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The Optimum Phase Ratio of Indonesian Triple Jump Athletes as an Index Detector for Triple Jump Performance

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Abstract

Distribution of triple jump phases was deemed as a technical factor because the phase ratio significantly affects the actual distance in the triple jump. The objective of this study was to identify the phase ratio that is a measure of effort distribution in the triple jump. Hop-dominant, balanced, and jump-dominant techniques were three triple jump techniques defined based on phase ratio which are compared with its of world triple jumpers. The descriptive method was used in this research and subjects were male Indonesian triple jump athletes whose films were taken to be analyzed using Dartfish motion analysis. The percentage analysis obtained from each phase was calculated by comparing it with the total distance of the jump. The largest percentage value of the three phases was the type of jump performed. The performance of the world's triple jumpers was used as a comparative model for analysis to assess the quality of the movement and each athlete's movement sequence form was compared with movement of world triple jumper. The data revealed that the ratio of hop, step, and jump phases was 32% :30% :38%. The phase ratio of Indonesian triple jumper that produced the greatest jump distance was achieved in the jump phase. Despite phase ratio of each subject was wildly different but it was a good index detector of perfect distribution phase that demonstrates the good practice model especially for Indonesia triple jumper athletes.

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INTRODUCTION

One of the three jumping events in track and field is the triple jump. It is competed not only at the national championship level but also in international competitions such as the SEA Games, Asian Games, and the Olympics (Ramadani et al., 2021). Comparing the results of Indonesian athletes with several elite triple jump athletes, the records are similar to those achieved by Adhemar da Silva (Brazil) in the 1950s, with a jump of 16.00 meters (Lenuța & Corina, 2021). However, there is a significant difference when compared to the world record held by Jonathan Edwards (England), who jumped 18.45 meters in 1995. More recently, at the 2022 Tokyo Olympics, Pedro Pichardo (Portugal) achieved a jump of 17.98 meters (Lenuța & Corina, 2021). Furthermore, at the World Athletics Championships in Budapest on August 21, 2023, Hugues Fabrice Zango was still unable to break the previous world record, achieving a jump of 17.64 meters (World Athletics, 2023).

Observing the difference between Indonesian triple jump athletes and world athletes, the difference is around 2.48 m, which is quite significant. Therefore, a deeper analysis shows that numerous requirements need to be met in order to achieve high performance in these events (Makaruk et al., 2015 ; Program et al., 2021). The triple jump is one of the track and field events that requires the jumper to generate maximal force repeatedly to maintain horizontal velocity during all phases of the jump (Eissa, 2014). It consists of a running approach, three take-off phases in which the athlete hops on one foot, lands on the same foot, steps onto the opposite foot, and finally jumps and lands in the sand pit (Mohammed, 2015; Dziewiecki et al., 2013). One of the most important considerations in triple jump techniques is the optimum phase ratio (Mohammed, 2015). In the triple jump, the distance measured from the toe of the athlete's takeoff foot on the board to the nearest mark made in the sand pit is referred to as the actual distance (Allen et al., 2016). The distance from the toe of the athlete's takeoff foot at the takeoff to the toe of their landing foot at the landing during each phase is referred to as the phase distance (Liu et al.,2015). Previous research conducted by Hay on world record performances from 1911 to 1985 showed a shift from a hop-dominated technique with a small step phase (40–41%:22%:36–38%) towards a hop-dominated technique with a larger step phase (37–39%:28–30%:31–33%), and later towards a jump-dominated technique (34–35%:28–30%:36–37%) [Allen et al, 2013]. Other research show that, when the ratio and distance outputs in the hop-step-jump phases were examined, Enas Gharieb used the jump dominant (De Silva) technique in his trials (4.17m-3.69m-4.69m). In the Berlin 2009 triple jump final, both female jumpers (37%-29%-34%) and male jumpers (37%-30%-33%) used the hop dominant technique. In the Daegu 2011 triple jump final, both female jumpers (36%-29%-35%) and male jumpers (36%-30%-34%) used balance dominant technique. It was also observed that male jumpers (35%-30%-34%) used balance dominant technique in the 1992 USA Athletics Olympic team trials (Sibel, 2021).

