Beyond the Numbers: Understanding the Practical Significance of Phase Ratios in Triple Jump

Nelio Alfano Moura, [1 2 3] **Pengpeng Han,** [4] **Tania Fernandes de Paula Moura,** [2 3] **Larissa de Paula Moura** [3]

[1]Esporte Clube Pinheiros - Brazil
[2]Centro de Excelência Esportiva - SE (SP) - Brazil
[3]M& M Atletismo - Equipe Maurren Maggi - Brazil
[4]Beijing Sport University - China

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Headline

Since at least the 1930s, the distribution of effort in the partial jumps - Hop, Step, and Jump (Figure 1) - has been considered a fundamental aspect of the triple jump technique (Bober, 1974; Doherty, 1953; Webster, 2018). Modern techniques have been named by Hay (1990) according to the percentage contribution of each phase to the total distance. In this classification, when the difference in contribution between the two longest phases is less than 2%, the technique is considered Balanced. If it exceeds 2%, it is either Hop-dominated or Jump-dominated. Although theoretically possible, Step-dominated efforts are not observed in practice.

Performance in the triple jump depends on the horizontal velocity at the end of the approach run and the ability to maintain as much as possible of that velocity until takeoff for the Jump (Čoh & Kugovnik, 2011; Dyson, 1977; Fukashiro & Miyashita, 1983). Generating vertical velocity in each phase is also necessary (Dyson, 1977), but results in losses of horizontal velocity (Allen et al., 2013; Yu, 1999). Moreover, since the impact forces during the landings of the Hop and Step are very high (Amadio, 1986), athletes are compelled to limit the distances achieved in these phases to reduce the risk of injury and the number of aborted jumps (Hay, 1995). Thus, the Hop and Step would represent submaximal efforts, followed by a maximal effort in the Jump (Hay, 1995). Considering that horizontal velocity and its conservation are closely linked to performance in the event, the distances achieved in the Hop and Step should be limited by controlling the takeoff angles (Dyson, 1977) through adjustments in production of vertical velocity and, consequently, flight times, without reducing the horizontal velocity.

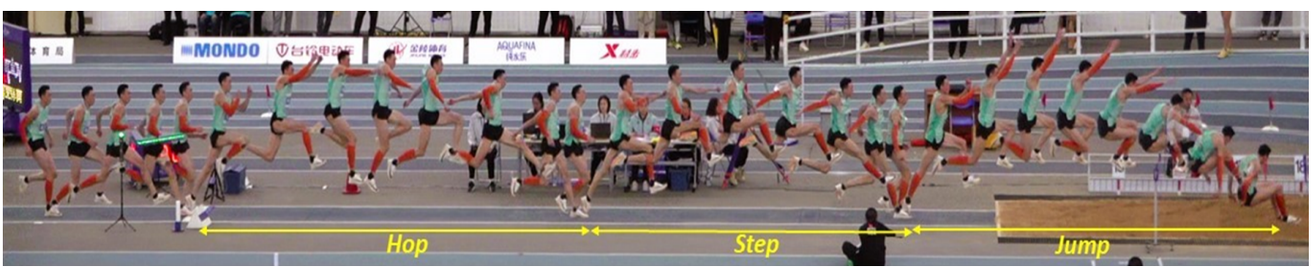

Fig. 1. Partial jumps in the triple jump.

Aim

It has been a consensus between researchers and coaches (Starzynski, 1987; Toledo, 1978; Yu & Hay, 1996) that there is no optimal distribution that universally applies to all jumpers. This distribution would vary according to individual characteristics, performance level, and the athlete's stage of preparation or career (King, 1996). Moreover, although general principles can be applied to both genders, there is a scarcity of studies addressing the women's triple jump. This brief article discusses the practical application of relevant aspects related to the distribution of partial jumps in men's triple jump and makes inferences for the women's event.

