EFFECTIVE BATON EXCHANGE IN THE 4X100 M RELAY RACE

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Abstract

Baton exchange effectiveness and speed are essential to performance in sprint relay races, often deciding team victory. An effective baton exchange requires athletes to complete it while at full speed, both by the incoming and the outgoing athlete. Our research aimed to determine the relationship between baton exchange time and the point in the exchange zone where the handoff is completed. The study was carried out among Polish national team sprinters (n=27), competing in the 4x100 m relays. We analyzed 168 men's and 62 women's baton exchanges across the annual training cycle. In a 30-meter track segment corresponding to the baton exchange zone, we measured the time the baton spent in this segment (exchange time, ET), using the Brower Timing Systems (TC-System, USA), and the exact point of the baton handoff in this zone (handoff point, HP). To show the relationship between ET and HP, we performed a linear regression analysis. We have found that the further the HP the shorter the ET. This dependence is more evident in women ($r=-0.66$, $r^2=0.44$ for 1st and 3rd exchanges, and $r=-0.72$, $r^2=0.52$ for 2nd exchange; both $P<0.001$) than in men ($r=-0.45$, $r^2=0.20$ and $r=-0.68$, $r^2=0.46$; both $P<0.001$, respectively). The results suggest that the further the baton exchange takes place in the exchange zone (longer HP distance) the more effective the exchange (shorter ET). However, the coefficient of determination ranging ($r^2=0.20$-0.52) indicates that HP explains at most 50% of the ET, and other factors should be taken into account. Nonetheless, the measuring technique proposed by us can provide coaches with additional data on baton exchange effectiveness and athletes' speed abilities.

Key words*: athlete, sprinter, speed, abilities.*

Introduction

Athletics mainly consist of individual events. The exception is all types of relay races which are very spectacular track events, frequently shown at the very end of competitions. Relays require the athletes to work together to achieve the best result and thus the highest possible ranking (Mach, 1991; Maisetti, 1996). An effective 4x100 m relay team is characterized by a synergy between athletes who can get an outcome better than the sum of their best times in a 100–m sprint (Mach, 1991; Bry et al., 2009). Athletes running in a sprint relay must have good acceleration ability and a high level of speed endurance (Mach, 1991; Ward-Smith and Radford, 2002; Kusy et al., 2015). However, even the four fastest sprinters in the world are ineffective as a relay team if they are unable to exchange the baton efficiently. A proficient handoff can partly compensate for a lack of speed but dropping the baton ruins chances for victory. The best example is the U.S. men's relay team which has failed 6 out of 9 times at the Olympic Games and World Championships since 2008.

The requirement for a good exchange is to perform it at the highest possible speed of both the passing athlete and the one receiving the relay baton. The passing athlete accelerates 35–40 m, reaches maximum speed at about 50–70 m, maintaining it for 20 m, and then speed decreases (Maćkała, 2007; Gajer et al., 1999). The athlete must be able to maintain the highest possible speed from the checkmark to the moment of handoff (Mach, 1991; Ward-Smith and Radford, 2002; Radford and Ward-Smith, 2003; Kantanista et al., 2016). However, it is not possible to exchange the baton at maximum speed, because it takes a high–level sprinter approximately 50 m to achieve top speed, while baton passing is performed after 25–30 m at the latest (Mach, 1991; Maisetti, 1996, Ward-Smith and Radford, 2002; Zhang and Chyu, 2000). The higher the speed, the shorter the time in the exchange zone, and thus more effective the baton exchange (Radford and Ward-Smith, 2003). The receiving athlete should accelerate as smoothly as possible to the maximum possible speed to obtain the desired speed (Fukashiro et al., 1992). If an exchange takes place after a 20-meter acceleration phase, the receiving athlete will attain 89% of their maximum speed (Ward-Smith and Radford, 2002). Completing an exchange in the first 10 m of the exchange zone indicates that the receiving athlete did not have enough time to accelerate optimally (Sugiura et al., 1995; Ward-Smith and Radford, 2002). During a perfect exchange, the baton transfer takes place on two strides in less than 1s (Oberste and Wiemeyer, 1991; Maisetti, 1996) with an optimal free space between runners of about 1.5–2 m (Oberste and Wiemeyer, 1991; Zhang and Chyu, 2000; Ward-Smith and Radford, 2002). Even a small loss of 'synergy' during baton passing can have a significant impact on the overall result (Zhang and

Chyu, 2000; Maisetti, 1996). The disharmony in handing the baton causes an increase in the exchange time (Zhang and Chyu, 2000; Radford and Ward-Smith, 2003; Bry et al., 2009). A good example of effectiveness is the men's Polish National relay team which does not have world–class athletes in the individual sprint events (100 m or 200 m) but still counts in the world classification (4th place during World Championships in 2011, the national record of 38.31 s set during Olympic Games in 2012).