One of the keys to success in obtaining optimum jump results is that athletes must be able to regulate the percentage of hops, steps, and jumps. If they fail to manage this distribution, the results will likely be unsatisfactory. The optimum effort distribution over the hop, step, and jump phases has been identified as a critical technical factor that affects the performance of the triple jump (Liu et al., 2015). The percentage of a phase distance to the actual distance is referred to as the phase percentage (Eissa, 2014). The ratio of the three phase percentages is referred to as the phase ratio (Thotawaththa et al., 2021). It is an indirect measure of effort distribution in the triple jump (Mcerlain-Naylor et al., 2021). It should be the first consideration of triple jump techniques (Mohammed et al., 2015). Without a solution to the optimum phase ratio problem, studies on all other factors in triple jump techniques must be considered in ignorance of what is required (Allen et al., 2016).

The triple jump is more technically difficult than the long and high jumps because it involves three consecutive, high-speed touchdowns and takeoffs, as opposed to the single touchdown and takeoff in each of the long and high jumps (Liu et al., 2015). The triple jump requires both technical and physical effort because its performance depends on three consecutive high-speed take-offs and landings (Ryu & Chang, 2015). The optimum effort distribution during the hop, step, and jump phases has been investigated as a crucial technical factor affecting the performance of the triple

jump (Liu et al., 2015). Previous studies have demonstrated that individualized optimum phase ratios exist due to the individualized relationships between the loss in horizontal velocity and the gain in vertical velocity during each phase of the triple jump (Bayraktar, 2017). However, the extent to which the phase ratio affects the actual distance in the triple jump is still unknown (Eissa, 2014). Based on published data of 73 elite triple jumpers at world championships or Olympic competitions, approximately 48% of the athletes utilize a hop-dominant technique, 44% utilize a balanced technique, and only 8% utilize a jump-dominant approach (Romer & Weimar, 2019). A study reported a mean actual triple jump distance of 16.57 meters, with phase distances of 5.95 m, 4.93 m, and 5.69 m for the hop, step, and jump phases, respectively, indicating that the field, on average, utilized a balanced triple jump technique (Krzysztof & Mero ., 2013). When examining the top eight competitors at the Olympics, four were hop-dominant jumpers, three were balanced jumpers, and one was a jump-dominant jumper. The mean actual triple jump distances for the hop-dominant group were 17.34 m, with mean phase distances of 6.43 m (hop), 5.31 m (step), and 5.60 m (jump), while the combined balanced and jump-dominant groups displayed mean actual triple jump distances of 17.49 m and mean phase distances of 5.99 m (hop), 5.36 m (step), and 6.15 m (jump)[Romer & Weimar, 2019].

Effort distribution should be seriously considered as a technical factor only if the phase ratio significantly affects the actual distance in the triple jump (Romer & Weimar, 2019). A recent study demonstrates that the phase ratio significantly affects the actual distance of the triple jump (Liu et al., 2015). There are no references indicating that research on this phase ratio has been conducted to identify the optimum phase ratio of Indonesian triple jump athletes. Thus, it is still not clear whether the hop-dominant, balanced, or jump-dominant technique is used. The purpose of this study, therefore, was to identify the phase ratio of hop, step, and jump as an index detector of triple jump performance. The findings of this research will be applied to triple jump training in the field, especially for Indonesian triple jump athletes.

METHODS

The method used in this research was descriptive method. It provided an overview of the jump ratio percentage by calculating the distances of the hop, step, and jump phases relative to the total distance and comparing them with world-elite triple jumpers using the deterministic model from Hay.

Participants

The subjects were seven skilled triple jump athletes who participated in the National Sports Championship. They were the best representatives from various provinces in Indonesia and had passed the selection criteria determined by the athletic competition committee.

Sampling Procedures

The number of subjects involved in this study was determined using total sampling, resulting in seven athletes. All subjects were selected as samples and their participation received official permission from the athletic competition committee.

