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Developing a Variation Index for Understanding Step Characteristics in the Long Jump Approach Run

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Abstract

Objectives. The prime objective of the study was to develop a new variation index that can be used to identify the mechanical variations in the step pattern of the approach run.

Materials and methods. Twelve national-level long jumpers (age 19 ± 0.32 years) were analyzed in this study. Five high-speed action cameras with a resolution of 1920 x 1080 pixels at 120 frames per second were used. The data obtained were digitized with Quintic Motion Analysis software (v.33). In order to construct a Variation Index, the method of partial least squares structural equation modeling (PLS-SEM) was used. Additionally, a Principal Component Analysis (PCA) was applied to construct latent variable for the PLS-SEM.

Results. The results of the study revealed that step variation was started at the last 5th step of the approach run. Moreover, mechanical variation was observed among the last three steps of the approach run. These findings suggest that mechanical preparation for the final take-off in the long jump might start during the middle phase of the approach run.

Conclusions. The Variation Index introduced in this study offers a detailed understanding of an individual's approach run technique. Coaches and athletes can use this information to implement precise training strategies for optimizing the preparation for the final take-off during the approach run.

Keywords: biomechanics, principal component analysis, PLS-SEM method, motion analysis, latent variable.

Introduction

The variation index introduced in this study is based on the Partial Least Squares Structural Equation Model (PLS-SEM). This study draws substantial inspiration from the work of Oliva-Lozano et al. (2024), who developed a similar synthetic index. Cefis and Carpita (2024) have also showed the applicability of the PLS-SEM model within the games and sport. The current study also like to acknowledge the work of Crocetta et al. (2021) for their valuable contributions in illustrating various approaches to constructing the PLS-SEM model under different conditions. In this study, we apply these established methods specifically to track and field events, exploring a new perspective within this domain. To our knowledge, this approach offers a unique application in track and field, contributing a novel angle to the field of sports analytics.

The approach run in long jump is a crucial phase that determines the athlete's jump performance (Linthorne, 2006). In order to achieve maximum jumping performance, athletes must have precise control over their speed, stride length and stability throughout the approach during the appraoch run (Linthorne et al., 2005). In the field of sports, slightest mechianincal variations in thestep pattern of the appraoch run can have significant impact on take-off Phase (Linthorne et al., 2005). Çetin, Özdemir, and Özdöl (2014) highlighted the kinematic differences in stride lengths among jumpers, showing that the last four strides are particularly influential on the jumper's transition to take-off (Çetin et al., 2014). As irregularities might disrupt momentum and reduce jump effectiveness, optimal velocity and controlled step regulation require (Yoshida et al., 2018). Ghareb et al. (2016) found that ground reaction force management during the approach might enhance the ability to transfer the generated force to vertical direction as well. This is critical to achieving a smooth transition during the flight phase (Ghareb et al., 2016). In the year 1985, Hay and Miller observed that elite athletes utilize specific techniques to control stride length

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and body posture, which maximizes kinetic energy transfer at take-off. Similarly, Theodorou et al. (2017) identified asymmetries in the approach stride as a factor that can impact take-off efficiency. The result of the study suggested that even minor adjustments in approach run can create considerable alteration in the long jump performance (Theodorou et al., 2017). Addressing these biomechanical changes might lead to more refined techniques for optimizing approach mechanics, potentially offering competitive advantages (Hay & Miller, 1985b). This understanding not only benefits coaches in training elite jumpers but also serves as a foundation for early stages of training (Graham-Smith & Lees, 2005; McCosker et al., 2021; Scott et al., 1997).

