Mean | 1.571428571 | Mean | 1.761904762 |
| Standard Error | 0.268530899 | Standard Error | 0.241874764 | Standard Error | 0.261254604 | Standard Error | 0.254216149 | Standard Error | 0.238095238 |
| Median | 2 | Median | 2 | Median | 1 | Median | 2 | Median | 2 |
| Mode | 3 | Mode | 3 | Mode | 0 | Mode | 3 | Mode | 3 |
| Standard Deviation | 1.23056317 | Standard Deviation | 1.108409414 | Standard Deviation | 1.197219 | Standard Deviation | 1.164964745 | Standard Deviation | 1.091089451 |
| Sample Variance | 1.514285714 | Sample Variance | 1.228571429 | Sample Variance | 1.433333333 | Sample Variance | 1.357142857 | Sample Variance | 1.19047619 |
| Kurtosis | -1.561428491 | Kurtosis | -1.180249163 | Kurtosis | -1.485013236 | Kurtosis | -1.448510473 | Kurtosis | -1.24992 |
| Skewness | -0.283252488 | Skewness | -0.422385672 | Skewness | 0.243321957 | Skewness | -0.085601725 | Skewness | -0.242924749 |
| Range | 3 | Range | 3 | Range | 3 | Range | 3 | Range | 3 |
| Minimum | 0 | Minimum | 0 | Minimum | 0 | Minimum | 0 | Minimum | 0 |
| Maximum | 3 | Maximum | 3 | Maximum | 3 | Maximum | 3 | Maximum | 3 |
| Sum | 36 | Sum | 39 | Sum | 28 | Sum | 33 | Sum | 37 |
| Count | 21 | Count | 21 | Count | 21 | Count | 21 | Count | 21 |

The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2695 – 2703

| AL | AM | AN | AO | AP | AQ | AR | AS | AT | AU | AV | AW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Performance of long jumpers in hang-style technique depends on left elbow angle* | | *Performance of long jumpers in hang-style technique depends on the right elbow angle* | | *Performance of long jumpers in hang-style technique depends on the left wrist angle* | | *Performance of long jumpers in hang-style technique depends on the right wrist angle* | | *Performance of long jumpers in hang-style technique depends on the trunk inclination angle* | | *Performance of long jumpers in hang-style technique depends on the head inclination angle* | |
| Mean | 1.619047619 | Mean | 1.476190476 | Mean | 1.666666667 | Mean | 1.80952381 | Mean | 1.095238095 | Mean | 1.142857143 |
| Standard Error | 0.24374255 | Standard Error | 0.254661752 | Standard Error | 0.261254604 | Standard Error | 0.254661752 | Standard Error | 0.227875926 | Standard Error | 0.241874764 |
| Median | 2 | Median | 2 | Median | 2 | Median | 2 | Median | 1 | Median | 1 |
| Mode | 1 | Mode | 0 | Mode | 3 | Mode | 3 | Mode | 1 | Mode | 0 |
| Standard Deviation | 1.116968687 | Standard Deviation | 1.167006753 | Standard Deviation | 1.197219 | Standard Deviation | 1.167006753 | Standard Deviation | 1.04425868 | Standard Deviation | 1.108409414 |
| Sample Variance | 1.247619048 | Sample Variance | 1.361904762 | Sample Variance | 1.433333333 | Sample Variance | 1.361904762 | Sample Variance | 1.09047619 | Sample Variance | 1.228571429 |
| Kurtosis | -1.326431719 | Kurtosis | -1.465558733 | Kurtosis | -1.485013236 | Kurtosis | -1.29908553 | Kurtosis | -0.579387964 | Kurtosis | -1.180249163 |
| Skewness | -0.092081857 | Skewness | -0.040999668 | Skewness | -0.243321957 | Skewness | -0.427342698 | Skewness | 0.667316741 | Skewness | 0.422385672 |
| Range | 3 | Range | 3 | Range | 3 | Range | 3 | Range | 3 | Range | 3 |
| Minimum | 0 | Minimum | 0 | Minimum | 0 | Minimum | 0 | Minimum | 0 | Minimum | 0 |
| Maximum | 3 | Maximum | 3 | Maximum | 3 | Maximum | 3 | Maximum | 3 | Maximum | 3 |
| Sum | 34 | Sum | 31 | Sum | 35 | Sum | 38 | Sum | 23 | Sum | 24 |
| Count | 21 | Count | 21 | Count | 21 | Count | 21 | Count | 21 | Count | 21 |