The "Currency" of the Triple Jump

In the triple jump, just like in life, there is no "free lunch". Jumping far, in any of the phases, comes at a cost, and that cost is determined in the currency of the jumping events: the horizontal velocity generated during the run-up. To produce a longer Hop, more horizontal velocity must be converted into vertical velocity, with the potential of negatively impacting the subsequent phases. This also applies to the Step. Although the "cost" of longer Hops or Steps may vary for different athletes, it certainly reaches a point where it becomes too "expensive": the losses in the next phase would outweigh the gains in the current phase.

Mathematical and Statistical Models

Several authors have sought to find objective parameters that could help to "prescribe" the optimal individual distribution. Although coaches intuitively advise Hop-dominated distributions for stronger jumpers and Jump-dominated distributions for faster jumpers (King, 1996; Locatelli, 1987), this relationship has not been objectively demonstrated. Furthermore, it is difficult to define what constitutes a "strong" jumper, as strength manifests in different and specific ways (Moura, 2018). Yu & Hay (1996) recommend choosing the technique based on the approach speed and the conversion coefficient between horizontal and vertical velocity at each support phase (A_1). According to this model, when $A_1 < 0.5$ (few losses of horizontal velocity for a given gain in vertical velocity), Hop-

dominated or Balanced techniques should be used. Using the currency analogy, it would be "cheap" for this jumper to generate vertical velocity, so he can invest in a longer Hop. For $A_1 > 0.9$ (greater losses of horizontal velocity for a specific gain in vertical velocity), the recommended technique would be Jump-dominated. The extra vertical velocity required to perform a longer Hop or Step would be too "costly" and would harm the subsequent phases and the total distance. When $0.5 < A_1 < 0.9$, the optimal individual technique should consider the approach speed, and the authors suggest caution in applying the model, as there could be errors of ± 2% in estimating the optimal percentage for each phase.

Other computer simulations have been conducted. Brimberg, Hurley, & Ladany (2006), for example, found increased performance in their simulations when the technique shifted from Hop-dominated to Jump-dominated, although they emphasize that the choice of the best distribution should be made individually. In both mentioned models, the simulations tend to generate recommendations that are not commonly seen in the real world, with optimized contributions from the Jump exceeding 40% and the Hop falling below 30%. On the other hand, in the model by Allen, Yeadon, & King (2016), manipulations of strength and approach speed resulted in distances ranging from 14.05 m to 18.49 m, with Hop-dominated or Balanced distributions, rather than Jump-dominated. The same group applied this optimization model to an athlete (personal best: 14.35 m) and found decreased performance when the Jump-dominated strategy was used (Allen, King, et al., 2016).

Graham-Smith & Brice (2019) analyzed data from the multiple medalist Christian Taylor using a model continuously developed by one of the authors. Considering the relationship between average approach speed and effective distance, they noticed that most of Taylor's jumps yielded results higher than predicted for his speed, leading them to speculate that his technique was optimum. When comparing data from the distances of the partial jumps and the approach speed plotted against the actual distance of the triple jump achieved by different athletes, the slope of the trend lines clearly showed that the better the result, the smaller the difference between the Hop and the Jump. According to this model, as performance increases, the technique progressively becomes less Hop-dominated. The authors state that in a database of 452 jumps, with actual performances ranging from 13.54 m to 17.99 m, the amount of Jump-dominated efforts - like those produced by Taylor - was minimal, although more frequent at the upper extreme.

The Pursuit of Jump-dominance in the Triple Jump

Hay (1995) claimed that most jumpers invest more in the Hop phase than would be advisable. He suggested that more jumpers should experiment with reducing the contribution of the Hop in favor of the Jump. Indeed, what is observed at all levels of competition is a higher frequency of the Hop-dominated efforts (Stanley et al., 2012), which is an intriguing preference since all three possibilities would be equally effective (Moura et al., 2016). In previous studies, in agreement with the model proposed by Graham-Smith & Brice (2019), we noticed that when the same jumper deviated from the Hop-dominated distribution, there was a tendency to achieve better performances, both within the same competition (Moura et al., 1994) and throughout a season (Moura et al., 2016), although it is unknown whether this trend persists over several years.