Research on the approach phase in long jump highlights key biomechanical and performance factors that impact overall jump distance (Panoutsakopoulos et al., 2010). Studies reveal that athletes make precise adjustments in stride length and approach velocity prior to the final take-off step (Çetin et al., 2014). this adjustment might play a pivotal role in maximizing jump distance (Çetin et al., 2014). These adjustments are not random; they are deliberate actions by the athlete to control the balance of both speed and precision for optimal performance (Çetin et al., 2014). Furthermore, their (Çetin et al., 2014) findings also suggest that the transition from approach to take-off requires careful regulation of step length and the position of the centre of mass. Step regulation in the approach run directly affects the efficiency of kinetic energy transfer (Bridgett & Linthorne, 2006). Elite athletes distinguish themselves through biomechanical alterations in the control of approach speed, balance and body positioning, setting them apart from less experienced jumpers (Hay & Miller, 1985a). Additionally, the relationship between preparation steps and ground reaction forces highlights the importance of force management in the last few steps. It might enable athletes to approach the take-off angle with optimal speed and control, enhancing performance and minimising take-off errors (Ghareb et al., 2016). Step symmetry is also found to play a crucial role, as irregularities can disrupt momentum, impacting jump distance (Panoutsakopoulos et al., 2021). Maintaining symmetry in the step regulation in the approach run might results in improved jump performance (Theodorou et al., 2017). It offers a technical advantage for athletes at all skill levels (Theodorou et al., 2017). On the other hand, Rhythm in the approach phase is equally significant (Yoshida et al., 2018). A consistent rhythm allows for a smooth transition from the run-up to take-off. As a result athletes are able to regulate gait patterns and maintain stable speed control, critical for setting up a powerful and stable take-off (et al., 2018).

The preparation for the final take-off during the approach is been a critical area of concern for sports scientists, coaches and athletes. Most of the studies have primarily highlighted the mechanics of the final steps before the take-off phase (Çetin et al., 2014; Panoutsakopoulos et al., 2010; Scott et al., 1997; Theodorou et al., 2017). Some of the studies have attempted to understand the mechanical characteristics and showed mechanical characteristics of these final steps significantly influence the take-off and overall jump distance (Graham-Smith & Lees, 2005). The mechanical changes, especially in the last phase of the approach, also help in minimizing errors before the final step, aiming to stabilize the athlete's position for take-off (Jaitner et al., 2001; Shimizu et al., 2018). However, while the mechanics of the three steps are well-studied, there is limited research on the mid-phase of the approach run, which could offer insight into the earlier preparatory adjustments that support the final take-off phase. A smoother transition between the mid-phase and the last steps might exist to optimise take-off mechanics (Graham-Smith & Lees, 2005; Lees et al., 1994). Past studies indicates that sudden mechanical changes are unlikely to occur solely in the final phase; instead, it might initiate in the mid-phase of the approach run, a area largely absent from existing literature (Shimizu et al., 2018; Zhang, 2016). Latest innovation and advancements in sports science and technology have enabled more precise analyses of long jump mechanics (Alexander, 1990; Graham-Smith & Lees, 2005). However, these methods often require costly, high-tech laboratory environments that may be inaccessible to grassroots athletes and amateur practitioners (Jaitner et al., 2001). To address this limitation, developing a theoretical model based could be very much useful for the coaches and athletes at all levels. This might create a practical, accessible framework for training and performance optimization without the need for expensive equipment.

In order to bridge up forementioned research gap, the prime objective of the current study was to introduce a variation index for last 10 step of the approach run. Secondly, the study also analysed each step to identify to mechanical changes during the approach run using the new variation index. This theoretical model that might be accessible for the coaches and athletes to understand the mechanical changes during the approach run. Coaches can identify the specific and individualized nature of the athlete to implant more precise training programme. Further, this theoretical model might be also applied for the better understanding the mechanical characteristics of the walking gait cycle and running gait cycle.

Materials and Methods:

The participants

The study comprised twelve (12) female Indian national-level long jumpers, with a mean age of 19 ± 0.32 years. All participants were finalists in the women's long jump event at the 22nd Junior Federation Athletic Championship 2023, held in Lucknow, Uttar Pradesh, India. Each athlete was capable of achieving jumps exceeding six meters, and they were purposively selected for the study. As data collection occurred during the official competition, no anthropometric data were collected. Formal permissions were obtained from the designated referee, technical delegates, and media manager before data collection. Consent was also obtained from the athletes and their coaches. This study received approval from the Research Advisory Committee of Tripura University, India.

Procedure for collecting data

A written consent were obtained prior to the data collection process. Each participant was allowed a maximum of six trials, only legal attempt was selected for analysis. The approach runs of the athletes were recorded using five high-speed action cameras. All cameras were positioned in predefined locations to capture the entire approach run phase. The height of each camera was set between 1.00 meter and 1.20 meters from ground level, and the perpendicular distance from the runway to each camera's position ranged from 7 to 10 meters.

