Biomechanics Symposia 2001 / University of San Francisco

RUNNING VELOCITIES AND BATON CHANGE-OVERS IN 4 x 100 M RELAY EXCHANGES

Aki I.T. Salo
Department of Sport and Exercise Science, University of Bath, Bath, United Kingdom

In 4 x 100 m relays, the baton exchange happens as an interaction between two athletes running at very high speed. The purpose of this paper was to study this interaction in relay exchanges. Three normal training sessions of the international level male 4 x 100 m relay team was videotaped over one competition season. Athletes' velocities in different parts of the exchanges and the positions at which the baton change-overs occurred were analysed. Although the take-over zone is 20 m long, it seems that it is beneficial to have the change-over as late as possible (the overall performance of athletes in the change-over had a correlation of $r = .667$ ($p < .000$) with the position of the baton exchange). Further, the outgoing athlete has a task to accelerate fully. However, the results indicated that the athletes perceive each others velocities and adjust their own running accordingly.

KEY WORDS: sprinting, running velocity, relay, baton exchange

INTRODUCTION: Relays are the only events in Athletics where the results depend on the team work and thus relay running has different demands on the athletes in comparison to the other Athletics events. Especially in 4 x 100 m relays, the baton exchange occurs as an interaction between two athletes running at high speed. The exchange is also semi-blind meaning that the receiving athlete does not see the baton as it is pushed into his hand.

The take-over zone in which the baton exchange must be commenced and completed is 20 m long. In a 4 x 100 m relay the receiving (outgoing) athlete can start to run 10 m before the take-over zone (Figure 1) and the athlete can use a self-adhesive check-mark on the track to help in judging the position of the incoming athlete (IAAF Handbook, 2000). The outgoing athlete has therefore accelerated for between 10 m and 30 m when the baton exchange happens. At the time of the baton exchange, the incoming athlete has run from 90 m to 110 m (first leg) or from 110 m to 130 m (second and third leg). Thus, at the time of the exchange, the outgoing athlete has not obtained full speed while the incoming athlete is already slowing down (e.g. Gajer et al., 1999). Consequently, the correct timing of the exchange and the interaction between the two athletes is critical to success.

Although there are several articles about sprint running, relay exchanges are rarely studied. This may be due to the above mentioned complexity of the exchange at high speed. Mostly, the relay related papers have concentrated on time saved between the athletes combined individual 100 m times and the relay team time (e.g. Maisetti, 1996). Zhang and Chu (2000), studied the exchanges specifically and tried to determine the check-mark distances based on the athletes' running velocities and distances between the athletes at the moment of exchange. However, data were from one team in one competition, thus making generalisation difficult.

The purpose of this paper was to study the interaction between pairs of athletes in relay exchanges, especially the influence of athletes' velocities and the position of the change-over in overall performance.

METHODS: Three normal training sessions of the international level male 4 x 100 relay team was videotaped over the one competition season. Nine athletes took part in the training sessions (the mean 100 m record for the athletes was 10.15 s). Not all athletes were involved in every session. The athletes were mixed in pairs based on advice from the team coach. This meant that there were various number of runs from different subject pairs. However, it is considered that there are so many external variables involved in the baton exchange between the two athletes that all samples were judged to be independent regarding the data which were obtained from the videotape. From the total of 37 exchanges, 30 were within the rules of the

International Amateur Athletics Federation and only these successful runs were included into this analysis.
A S-VHS video camcorder (Panasonic DP-200) was located at the curve centre. In different sessions, the trials were performed either in lane 4 or 5 of the outdoor tracks and either the 2nd or 3rd take-over zone. A video operator followed the athlete with the baton by panning through the whole sequence. An incoming athlete started to run 40 m before the acceleration zone (see Figure 1). During the take-over zone, usually both athletes were in the field of view of the video camcorder. However, occasionally the outgoing athlete entered the take-over zone before the camera view reached him causing some missing data. In the laboratory, a video time code (using a For-A videotimer) was inserted onto the videotapes. Consequently, the time of each athlete's trunk passing the following marks was taken: incoming athlete at the marks of A, B, C and D, outgoing athlete at the marks of C, D and E. All the marks were at 10 m intervals. However, the marks were offset 0.5 m from the official lane marking towards the incoming runner, as in the videotaping situation photocells were also used in marks B, C and E. The reason for this offset was that the outgoing athlete could incidentally break the photocell beam on mark B, where he is waiting, if the photocell was positioned exactly at the official lane mark. The still pictures of the videotape were 0.02 s intervals. However, by making the judgement, whether the trunk was at the mark at the video field or between the consecutive fields, the time was split to 0.01 s intervals.