In building his proposal that elite triple jumpers should more frequently explore the Jump-dominated technique, Hay (1993, 1999) suggests that the last three world record holders in men's triple jump have used this distribution. Although there are controversies regarding the phase ratios in two of these cases (Butler, 2019; Camargo-Junior et al., 2020; Hay, 1992, 1999), this seems to be a strong argument in favor of intentionally pursuing this technique, which could be achieved mainly through the control of effort intensity in the Hop phase, reducing its length.

The pursuit of the Jump-dominated technique is not actually new. In 1938, in his classic work "Coaching and Care of Athletes," Webster (2018) already mentioned the proposal made by Finnish coach Armas Valaste for beginner athletes, suggesting shifting from jumps that would be classified today as Balanced to Jump-dominated, without going through the Hop-dominated strategy. In the same book, the author states that the goal of the Japanese, who had the best school of triple jumpers in the 1930s, in their preparation for the 1936 Olympic Games, was to produce Jump-dominated efforts. However, during the Games, despite Naoto Tajima winning the gold medal and setting a new world record, what was seen was a Hop-dominated technique.

Although the individual association between less Hop-dominance and increased performance appears clear, what happens to the actual distance achieved in each partial jump when athletes deviate from this distribution? A basic fact to keep in mind in this discussion is that we cannot determine the percentage contribution of each phase until the whole jump is finished. In triple jump, it is common to accumulate errors from phase to phase, which results in less variation in Hop performance compared to Step and Jump (Allen et al., 2013). Any error in the transition from one phase to another compromises the distance in the subsequent phase, causing an increase in the percentage contribution of the previous phase. If this error is corrected in another attempt, the percentage contribution of the first phase will decrease, even if its actual distance is not smaller. In this situation, it's clear that the total distance of the triple jump will be greater. However, if we only consider the percentage values, we may mistakenly conclude that reducing the Hop led to improved performance. In fact, the Hop may have remained the same, or even increased. Miller & Hay (1986) reported the characteristics of Willie Banks' world record (17.97 m) set in 1985, noting that he employed the Jump-dominated technique (35.1% - 27.6% - 37.3%, with partial distances of 6.30 m - 4.96 m - 6.69 m). Banks had another jump analyzed from a competition three years prior (17.62 m), where he used a Balanced technique (34.8% - 29.3% - 35.9%, with partial distances of 6.13 m - 5.17 m - 6.32 m). The distances achieved in the Hop and Jump phases increased when setting the World Record, accompanied by a reduction in the Step phase. His technique was classified as Jump-dominated because the final phase exhibited a greater increase, not because the Hop phase had decreased.

While it may be accurate to state that an excessively long Hop can lead to reduced total distances or even the abortion of the jump, determining individually what constitutes an excessively long Hop remains a challenge. On the other hand, it has been accepted that the ability to maintain horizontal velocity throughout the three phases is one of the most important aspects of the triple jump (Fukashiro et al., 1981; Fukashiro & Miyashita, 1983), and that the actions of the jumper during successive landings and take-offs influence this ability (Arnold, 1986; Hunter et al., 2019; King, 1996; Koh & Hay, 1990). Thus, we can assume that the capacity to perform active landings, minimizing the loss of horizontal velocity in each phase while generating optimal values of vertical velocity and rotations, represents the dominant factor in the technique of the triple jump (King, 1996). Athletes who master these actions could conserve more energy at each

support phase, maintaining higher levels of horizontal velocity and balance during the flight phases, increasing the contribution of the Jump to the total distance and, consequently, the overall result of the triple jump, while simultaneously moving away from the Hop-dominated distribution. King (1996) emphasizes the philosophy frequently adopted by coaches that the triple jump represents a "continuous rhythmic pattern of movements," which can only be manifested when the transition between the jumps is well-executed. The percentage contribution of the three phases would thus be an effect of these actions and the pursuit of rhythm, just like the total distance, rather than the cause of performance variation. These factors may also explain the observed phenomenon when tracking jumpers over time: as mentioned before, results typically improve when the athlete becomes less Hop-dominated.