Tools and instruments used

Five high-speed action cameras (Go Pro Hero 11) were used to record the movements. All the cameras were set in linear mode for the recording. The movements were recorded with a resolution of 1920 × 1080 pixels at 120 frames per second. The camera height was fixed at 1.20 meters. The position of the cameras is presented in the following Figure (A). A calibration box of length 1 meter was used as a reference for the recorded videos. The calibration stick was first set in a perpendicular direction to the surface (x-axis) and then also set in parallel to the surface (y-axis). The calibration was done before each optical axis of the three cameras.

The recorded videos were subsequently digitized and analyzed using Quintic Motion Analysis software (v.33). A total of 21 two-dimensional body segments were digitized to enable linear data transformation. In order to determine intra-reliability, all the recorded movements were digitized twice with two different experienced individuals within two weeks. A total number of 55 officially successful jump attempts were analysed in this study.

Construction of the Variation Index

At first, we calculated the variation within each step based on the biomechanical parameters for all athletes. A correlation analysis was conducted to remove collinearity to introduce a new variation index. Further, a Principal Component Analysis (PCA) was performed as an exploratory analysis to identify primary factors within the biomechanical parameters for the index and to select the most relevant variables. As a result, 9 biomechanical parameters were selected from all three principal components. The analysis revealed three significant latent components (eigenvalues greater than 1) that accounted for approximately 83 % of the original variability. For each latent component, variables with a loading factor of $|\lambda| > 0.65$ were selected following a varimax rotation. In total, 9 variables closely associated with their respective components (see Table 1) were chosen.

The Variation Index created using biomechanical parameters through a stepwise approach. Due to the nature of the data, the PLS-SEM method, a non-parametric approach, was chosen. A hierarchical Second-Order PLS-SEM model was employed to consolidate multiple biomechanical parameters into a single composite index. The model was executed using smartPLS (version 3.3.7) and the R package seminR (version 2.3.2), with 3000 bootstrap resamples performed for result validation. The process followed the Mixed Two-Step approach, starting with the estimation of lower-order constructs, which were then utilized to compute the higher-order construct, the Variation Index.

The index is constructed using three components based on biomechanical parameters identified by the Principal Component Analysis. Component 1 includes the Maximum Amortization Angle (MA), the Height of the Center of Mass (CM) during the Maximum Amortization Angle (MAH), the Height of the CM during the initial contact of the foot with the ground (TDH), and the Height of the CM during the initial touch-off of the foot from the ground (TOH). Component 2 consists of the Maximum Amortization Angle (MA), Step Length (SL), and the Contact Duration of the foot with the ground (CD). Lastly, Component 3 comprises the Touch-Down Angle of the Center of Mass (TDA) and the Touch-Off Angle of the Center of Mass (TOA). In order to calculate the index for step number 'n' with 9 biomechanical parameters, the following derivations were done(based on the weights w of Figure 1). The first latent component is derived from the first principal component, while the second and third latent components are derived from the second and third principal components, respectively.

Firstly, three latent components are calculated for each nth step of the approach run.

Latent Component 1_n = $(1.087 \times MA_n) + (-0.812 \times MAH_n) + (0.492 \times TDH_n) + (0.069 \times TOH_n)$

Latent Component 2_n = $(0.499 \times MA_n) + (0.123 \times SL_n) + (0.548 \times CD_n)$

Latent Component 3_n = $(-0.383 \times TDA_n) + (0.777 \times TOA_n)$

[Each step is represented by n, where, n = 1, 2, 3,…9,10]

Finally, with these three latent components, the Variation index is now calculated as follows

Variation Index = $(0.0174 \times \text{Latent component } 1_n) + (0.526 \times \text{Latent component } 2_n) + (0.105 \times \text{Latent component } 3_n)$

Structural equation Modelling Analysis

The calculated variation index in this study represents the relationship between the mechanical variation of the approach run in each step. The score of composite reliability is 0.957, which more than 0.70. This indicates the trustworthy of the current model (Hair & Alamer, 2022). Fruther more this score of the cronbach's Alpha (0.911), which shows that calculated index in reliable and and are abopve the required value of 0.60 (Hair & Alamer, 2022). This is also supported by the score of Average Variance Extracted (AVE), which is also greater than 0.50 (table 1). The SRMR value of the model can describe if the variation index is fit for this study or not. According to the Hu & Bentler (1999) the SRMR value should be less than 0.10. As shown in the table 1 the current SRMR value is 0.080 <0.10. which indicates that model is appropriate for this study (Hu & Bentler, 1999).