One way to assess the technical quality of the relay is to calculate the difference between the sum of individual personal best results in the 100 m and the time obtained by the relay team. This simple parameter accurately defines the efficiency of the relay team, reflecting the ability to effectively transfer the relay baton between sprinters, and thus determines the final result (Mach, 1991; Maisetti, 1996). The individual performance levels have often indicated which relay team should win, although, in reality, this was far from the truth. The victory of Great Britain's 4x100 m men's team in the 2004 Olympic Games was surprising because the sum of the individual results (40.77 sec) did not place this team as one of the favorites, unlike the U.S. team (39.59 sec) which ultimately took second place. The reason was extensive differences in technical quality between the relay teams which proved that a well–trained team could win against a faster but less trained one.

Gerard Mach (1991) presented a method of selection for the relay to maximize performance at the international level. He also presented examples of practical training drills for relay team preparation. One of them is the exercise of passing the baton in the exchange zone using electronic equipment measuring the speed of each runner, which helps determine the location of the checkmark. For the first time, Mach (1991) indicated the need to measure sprinters' speed during baton passing to determine the proper location of the control mark. So far, no research has mathematically proven the relationship between the sprinting speed or time and the baton exchange point in the zone to assess exchange effectiveness. In this study, we have presented and described a simple method, which provides additional data on relay exchange effectiveness, performance, and sprinters' speed abilities.

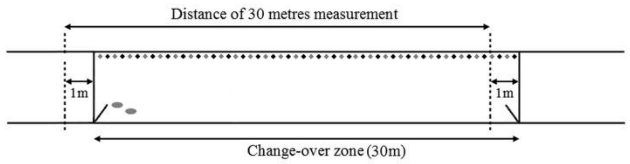
Highlighting the fact that the 4x100 m world record has not been broken since the 2012 Olympic Games for both men and women, there is no doubt that it will be extremely difficult to break it in the near feature. Thus, relay teams have to reach for every possible additional resource to increase their chances of winning, especially during the pre–Olympic year. The main aim of this research was to present an effective and practical way to obtain additional information in top relay teams on the example of the women's and men's Polish national 4x100 m relay team. Moreover, the research aimed to show the relationship between the time the baton spends in the exchange zone (exchange time; ET) and the point (meter) in the zone where the exchange is completed (handoff point; HP) as a measure of effective baton exchange.

Methods

The study included 16 male (aged 27±4 years, height 182±3 cm, body mass 80.3±5.5 kg, 100 m personal best 10.3±0.1 s) and 10 female (aged 27±3 years, height 170±4 cm, body mass 60.6±2.5 kg, 100 m personal best 11.4±0.1 s) sprinters, members of the Polish national team. In total, 168 and 62 baton exchanges were recorded for men and women, respectively. The exchanges that did not comply with the regulations (overrunning the exchange zone, dropping the baton) or when it was not possible to determine the HP were excluded from the analysis. The measurements were conducted during training sessions from May to August (specific preparation and competition phase) at stadiums certified by the International Association of Athletics Federations (IAAF).

Polish National Team sprinters used the 'push–forward' pass technique. The order in which sprinters ran was selected by the team coach depending on their suitability. To determine the HP, the position of the baton within the exchange zone at the moment of handoff was determined with an accuracy of 0.5 m (videorecording). The tests were conducted following IAAF regulations from November 1st, 2017. In the 4x100 m relays, each exchange zone is currently 30 m long, of which the scratch line is 20 m from the start of the zone (art. 170.3). The incoming sprinter performed a 50–meter maximum run. The outgoing sprinter started from a standing position, and when the incoming sprinter reached the checkmark, the outgoing sprinter lowered and turned his torso forward, which allowed him/her to accelerate in a controlled and smooth manner (30–meter run). This starting position for the outgoing sprinter in the second and subsequent legs is currently the most commonly used (Mach, 1991; Maisetti, 1996). The 30–meter time measurement was performed using timing gates with 0.01–sec accuracy (TC–System, Brower Timing Systems, USA). The ET was measured from when the incoming runner (carrying the baton) reached the first timing gate (set one meter before the exchange zone to prevent activation by the outgoing runner) until the outgoing runner left the zone after the baton handoff (the second time gate was set one meter before the end of the exchange zone) (Fig. 1). For baton exchange analyses, we decided to divide exchanges by their specificity (straight–line vs. bend running) into two categories: (i) combined first and third exchanges and (ii) second exchange.

Figure 1. The distance of 30 meters used to measure the time of baton exchange.