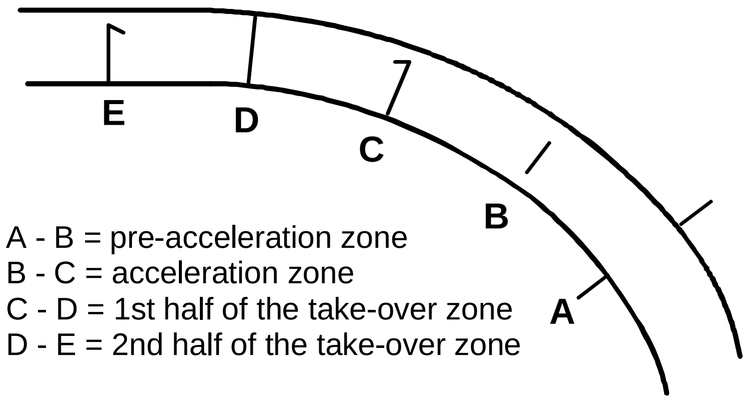
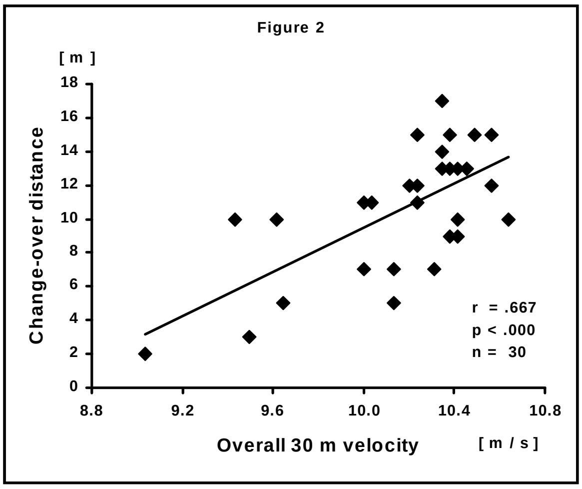


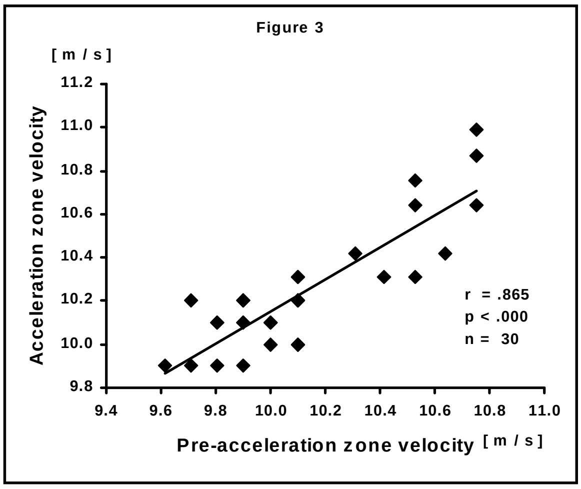
Figure 1 - The measurement set up.

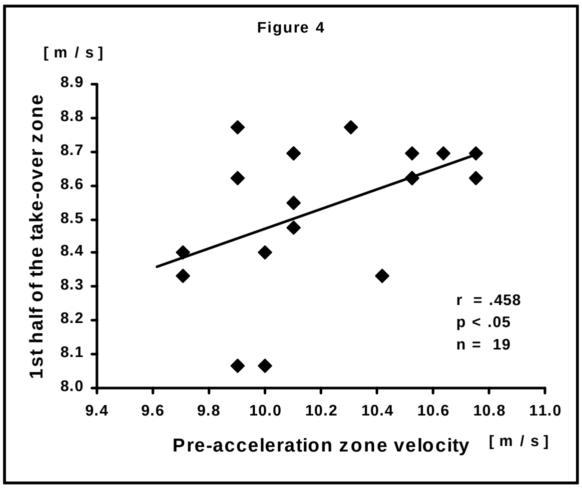
The times were converted to the average velocities in each 10 m section. The author recognises that especially the outgoing athlete is accelerating almost all the time, thus the average velocity is not the best indicator of the performance. The acquired average velocities were as follows:
- incoming athlete at the pre-acceleration zone (A-B)
- incoming athlete at the acceleration zone (B-C)
- incoming athlete at the first half of the take-over zone (C-D)
- outgoing athlete at the first half of the take-over zone (C-D)
- outgoing athlete at the second half of the take-over zone (D-E)
- the overall 30 m velocity of the exchange from B to E (incoming athlete was breaking the mark at B and outgoing athlete was breaking the mark at E - this illustrates how quickly the baton has passed these zones).

Also, the distance of the actual change-over within the take-over zone was estimated from the videotape with 1 m accuracy. It is difficult to determine the exact moment of the change-over, as it usually happens over a stride or two. However, the location was estimated at the point, when it was decided that the outgoing athlete had full control of the baton. Data were collected into the Excel software and consequently the Pearson Product Moment correlation was performed between the variables.