Table 1. Measurements of the model estimation value and model FIT validity

Cronbach's Alpha	Rho-A	Composite reliability	Average Variance Extracted (AVE)	SRMR		R-Squared	
				Saturated model	Estimated model	R-square	R-square adjusted
0.911	0.911	0.957	0.918	0.080	0.080	0.774	0.661

Furthermore, the coefficient of the determination of the model or R-squared value indicates that the introduced variation index is influenced by 77.4 % from the included biomechanical variables in the present study.

Results

In this following section the result of the analysis is being discussed.

In the table 2, average score of the selected biomechanical parameters is mentioned. The average value of the selected biomechanical parameters starts from the last 10th step to last step that is final take-off step. All the measurements were mention according to the SI unit.

The table 3 represents the identified major components found as a result from the PCA analysis. The first Principal Component includes 4 biomechanical parameters namely, MA (Maximum Amortization Angle),MAH (Height of the CM during Maximum amortization Angle), TDH (Height of the CM during initial contact of the foot with ground) and TOH (Height of the CM during initial touch off of the foot from the ground). The first Principal Component explained more than 83% of the variation. In the second Principal components includes MA (Maximum Amortization Angle), SL (Step Length) and CD (ground contact duration). More over the third principal component was found with two mechanical parameters which are TDA (Touch down angle of the CM) and TOA (Touch off angle of the CM).

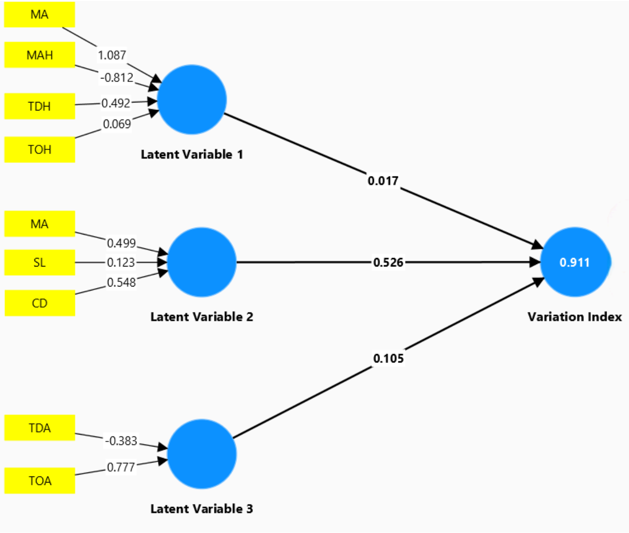

Fig. 1. Schematic diagram for calculating Raw Variation Index

In the figure 1, the three latent variable and its connection of the calculated variation index is represented with a schematic diagram.

In the table 4 calculated score for each three latent variables along with the variation index for the respective step is showed. In the last column of the table 4, difference

Table 2. Description of the selected biomechanical variables

Step number	CD (Sec)	MA (Degree)	TDA (Degree)	TOA (Degree)	SL (meter)	TDH (meter)	MAH (meter)	TOH (meter)
10	0.124	140.325	72.650	54.713	1.679	6.477	7.075	0.896
9	0.120	140.125	74.288	55.113	1.694	6.664	7.202	0.916
8	0.119	139.500	74.975	52.913	1.721	6.453	7.076	0.906
7	0.124	135.950	72.113	54.950	1.736	6.655	7.082	0.880
6	0.119	141.163	71.975	56.488	1.740	6.477	7.052	0.897
5	0.116	138.950	74.150	53.600	1.736	6.688	7.192	0.911
4	0.114	138.175	74.138	53.125	1.751	6.453	7.077	0.899
3	0.114	118.680	72.025	55.363	1.754	3.464	4.303	0.883
2	0.157	130.700	68.300	53.613	1.799	8.625	6.981	0.887
Final Take-off step	0.173	118.829	59.300	70.088	1.724	6.171	6.651	1.099