Statistical analyses were performed using STATISTICA 13.1 software (TIBCO Software Inc., Palo Alto, CA). All values were presented as means ± SD. To analyze the relationship between the overall 30–m exchange zone time and change–over distance, a linear regression analysis was used. The significance level was set at P≤0.05.

Results

Figure 2 shows a significant inverse relationship between the ET and HP in men ($r=-0.51$, $r^2=0.25$, $P<0.001$) and women ($r=-0.68$, $r^2=0.46$, $P<0.001$) for combined handoffs in all three exchanges.

In Figure 3, the relationships were presented for the combined first and third exchanges and separately for the second exchange. Similarly, all the relationships between ET and HP were significant and inversely proportional. In men, the correlations were $r=-0.45$ ($r^2=0.20$, $P<0.001$) for combined first and third exchanges and $r=-0.61$ ($r^2=0.46$, $P<0.001$) for the second leg. In women, the relationships were $r=-0.66$ ($r^2=0.44$, $P<0.001$) and $r=-0.72$ ($r^2=0.52$, $P<0.001$), respectively.

Figure 2. Relationship between the baton exchange time over the 30 m zone and the handoff point in the exchange zone in male and female 4x100 m relay teams (combined data for all three exchange zones).

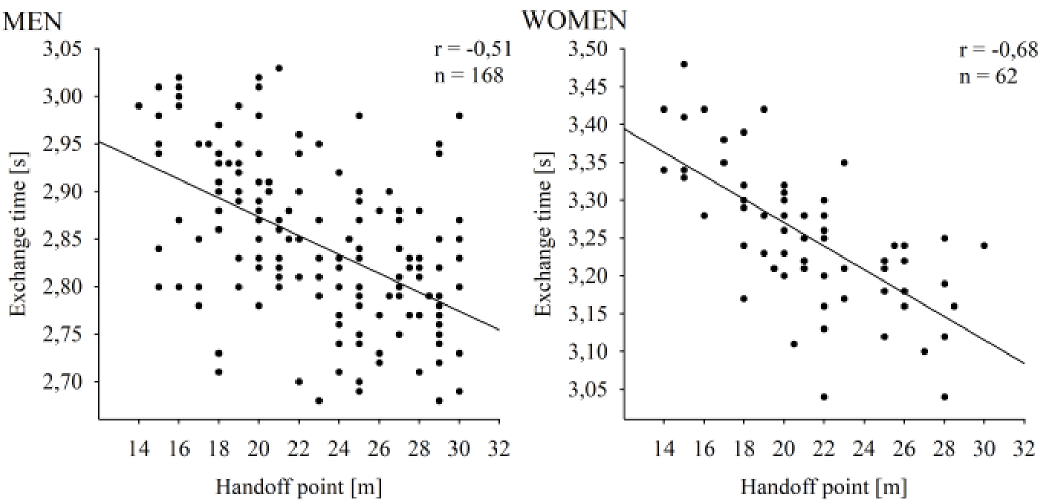
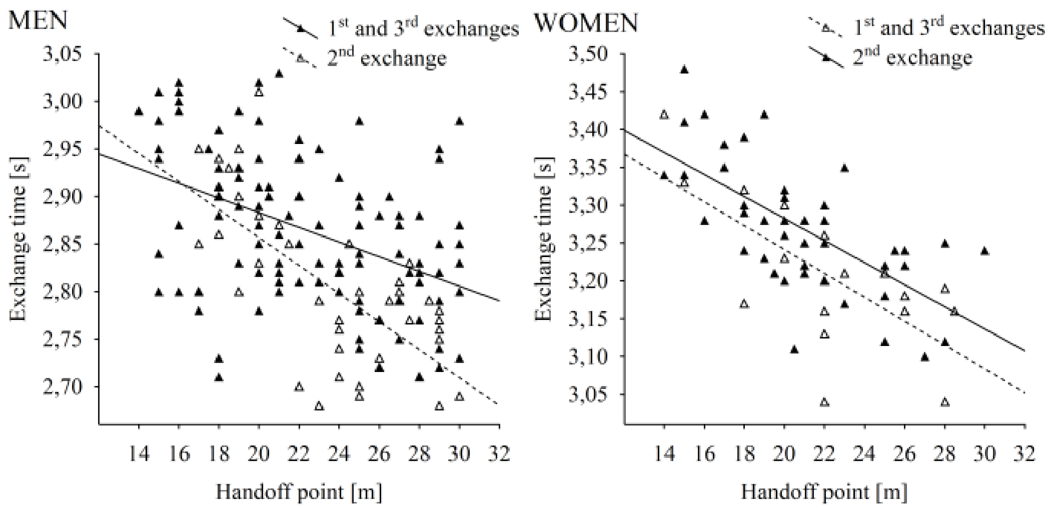


Figure 3. Relationship between the baton exchange time over the 30 m zone and the handoff point in the exchange zone in the combined first and third (black, solid line) exchanges and the second (open, dotted line) 4x100 m relay exchange.