Materials and Apparatus

Data collection was conducted using a set of devices consisting of three Sony video cameras, type ZR 70 MC, mounted on tripods with a speed of 25 fps and a shutter speed of 1/1000 sec. These cameras were placed beside the jump areas for the hop, step, and jump phases, where the athletes make their final push during takeoff. The film data was then converted into a computer using 2-D Dartfish 2.5 software.

Procedures

Films were taken of the seven triple jump athletes involved in the National Sports Championship, and only the best jump results were analyzed. To obtain valid film data, the cameras were set in a still position on tripods and placed as far back as possible to minimize perspective error. The plane of motion was kept perpendicular to the camera's optical axis. Panning techniques (camera movements) were also used, especially starting from the hop, through the step, and the jump, to the landing. To measure the real distance, a series of markers was placed in carefully measured locations along the inside edge of the track between the runway and

each camera. These markers served as reference measurements. The camera configuration in the field can be seen in the figure 1.

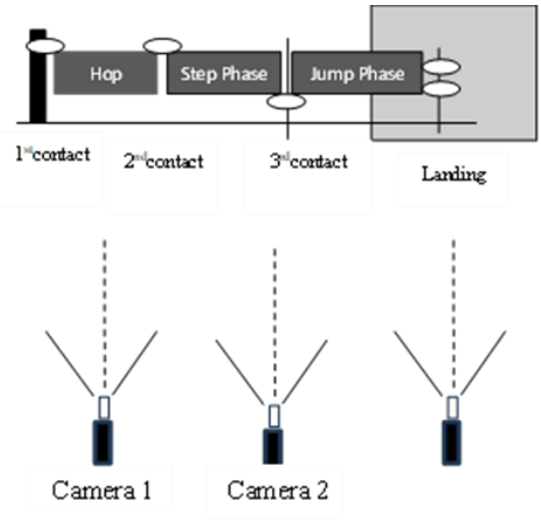

Fig 1. Camera Configuration

Data Analysis

The design of this study was descriptive, where in all the data were utilized to provide an overview of the hop, step, and jump phase ratios of all subjects. Additionally, the analysis involved both quantitative data and qualitative data about the movement performance obtained from the subjects' movements. These data were analyzed using the deterministic model from Hay (1997).

Table 1 shows the data on hop, step, jump distance, phase ratio, technique, and total distance of the subjects. Table 2 shows the horizontal distance from the hip to the landing foot, stride number, and takeoff time during the takeoff, respectively.

The data revealed significant variations in jump distances. Table 1 demonstrates that the highest values for hop, step, jump, and total distance were 5.26 m, 4.90 m, 6.28 m, and 15.69 m, respectively. On average, Indonesian triple jumpers achieved a hop of 4.75 m, a step of 4.51 m, and a jump of 5.65 m, resulting in an average total distance of 14.91 m. The calculated phase ratio of 32%: 30%: 38% indicates a jump-dominated phase ratio. This result signifies that jumping dominance occurs during the jump phase. These findings are evident in Table 1, where five subjects demonstrate a greater value of the jump phase ratio compared to others who predominantly use balanced and hop-dominated techniques.

Observing Table 2, the data reveals the number of steps, total time, run-up time, horizontal distance, and takeoff time for the three phases. The average number of steps taken by Indonesian triple jumpers was 18, with a total time of 6.42 seconds and a run-up time of 4.43 seconds. The highest number of steps was taken by S6 (22 steps), while the lowest number of steps was taken by S7 (15 steps). Takeoff time, representing the duration of foot contact with the ground after landing for each phase, was 0.122 seconds for the hop phase, 0.148 seconds for the step phase, and 0.164 seconds for the jump phase.