Table 3. Summarization of results from the Principal Component Analysis (PCA)

Component Name	Variables	Description of the variables
Component 1	MA	Maximum Amortization Angle
Component 1	MAH	Height of the CM during Maximum amortization Angle
Component 1	TDH	Height of the CM during initial contact of the foot with ground
Component 1	TOH	Height of the CM during initial touch off of the foot from the ground
Component 2	MA	Maximum amortization angle
Component 2	SL	Step length
Component 2	CD	Contact duration of the foot with ground
Component 3	TDA	Touch down angle of the CM
Component 3	TOA	Touch off angle of the CM

Table 4. Latent variables for each Phase

Steps Numbers	Latent Variables			Calculated variation Index	Difference between the index for respective steps
	L1	L2	L3		
10	1.397	1.402	0.304	1.281397	
9	0.702	0.609	0.262	0.581808	0.7
8	0.754	1.055	1.430	1.248548	0.67
7	3.623	1.539	0.775	1.419258	0.17
6	0.747	1.235	0.733	1.254895	0.16
5	0.585	1.241	0.698	1.25857	0
4	2.166	0.558	0.434	0.513	0.75
3	3.393	3.306	0.577	2.986758	2.47
2	3.538	2.059	0.854	1.912223	1.07
1	1.895	2.569	0.937	2.462679	0.55

between the variation index with the following index is displayed. It was found that the difference between the variation index is very low (less than 1) for the 9th, 8th,7th and for the 6th step respectively. However, the difference between the index is increasing from the last 5th step to the second last step (figure 2).

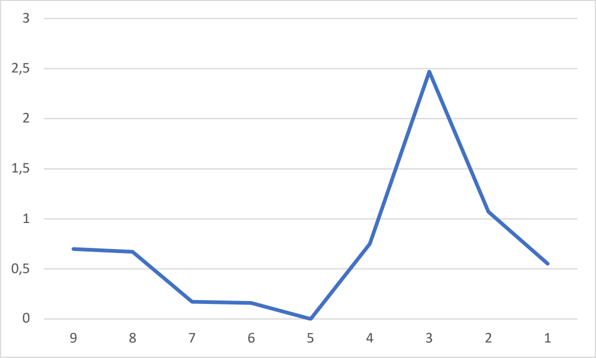

Fig. 2. Graphical representation of value of the difference between the index for respective steps

Discussion

Understanding mechanical variation of the long jump's approach run are the key factor for initiating final take-off phase. Introducing a Variation Index for the approach run might help our coaches and athletes to identify the potential biomechanical. The present study identified four key kinematic variables that collectively account for over 80 % of the variation. These variables are Maximum amortisation angle (MA), Height of the CM during Maximum amortisation Angle (MAH), Height of the CM during initial contact of the foot with the ground (TDH) and Height of the CM during initial touch off of the foot from the ground (TOH). Secondly, the calculated index observed mechanical alteration among the step characteristics, especially in the mid phase of the approach run. Alteration in the mid phase of the approach might indicates earlier preparation prior to the final take-off step. The result of the study might provide coaches and athlete a better understanding of their approach technique in the long jump.