Discussion

This is the first study to investigate the relationship between ET and HP in a 30–meter exchange zone in highly trained sprinters. The measurements were carried out during training sessions in the specific preparation and competition phases. Not only male sprinters were tested, but also, for the first time, a female 4x100 m relay team. The study procedure took into account the latest changes in IAAF regulations that extended the exchange zone to 30 m. Our research has shown that (1) there is a significant inverse relationship between ET and HP, i.e. the further the baton handoff is completed in the exchange zone, the shorter the time the baton spends in the exchange zone and that (2) the correlation between ET and HP is slightly higher in the female than male relay team.

Many factors influence the success of sprint relay teams, however, some of them are beyond the coach and sprinters' control, e.g. lane draw (Ward-Smith and Radford, 2002), wind conditions, or ambient temperature. Earlier research showed that one of the most relevant factors is baton pass efficiency, the exact point of baton exchange, and the free distance between runners during the change–over (Ward-Smith and Radford, 2002). Time spent in the exchange zone shows how much the relay team can benefit from each perfectly made handoff. No other sprint events (200 m, 400 m, 4x400m) are more challenging regarding maximum speed endurance as bend running in a 4x100m relay (Mach, 1991). Therefore, it is especially important to improve these skills in training. To be effective, baton–passing training should be integrated into the training process taking into account changes in sprinter's maximum strength and speed, resulting in utilizing the maximum capabilities of each runner. During the general preparation phase, relay training should be used as part of the warm–up, while during the specific preparation phase, the baton–passing practice should be used as part of speed–endurance training sessions. During tapering and competition phases, the method described in this study should be used as the main relay training method to allow more objective monitoring of the baton exchange at the optimum possible maximum speed and determining an exact checkmark location for the outgoing runner.

Even at the international level, i.e. World Championships and Olympic Games, very often relay teams are disqualified or do not reach the finish line. Radford and Smith (2003) reported that a significant percentage of male relay failures took place at the World Championships in 1995–2001 (25.5% – 26 from 102 teams). We analyzed the frequency of failures after 2000. The percentage of men's relay teams that did not finish or had been disqualified at World Championships and Olympic Games in 2000–2019 was similar (21.1%, 56 out of 266 teams). After 2000 in women's relay teams, the failure rate at the Olympic Games and World Championships was 17.3% (45 out of 260 teams). This data shows better effectiveness of women's relays, which is most likely related to the lower running speed, which directly affects baton handoff security. Over the last two decades, men's relay effectiveness has improved, although there is still a large percentage of failures. This suggests a strong need to improve relay exchange precision to drop this number to a comparable level seen in other track events. As shown in the video analysis from the World Championship in Tokyo (1991), 33% of exchanges in men and 71% in women took place in the first half of the 20–meter takeover zone. This means that most relay teams do not fully exploit their maximum potential in baton passing at the highest possible speed (Fukashiro et al., 1992). The exchange performed with each subsequent meter gives the team a chance to decrease their sprint time. Improving the baton exchange speed and thus reducing its duration should positively affect performance during competition. This improvement may seem trivial but it should be remembered that victory in sprint events is most often determined by hundredths of a second, e.g. only 0.6 s separated the first and the last team in the 2004 Olympic Games final (Bry et al. 2009).

Our research has shown that there is a significant inversely proportional relationship between the ET and HP. It confirms the practical principle applied intuitively that it is the most effective to pass the baton at the end of the exchange zone when the outgoing runner reaches a higher speed. For baton passing at the second exchange, there is a higher correlation between ET and HP than in the combined first and third exchange. This may be related to the speed achieved by outgoing sprinters during bend running, which is lower than during straight–line running (Greene, 1985). Performing an exchange at a lower speed by the incoming runner does not force the outgoing runner to accelerate at maximum. This is potentially problematic because if both runners do not run at full speed, then each time they run at a submaximal (different) speed, the checkmark will be at a different place. Thus the exchange may take place in a larger range of distances in the exchange zone.

Conclusion

In conclusion, our research has shown a significant inversely proportional relationship between ET and HP. However, although this correlation is statistically significant, it is not very strong (r^2=0.20–52). This suggests that other factors play a role in addition to time spent in the takeover zone and the point of baton handoff. Therefore, baton exchange efficiency should be further studied to fully understand its dynamics. Nevertheless, we believe that the measurement method presented in this study may provide valuable objective information regarding sprinters' speed during the baton exchange.

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