**Table 1: Statistics for long jumpers with the variables of kinematical at landing in technique of Hang style**

It has been found from the table 1 that Standard deviation, and mean value for angle of left ankle joint 1.12 and 1.38, Standard deviation, and mean value for angle of right ankle joint is 1.06 and 1.86. Standard deviation, and mean angle of left knee 1.16 and 1.57, Standard deviation, and mean angle of right knee 1.23 and 1.71. Standard deviation, and mean angle of left hip 1.10 and 1.86, Standard deviation, and mean angle of right hip 1.20 and 1.33, Standard deviation, and mean angle of left shoulder 1.16 and 1.57, Standard deviation, and mean angle of right shoulder joint 1.09 and 1.76. Standard deviation, and mean angle of left elbow shows 1.12 and 1.62, Standard deviation, and mean angle of right elbow 1.16 and 1.48. Standard deviation, and mean angle of right wrist 1.17 and 1.80, Standard deviation, and mean angle of left wrist 1.19 and 1.67, Standard deviation, and mean angle of head inclination 1.10 and 1.14 along with Standard deviation, and mean angle of trunk inclination 1.04 and 1.09. We have also found the standard deviation and mean value of age group of the participants is 1.08 and 1.81 and the standard deviation and mean value are 0.80 and 0.62 respectively.

It has been discussed that the variables of the kinematics are analyzed with various phases of technique related to the hanging style. The performance of the long jump in this technique of hang style determines the variables of kinematics. The biomechanical approach includes the process of take-off from the ground and the landing that shows the success of the long jumper. On the other hand, Westermann *et al.* (2020) have found that biomechanical analyses have been performed by both genders with differences in the strength of muscle for performing takeoff and landing. It has been seen that various foot-setting effects are determined for the long jump position. Straddle position of foot placement therefore has

The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2695 – 2703
started from the instant line for performing the activity of the jumper. There found some movement of horizontal jumping that requires coordination for complex motors. Arm motion has also a role in setting the performance level further and giving better results during the sprint. Different settings of the foot have been determined for the quality of the long jump along with the placement of straddle placement of the foot. The standing performance of the long jump has affected by the countermovement level, muscle strength, and maximum joint during the sprint (Zhang *et al.* 2023). There has found variables related to kinematics include the knee joint, ankle joint, joint of the hip, joint elbow, joint of shoulder, joint of the wrist, head inclination angle, and trunk inclination angle. It has been found from other article that, Velocities for the vertical and horizontal can be measured by the determination of the center for the athlete's mass along with the angle for taking off for the athlete (Lupo*et al.* 2022). From this study, it can be said that the landing with a technique of hanging style for the long jump has been remarkable to continue good performance for the long jumpers.

**Findings**

In this paper, it has found that the aspects of the kinematical technique are analyzed for hang style. There found a result of kinematic variables in degree in hang style technique at landing. We have found the standard deviation and mean value of age group of the participants is 1.08 and 1.81 and the standard deviation and mean value are 0.80 and 0.62 respectively It has also been found that Standard deviation, and mean value for angle of left ankle joint 1.12 and 1.38, Standard deviation, and mean value for angle of right ankle joint is 1.06 and 1.86. Standard deviation, and mean angle of left knee 1.16 and 1.57, Standard deviation, and mean angle of right knee 1.23 and 1.71. Standard deviation, and mean angle of left hip 1.10 and 1.86, Standard deviation, and mean angle of right hip 1.20 and 1.33, Standard deviation, and mean angle of left shoulder 1.16 and 1.57, Standard deviation, and mean angle of right shoulder joint 1.09 and 1.76. Standard deviation, and mean angle of left elbow shows 1.12 and 1.62, Standard deviation, and mean angle of right elbow 1.16 and 1.48. Standard deviation, and mean angle of right wrist 1.17 and 1.80, Standard deviation, and mean angle of left wrist 1.19 and 1.67, Standard deviation, and mean angle of head inclination 1.10 and 1.14 along with Standard deviation, and mean angle of trunk inclination 1.04 and 1.09.. A remarkable difference between the long jumper's performance and the kinematic variables has been found (Ruan *et al.* 2022). Various phases of hang style are found in the study. There have been found variables kinematics include the knee joint, ankle joint, joint of the hip, joint elbow, joint of shoulder, joint of the wrist, head inclination angle, and trunk inclination angle. The determination of the knee flexion in an angle along with the take-off of the trunk's posterior position helps the long jumper to perform smoothly.