The result from the first Principal Component Analysis identified 4 biomechanical parameters. These parameters are MA, MAH, TDH and TOH and accounted for 83% of the total variation. The maximum knee flexion angle during swing phase allows efficient transition in the support phase. This increases both propulsive forces and step length of the running gait cycle (Mann & Herman, 1985). However, excessive knee flexion can extend ground contact time, decrease step frequency and eventually hinder performance (Maćkała et al., 2015). Similarly, a lower center of mass at touchdown provides more steady and efficient force application (Mann & Herman, 1985). Position of the low centre of mass might enhance acceleration during the approach run (Mann & Herman, 1985). On the other hand, Mattes et al. (2021) also showed that the angle of foot touchdown relative to the body's center of mass is vital for optimizing ground reaction force application while minimizing braking forces (Mattes et al., 2021). The current study also found that the maximum amortization angle (MA), Step length (SL) and Contact duration of the foot with the ground (CD) also explained a considerable variance in the approach run. Increased step lengths are generally associated with higher running velocities with optimal step frequency (step per second). As they enable the athlete to cover more distance in minimum time (Majumdar & Robergs, 2011). However, the balance between these two variables, step length (SL) & step frequency (SF), also plays an essential role in maintaining optimal velocity for the athletes. Elite sprinters may rely more on either SL or SF to reach peak velocity, highlighting the need to consider this variability in training programs (Bezodis et al., 2011; Salo et al., 2011). Athletes might adjust the SL-SF balance to maintain velocity with increasing SL and reducing SF during deceleration (Bezodis et al., 2011). Consequently, step frequency (SL) becomes an essential variable to achieve high running velocities. The duration of foot contact with the ground equally influences the capacity to generate propulsive forces in the approach run. As observed in elite sprinters, reduced contact times facilitate greater step frequencies, thus providing higher running velocities (Maćkała et al., 2015). The Principal Component Analysis (PCA) also identified the touchdown angle of the centre of mass (TDA) and take-off angle of the centre of mass (TOA) as important factors in maintaining optimal velocity during the approach run. The angles at which the foot strikes and leaves the ground are also crucial. A sharper touchdown angle, where the foot hits the ground at a more acute angle, helps facilitate the storage and release of elastic energy, improving running efficiency and velocity (Panoutsakopoulos et al., 2021). Similarly, a more acute take-off angle, where the foot leaves the ground, allows for a more efficient transition from braking to propulsion in the step cycle (Panoutsakopoulos et al., 2021; Theodorou et al., 2017).

The step variation index created in this study is very new approach to this field, within our knowledge. Though the mathematical calculations of this PLS-SEM structural model is an established approach in the sport field (Cefis & Carpita, 2024), but has yet to be applied for the identification for the step variation in the long jump approach run. This variation index is based on some of the prime contributory factors that was computed in PCA. The variation index indicates the level of variation among the prime biomechanical contributory factors in each step of the approach run. On the other hand, the difference between the variation index denotes the level of variation in between two consecutive steps. The higher value of difference between the index indicates lower variation level in between the steps and vice versa. If the difference between the index for two consecutive steps is closer to the value of zero or equal to zero, meaning that those two consecutive steps is similar in nature. This might be very helpful to identify the variation among the steps to study the nature of the step characteristic. Figure 2 shows that from the last 10th step to the last 5th step, the variation among the steps is very similar. However, a drastic change is observed after the 5th steps (fig 2). It is observed that difference between the variation index is relatively higher specially in the last 4th, last 3rd, last 2nd and last steps (Take-off step) of the approach run. This might indicate that these steps are very much differs from the each other. They possessed unique mechanical characteristics for the last phase of the approach run. Additionally, the index value is found comparatively higher in the last 3rdstep. Past studies showed that initial preparation for the last 3rdstep is starts by slightly shortening step length and lowering the center of gravity (CG) (Panoutsakopoulos et al., 2021). This adjustment helps the athlete maintain horizontal velocity while beginning to prepare for the vertical lift needed for take-off (Hay & Nohara, 1990; Panoutsakopoulos et al., 2021). Controlling the velocity in this step is becomes crucial to make necessary adjustment in running cycle. Since excessive or insufficient adjustments might affect the effectiveness of the following steps (Çetin et al., 2014). It was observed that in athletes tends to lowers the CG with a slightly lengthened step in the second last step (Linthorne et al., 2005). This allows the athlete to adjust momentum while balancing horizontal and vertical components of the resultant momentum. Absorbing horizontal momentum creates the required stability for an optimal take-off position. It provides smooth transition to the final take-off phase (Béres et al., 2014). In the final take-off step, step length is shortened to maximize vertical adjustment and prepare the CG for the jump (Linthorne et al., 2005). This is essential for effective loading the take-off leg, allowing the athlete to apply maximum force against the ground (Kariyama et al., 2017). This helps to efficiently convert horizontal velocity into vertical lift, which is critical for jump distance (Theodorou et al., 2017). Together, all these adjustments in step length and CG positioning ensure a continuous and efficient transition into take-off phase.