Nevertheless, knowing the distribution of partial jumps provides us with a clue about the actions to take to improve performance. In the finals of the World Championships and Olympic Games from 1983 to 2019, where the phase ratios have been measured, the average contribution of the Step among medalists is 30.3 ± 1.3% (Camargo-Junior et al., 2020). These values align with the observation of Hay (1993) that elite jumpers aim for Step contributions of around 30% and with computer simulations conducted by Allen et al. (2013), who noted that significant deviations from 30% in the Step, whether lower or higher, are associated to decreases in total distance. Thus, we can assume that distributions with a Step contribution below 28% are undesirable, as losses in this phase are unlikely to be compensated for in the Jump phase (although in the case of Willie Banks' World Record, the Step contribution was only 27.6%). On the other hand, values exceeding 32% may indicate excessive vertical velocity production in the Step, which would diminish the required horizontal velocity for a successful Jump. A practical method for estimating the vertical velocity generated during each phase and assessing the adherence to the rhythmic aspect of the jump is by monitoring the flight time (King, 1996). In Table 1, we present unpublished data collected by the authors, which can provide an initial reference, including for women, who have been underrepresented in research compared to their male counterparts. These data reveal that although women exhibit support times only slightly longer than men, they demonstrate significantly shorter flight times, particularly in the Step. This discrepancy suggests a greater difficulty for women in generating vertical velocity throughout the triple jump. Consequently, it is possible that the optimal techniques commonly pursued by males may not be effective for females.

Table 1. Support and flight times(s) in the three phases of the triple jump, for both sexes.

	Hop		**Step**		Jump	
	Support	Flight	Support	Flight	Support	Flight
Men	0.116 ± 0.025*	0.531 ± 0.037**	0.148 ± 0.034	0.449 ± 0.047**	0.163 ± 0.037	0.675 ± 0.064**
Women	0.126 ± 0.014	0.497 ± 0.025	0.153 ± 0.015	0.339 ± 0.058	0.165 ± 0.019	0.626 ± 0.028
Cohen's d	0.49	1.08	0.19	2.08	0.07	0.99

Men: n = 115 (Triple jump performance: 16.90m ± 0.74m). Women: n = 39 (Triple jump performance: 13.68m ± 0.62m) *p $<$ 0.05, **p $<$ 0.0001

Notes: The values presented are based on World Championships and Olympic Games official reports, and unpublished data collected by the authors. $p-$values and Effect sizes were calculated using online tools: `https://www.graphpad.com/quickcalcs/ttest1/?Format=SD` and `https://www.socscistatistics.com/tests/`.

Recently, we published a case study on Chinese triple jumper Zhu Yaming, the Olympic silver medalist in Tokyo, who seems to have benefited from changes in his jump distribution. His technique shifted from Hop-dominated to Balanced, while also experiencing practically significant improvements of 1% (17 cm) in his performance (Moura et al., 2023). In his case, however, the actual distance of the Hop decreased, in favor of gains in the distances of the Step and Jump. Novel studies focusing on triple jump techniques are needed to evaluate the hypothesis that active landings are related to a more efficient horizontal-to-vertical velocity conversion, impacting the distances achieved at the distinct phases and then, the phase ratios.

Practical Applications

- The partial distances in the triple jump (in meters), the phase ratios (in percentage values), the classification of technique, and the flight times for each phase offer valuable practical information for coaches in making informed decisions concerning potential strategies aimed at optimizing individual performance in the triple jump.
- It is imperative to recognize that this information is limited and should be considered collectively and with caution, as phase ratios are a consequence rather than a determinant of the actions that govern performance in the triple jump.
- This shift in perspective will enable coaches to refine their training strategies to foster improvements in triple jump performance.

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