**Conclusion**

It has been concluded that, remarkable differences have been found between the variables of kinematics and the performance of the long jumpers. Long jumps involve several 4 phases during the jump and those phases help the athlete to perform well during their run. Different variables of kinematics related to the study have the speed approach, length of stride, foot planting angle, knee angle, and the last stride velocity. The athlete is more or, less aware of

The Ciência & Engenharia - Science & Engineering Journal
ISSN: 0103-944X
Volume 11 Issue 1, 2023
pp: 2695 – 2703
the terminal velocity that is achieved during the run. Phases of the dash are essential to maintain the distance that is essential for completing all phases. The landing phase has importance in completing the phase with perfection by getting flexion in the muscle that increases the performance for the final distance. Three-dimensional parameters for the kinematics have been discussed including the flight and the takeoff. The lower performance of the jump is determined mainly by the velocity approach that lowers the height of BCM. There found a last stride on the approach of angle and those approaches are evident for larger and imbalanced movements. Leg placement during the take-off in a frontal plane has been correlated with the inclination during the phase of take-off. It has been seen that the long jump often depends on successful performance and depends on coordination at a higher level for both the segments of the lower and upper body. Jump distance is insensitive to the starting position that determines the knee flexion in an angle along with the take-off of the trunk's posterior position. There is some long jump that often depends on successful performance and those depend on coordination at a higher level for both the segments of the lower and upper body. The kinematical technique for the hanging style in the long jump is a remarkable impact on the performance.

**References**

[1] Azuma, A. and Matsui, K., 2021. Relationship between jump distance for running long jump and physical characteristics of male students in PE class.*Advances in Physical Education*, *11*(02), p.232.

[2] Burhaein, E., Ibrahim, B.K. and Pavlovic, R., 2020. The relationship of limb muscle power, balance, and coordination with instep shooting ability: A correlation study in under-18 football athletes. *International Journal of Human Movement and Sports Sciences*, *8*(5), pp.265-270.

[3] Dawadi, S., Shrestha, S. and Giri, R.A., 2021. Mixed-methods research: A discussion on its types, challenges, and criticisms. *Journal of Practical Studies in Education*, *2*(2), pp.25-36.

[4] Elfmark, O., Ettema, G., Groos, D., Ihlen, E.A., Velta, R., Haugen, P., Braaten, S. and Gilgien, M., 2021.Performance analysis in ski jumping with a differential global navigation satellite system and video-based pose estimation.*Sensors*, *21*(16), p.5318.

[5] Jia, S.W., Lam, W.K., Huang, Z., Baker, J.S., Ugbolue, U.C. and Gu, Y., 2022. Influence of metatarsophalangeal joint stiffness on take-off performances and lower-limb biomechanics in jump manoeuvres. *Journal of Sports Sciences*, *40*(6), pp.638-645.

[6] Lupo, C., De Pasquale, P., Boccia, G., Ungureanu, A.N., Moisè, P., Mulasso, A. and Brustio, P.R., 2022. The Most Active Child Is Not Always the Fittest: Physical Activity and Fitness Are Weakly Correlated. *Sports*, *11*(1), p.3.

[7] Maćkała, K., Synówka, A., Ćorluka, M. and Vodicar, J., 2021. Impact of plyometric training on the power of lower limbs in moderately advanced female volleyball players. *ActaKinesiologica*, *15*(1), pp.5-12.

[8] McCosker, C., Renshaw, I., Greenwood, D., Davids, K. and Gosden, E., 2019. How performance analysis of elite long jumping can inform representative training design

through identification of key constraints on competitive behaviours. *European journal of sport science*, *19*(7), pp.913-921.

[9] Nishimura, S., Kinomura, Y., Kobayashi, Y., Matsuzaki, R., Matsushita, S. and Ikeda, N., 2019. Learning Outcomes for Physical Education in Long Jump: Is it Possible for 5th Graders to Learn Take-off Techniques that Enable Greater Vertical Velocity?.*International Journal of Sport and Health Science*, *17*, pp.A37-A53.

[10] Reddy, T.O. and Singh, V., 2021.Regression equation of linear kinematical variables with the performance at different phases of hang style technique in long jump.*International Journal of Physical Education Sports Management and Yogic Sciences*, *11*(3), pp.12-28.

[11] Ruan, M., Zhang, Q., Zhang, X., Hu, J. and Wu, X., 2022.Differences in strength and landing biomechanics between female jumpers and swimmers.*Isokinetics and Exercise Science*, *30*(1), pp.69-78.

[12] Westermann, K., Lin, J.F.S. and Kulić, D., 2020. Inverse optimal control with time-varying objectives: application to human jumping movement analysis. *Scientific reports*, *10*(1), p.11174.

[13] Zhang, W., Chen, X., Xu, K., Xie, H., Li, D., Ding, S. and Sun, J., 2023. Effect of unilateral training and bilateral training on physical performance: A meta-analysis. *Frontiers in Physiology*, *14*, p.607.

[14] Zhang, X., Liu, C. and Peng, M., 2022. Three-dimensional trajectory designs for unmanned aerial vehicle-enabled communications with kinematic constraints. *IEEE Transactions on Vehicular Technology*, *71*(10), pp.10910-10922.

[15] Reddy, T.O. and Singh, V., 2020.Correlation of long jump performance and selected angular kinematical variables at landing of hang style technique in long jump.