The current study found that the variation of the last phase of the approach is begins from the last 5th step. This might be the earlier preparation for the take-off, where preliminary biomechanical adjustment begins. Initiating adjustments from the mid phase of the approach run highlights the importance of progressive biomechanical preparation before take-off (Panoutsakopoulos et al., 2021; Theodorou et al., 2017). Hay and Nohara (1990) in their study mentioned the preparation for the final take-off might begin several steps before the take-off board. It allows the athletes to manage their final approach velocity and body positioning for the final take-off. Adjusting key mechanical parameters such as step length, velocity, and positioning of the center of gravity (CG) etc. prior to the final take-off, collectively contribute for optimum momentum and take-off angle (Hay, 1988; Lees et al., 1994). This adjustment might be crucial for accurate foot placement on the take-off board for final take-off. Further, Bridgett and Linthorne (2006) mentioned that prior to the final take-off, athletes must carefully balance and maintain horizontal momentum to maximize jump distance. The mechanical adjustments from the mid approach phase might help athletes gradually regulate their step pattern for the final take-off. As a consequence, it reduces the risk of unexpected changes during last phase of the approach and enabling athlete for optimum execution of the final take-off phase (Arampatzis et al., 1999; Glize & Laurent, 1997).

This study has several limitations worth considering. Firstly, its observational nature excludes cause and effect relationship between biomechanical parameters and performance outcomes. The analysis relied solely on two dimensional kinematic data, which might be inadequate when compared to the three dimensional data. Additionally, the limited sample size and population may constrain the generalizability of the findings to a broader context. Using PCA and the newly developed "Step Variation Index" represents an innovative approach, which might need more replication and comparison with other established methods. Finally, the impact of biomechanical adjustments on performance may vary across different athlete skill levels and training backgrounds, which was not extensively explored in this study.

Conclusions

The study approached a new theoretical model to understand the approached run mechanics the long jump approach run. According to the objective of the study, a "variation index" is constructed based on the PLS-SEM model. As a result, this model identified that mechanical variation in the step characteristic exist in the mid phase of the approach run. This might be the preparation for the athlete before the last phase of the approach run in order to perform precise and controlled final take-off.

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Conflict of Interest

If the authors have any conflicts of interest to declare.

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Розробка індексу варіації щодо розуміння характеристик виконання кроків у стрибках в довжину з розбігу

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 4 табл., 2 рис., 36 джерел.

Мета дослідження. Основна мета дослідження полягала в розробці нового індексу варіації, який можна використовувати для визначення механічних варіацій щодо структури кроків під час виконання розбігу.

Матеріали та методи. У цьому дослідженні проаналізовано дванадцять стрибунів у довжину національного рівня (вік 19 ± 0,32 року). Було використано п'ять високошвидкісних екшн-камер з роздільною здатністю 1920 × 1080 пікселів з частотою 120 кадрів на секунду. Отримані дані були оцифровані за допомогою програмного забезпечення для аналізу рухів спортсменів "Quintic Motion Analysis" (v.33). Для побудови індексу варіації застосовано спосіб моделювання структурними рівняннями за методом найменших квадратів — "Partial least squares structural equation modelling" (PLS-SEM). Крім того, застосовано метод головних компонент (МГК) з метою побудови латентної змінної для PLS-SEM.

Результати. За результатами дослідження встановлено, що варіація кроку починається на останньому 5-му кроці розбігу. Крім того, механічна варіація спостерігалася між останніми трьома кроками розбігу. Отримані дані свідчать про те, що механічна підготовка до фінального відштовхування у стрибках у довжину може починатися під час середньої фази розбігу.

Висновки. Індекс варіації, представлений у цьому дослідженні, надає детальне розуміння техніки індивідуального розбігу. Тренери та спортсмени можуть використовувати зазначену інформацію з метою впровадження чітких тренувальних стратегій щодо оптимізації підготовки до фінального відштовхування під час виконання розбігу.

Ключові слова: біомеханіка, метод головних компонент, метод PLS-SEM, аналіз рухів, латентна змінна.

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