RESULT

Table 1. Distance and Phase Ratio

Subject	Hop Distance (m)	Step Distance (m)	Jump Distance (m)	Phase Ratio	Technique	Distance Total (m)
S1	4,51	4,90	6,28	29% :31% :40%	Jump – dominated	15,69
S2	4,77	4,45	6,24	31% :29% :40%	Jump - dominated	15,46
S3	5,26	4,19	5,79	35% :27% :38%	Jump - dominated	15,24
S4	4,58	4,49	5,80	31% :30% :39%	Jump - dominated	14,87
S5	5,06	4,75	4,92	34% :32% :34%	Balanced	14,73
S6	4,10	4,36	6,20	28% :30% :42%	Jump - dominated	14,66
S7	4,95	4,46	4,31	36% :33% :31%	Hop - dominated	13,72
Average	4,75	4,51	5,65	32% :30% :38%	Jump - dominated	14,91

Table 2. Horizontal Distance from the Hip to the Landing Foot, Stride Number, and Take Off Time

Subject	Stride Number	Time Total (sec)	Run-up Time (sec)	Horizontal Distance			Take off Time (sec)		
				Hop	Step	Jump	Hop	Step	Jump
S1	18	07,06	05,05	0,42	0,52	0,70	0,134	0,150	O,184
S2	18	06,18	04,13	0,44	0,49	0,70	0,083	0,150	0,167
S3	20	07,06	05,12	0,65	0,46	0,42	0,117	0,134	0,150
S4	13	06,17	04,18	0,39	0,53	0,65	0,150	0,167	0,183
S5	18	06,18	04,29	0,41	0,54	0,68	0,134	0,150	0,183
S6	22	07,18	05,18	0,38	0,56	0,62	0,117	0,134	0,133
S7	15	05,10	03,22	0,37	0,38	0,51	0,116	0,150	0,150
Average	18	06,42	04,43	0,44	0,50	0,61	0,122	0,148	0,164

DISCUSSION

The objective of this study was to investigate the phase ratio between hops, steps, and jumps of Indonesian triple jumpers, revealing results of 32%, 30%, and 38%, respectively. This percentage indicates that jumping dominance occurs predominantly in the jump phase (jump-dominated). In comparison, the ratio between hops, steps, and jumps for many world champions shows 34.0: 29.5: 36.5 (Graham-Smith & Brice, 2023). It can be concluded that most Indonesian triple jumpers exert more pressure, especially in the final phase, the jump phase.

Notable differences in strength of leg muscles, techniques employed during the hop, and optimum horizontal speed maintained during the hop were observed. The largest hop distance was achieved by S3 at 5.26 m, while the smallest hop was achieved by S6 at 4.10 m. Similarly, the largest step distance was achieved by S1 at 4.90 m, and the smallest step distance was achieved by S3 at 4.19 m. The largest jump distance was achieved by S1 at 6.28 m, while the smallest jump distance was achieved by S7 at only 4.31 m.

Whereas, the previous study reported that jump dominant groups displayed mean actual triple jump distances of 17.49 m and mean phase distances of 5.99 m (hop), 5.36 m (step), and 6.15 m (jump) [Romer & Weimar, 2019]. A crucial aspect emphasized in the analysis is the need for athletes to generate controlled optimum horizontal speed until the first takeoff (hop) occurs (Bayraktar, 2017), followed by effective utilization of leg muscle power in subsequent phases (Dziewiecki et al., 2013).

Furthermore, the horizontal distance from the pelvis to the tip of the landing foot for Indonesian triple jumpers was recorded as 0.44 m (hop), 0.50 m (step), and 0.61 m (jump), respectively. Contrasting these measurements with research involving 16 world triple jumpers revealed slightly different distances: 0.55 m (hop), 0.53 m (step), and 0.60 m (jump) [Allen et al., 2013].

Additionally, the takeoff time, representing the duration the feet adhere to the ground after landing for each phase of hop, step, and jump, was found to be smaller than the world record set by Victor Saneyev (Rusia), with times of 0.133 sec, 0.155 sec, and 0.180 sec (Santhosh & Shabu, 2019). This suggests that most Indonesian jumpers execute takeoffs too fast and too horizontally, resulting in insufficient force impulse (Coh et al., 2015). However, elongating landing time should be avoided to prevent reductions in horizontal forward speed and increases in vertical speed (Allen et al., 2013; Haridy, 2015). The analysis highlights the importance of adequate leg power for executing an active landing during takeoff, especially as horizontal speed decreases and contact time with the ground lengthens (Liu et al., 2015). Comparing Indonesian athlete S1's takeoff times with those of world champions underscores the need for athletes to strive for optimal performance metrics (Teferi & Endalew, 2020). From the table 2, S1 took times of 0.134 sec, 0.150 sec and 0.184 sec. The traditional approach, using former world champion Jonathan Edwards as a benchmark, reveals disparities in hop, step, and jump distances between Indonesian and world-class athletes (Lenuța & Corina, 2021), with his jumping achievement of 18.29 m, with a hop distance ratio (6.05 m), step (5.22 m), and jump

(7.02 m), thus the distribution is about 33%, 29%, and 38%, respectively. Comparing with the average jump of Indonesia triple jumpers, then the hop distance is 6.05 – 4.75 = 1.3 m, step (5.22 – 4.51 = 0.71 m), and jump distance (7.02 – 5.65 = 1.37 m). This indicated that during these three phases, world athletes have shown their dominance with a difference in numbers that is almost close to an average of 1.3 m. They have an advantage not only in terms of the power of his two legs during takeoff and landing, but also especially in terms of the technique used during takeoff, flight and landing.

The study findings underscore the critical importance of understanding and optimizing the phase ratio in triple jump performance for Indonesian athletes. Coaches and athletes must prioritize determining the ideal phase ratio before addressing other technical challenges. Neglecting this aspect may lead to unconscious errors that hinder overall performance (Allen et al., 2013). Additionally, the study reveals that many Indonesian jumpers exhibit a tendency to take off too quickly and horizontally, resulting in insufficient force impulse generation. To address this, athletes should focus on increasing vertical speed, particularly during the jump phase, regardless of their chosen technique (Liu et al., 2015); Abdelkader et al., 2018). Adequate leg power support is essential for executing active landings and optimizing performance, especially as horizontal speed decreases (Allen et al., 2013). According to this study on the optimum phase ratio, Indonesian triple jumpers should jump with their maximum vertical jumping effort during the jump phase regardless the techniques in terms of phase ratio. Another important point obtained from the results of this study suggest that the double-arm swing technique (power oriented) had the highest production of vertical velocity (as shown by S1). Therefore, the double-arm swing technique appeared to be optimum for the jump phase of the triple jump. This statement is in line with the previous research results which stated that some elite triple jumpers use a symmetrical double-arm technique indicates that it is possible to control such rotations without utilizing an asymmetrical technique and so the symmetrical technique is as viable as an asymmetrical technique in this respect (King & Yeadon, 2015). Overall, the study provides valuable insights into individual phase ratios and their impact on triple jump performance. By utilizing this knowledge, coaches and athletes can tailor training programs to address specific technical challenges and enhance overall performance levels.

CONCLUSION

The conclusions drawn from the research shed light on several key aspects of triple jump performance among Indonesian athletes. The phase ratio between hops, steps, and jumps of the Indonesian triple jumpers was respectively 32%, 30%, and 38%. The triple jump technique used by Indonesian athletes was jump-dominant, and the double-arm swing technique produced the furthest jump distance. This research has provided evidence that the identification of phase ratios is very important for Indonesian triple jumpers because it significantly affects their actual distance in the triple jump. This research only revealed the phase ratio of three phases using two-dimensional analysis. Further research is recommended to examine several important kinematic variables that influence the jump results of the Indonesian triple jumper using 3-dimensional computer analysis.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

REFERENCES

Abdelkader, G., Madani, R., & Bouabdellah, S. (2018). Impact of the collision and push angles on the phases hop, step and jump in the triple jump and their relationship to the stage of take-off. European Journal of Physical Education and Sport Science.

Allen, S. J., King, M. A., & Yeadon, M. R. (2013). Trade-offs between horizontal and vertical velocities during triple jumping and the effect on phase distances. Journal of Biomechanics, 46(5), 979-983.

Allen, S. J., King, M. A., & Yeadon, M. F. (2016). Optimisation of phase ratio in the triple jump using computer simulation. Human movement science, 46, 167-176.

Bayraktar, I. (2017). Relationships between Horizontal Velocity Variables and Jump Performance In The Triple Jump. Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health, 17(2).

Čoh, M., Matjačić, Z., Peharec, S., Bačić, P., Rausavljević, N., & Maćkala, K. (2015). Kinematic, dynamic and EMG analysis of drop jumps in female elite triple jump athletes. Collegium antropologicum, 39(Supplement 1), 159-166.

Dziewiecki, K., Mazur, Z., & Blajer, W. (2013). Assessment of external and internal loads in the triple jump via inverse dynamics simulation. Biology of sport, 30(2), 103-109.

Eissa, A. (2014). Biomechanical evaluation of the phases of the triple jump take-off in a top female athlete. Journal of human kinetics, 40, 29.

Graham-Smith, P., & Brice, P. (2023). What would it take to break the world record in the men's Triple jump. ISBS Proceedings Archive, 41(1), 43.

Ibrahim Haridy, A. M., Abdel-Raouf Diab, M., Ismail El-Shaer, O., & Mohamed Abdel-Gawad, M. (2015). Changes in vertical and leg stiffness during triple jump performance. Journal of Applied Sports Science, 5(1), 55-60.

King, M. A., & Yeadon, M. R. (2015). Advances in the development of whole body computer simulation modelling of sports technique. Movement & Sport Sciences-Science & Motricité, (90), 55-67.

Krzysztof, M., & Mero, A. (2013). A kinematics analysis of three best 100 m performances ever. Journal of human kinetics, 36(1), 149-160.

Lenuţa, D., & Corina, Ţ. (2021). The Evolution of The World and National Record In Men's Triple Jump. Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health, 21.

Liu, H., Mao, D., & Yu, B. (2015). Effect of approach run velocity on the optimal performance of the triple jump. Journal of Sport and Health Science, 4(4), 347 -352.

Makaruk, H., STARzAK, M. A. R. C. I. N., & SADOwSKI, J. (2015). Does step length adjustment determine take-off accuracy and approach run velocity in long and triple jumps?. Human Movement, (3), 124-129.

McErlain-Naylor, S. A., King, M. A., & Felton, P. J. (2021). A review of forward-dynamics simulation models for predicting optimal technique in maximal effort sporting movements. Applied Sciences, 11(4), 1450.

Mohammed, Z. (2015). The Impact of the Three Pushes Takeoffs Angel's Phases and Their Distributions Strides Lengths on the Performance in Triple Jump. International Journal of Modern Trends in Engineering and Research (IJMTER), 2(07), 317-323.

Mohammed, Z., Idriss, M. M., Ali, B., Nasreddin, B. M., & Abd-el-Kader, G. (2015). The Impact of the Techniques and Tactics Appropriate by the Athletes in Phase Triple Jump and Their Relationships with the Finale Results. Journal of Sports Science, 3(4).

Mohammed, Z. (2015). The impact of push phases takeoffs angles on performance in the dominant hop technique. Open Access Library Journal, 2(11), 1-7.

Ramadani, L., Rashiti, N., Shkodra, M., & Heta, G. (2021). Influence of some anthropometric and motor parameters on triple jump. Journal of Education, Health and Sport, 11(12), 38-46.

Romer, B., & Weimar, W. (2019). Phase ratios of American collegiate triple jumpers. Journal of Physical Education and Sport, 19(1), 645-651.

Ryu, J. K., & Chang, J. K. (2015). The Velocity Conversion Coefficient and Consistency for the Optimal Phase Ratio on the Performance of the Women's Triple Jump. Korean Journal of Sport Biomechanics, 25 (1), 39-47.

Santhosh, R., & Shabu, S. J. (2019). Kinematic analysis on selected biomechanical parameters of hop phase in tipple jump. Int J Physiol Nutr Phys Educ, 4, 149-151.

Teferi, G., & Endalew, D. (2020). Methods of Biomechanical Performance Analyses in Sport: Systematic Review. Am. J. Sports Sci. Med, 8, 47-52.

Thotawaththa, P., & Chandana, A. (2021). A Triple Jump Performance Optimization Model Based on Flight Phase Biomechanical Factors. IOSR Journal of Sports and Physical Education (IOSR-JSPE), 8 (4), 10-17.