RESULTS AND DISCUSSION: The discussion will concentrate on the selected three statistically significant correlations. These were the relationships between 1) the overall 30 m velocity and the change-over distance, 2) the incoming athlete's velocity at the pre-acceleration zone and the outgoing athlete's velocity in the first half of the take-over zone and 3) the incoming athlete's velocity at the pre-acceleration zone and the acceleration zone. Overall, it seems that the athletes performed best when the change-over distance was the farthest (from the point C, i.e. from the start of the take-over zone) (Figure 2). The correlation revealed an r-value of .667 ($p < .000$). Theoretically, when the change-over happens later in the take-over zone, the outgoing athlete has taken most advantage of the acceleration. Also, as the outgoing athlete is accelerating and the incoming athlete is potentially slowing down, the timing of the exchange is crucial. Thus, the further the change occurs in the take-over zone, the less room there is for an error. If the change-over does not happen at the first attempt, there is no time or space to try again, as the outgoing athlete has already left the take-over zone. Despite this, there was a strong correlation between the overall performance and the change-over distance in this study. It is good to remember that only successful exchanges were included to the study. However, it may be that the qualitative analysis of those unsuccessful trials could reveal important information.







Figures 2-4 - Selected statistically significant relationships (see text for further clarification).

The incoming athlete's velocity at the pre-acceleration zone should have a statistically significant correlation with the same athlete's velocity 10 m later in the acceleration zone, as these are not independent variables. Thus the r-value could be expected to be very close to 1. However, this study revealed an r-value of 0.865 potentially showing that the incoming athlete has modified his velocity in relation to the acceleration of the outgoing athlete (Figure 3). This modification of each athlete's running velocity in relation to each others is also seen in the third and perhaps most surprising correlation discussed in this paper, i.e. between the incoming athlete's velocity at the pre-acceleration zone and the outgoing athlete's velocity in the first half of the take-over zone (the r-value was .458 ($p < .05$) - see also Figure 4). When the incoming athlete is in the pre-acceleration zone, the outgoing athlete starts running based on the check-mark. After this, the outgoing athlete runs without having any eye contact with the incoming athlete. The outgoing athlete must trust that the incoming athlete will catch him and pass the baton before the end of the take-over zone. Consequently, the outgoing athlete's task is to accelerate fully. However, this statistically significant correlation revealed that the outgoing athletes in this study may have responded to their own perception of the incoming athlete's velocity and accelerated accordingly. Although, this adjustment is against the training principles, it is not all regrettable, as some modification gives a better chance for the exchange to happen. As the correlation was not the strongest possible, this finding should be considered with care. Also, there were unfortunately some missing values in these variables due to the video set up. However, the idea of athletes reacting to their perception in this context is an interesting one and should be studied further to fully understand the dynamics in the relay exchange. Despite the evidence of adjustment occurring, the earlier correlation indicated that the outgoing athlete should accelerate as hard as possible, as that was the key for the late change-over, which subsequently decreased the time that the team and the baton spent in the take-over zone.

Performances reported in this paper naturally varied between the different pairs. The best quartile of the times within the 20 m take-over zone calculated from the incoming athlete entering the zone until the outgoing athlete leaving the zone were between 1.86 s and 1.90 s. Sugiura et al. (1995) reported the range of times between 1.81 s and 2.02 s from the best three teams in the World Championships in 1991 in all three changes. Thus, the best runs in this study were in the middle of that range from the World Championship competition. The time of 1.86 s meant that the baton passed the take-over zone at the velocity of 10.8 m/s. As high calibre athletes like those in this study can run at over 11 m/s, it shows that there is still room for improvement in exchanging the baton. Consequently, more training should be done to improve the efficiency of the exchanges.

In conclusion, although the take-over zone is 20 m long, it seems that it was beneficial to have the change-over as late as possible. This requires trust between the athletes and lots of training to ensure that the check-marks are in the correct position. Also, the results indicated that the athletes perceived each others velocities and adjusted their own running accordingly.

REFERENCES:

Gajer, B., Thépaut-Mathieu, C., & Lehénaff, D. (1999). Evolution of stride and amplitude during the course of the 100 m event in athletics. *New Studies in Athletics*, **14**(1), 43-50.

IAAF Handbook (2000). pp. 130-132. Monaco: International Amateur Athletics Federation.

Maisetti, G. (1996). Efficient baton exchange in the sprint relay. *New Studies in Athletics*, **11** (2-3), 77-84.

Sugiura, Y., Numazawa, H., & Ae, M. (1995). Time analysis of elite sprinters in the 4x100 metres relay. *New Studies in Athletics*, **10**(3), 45-49.

Zhang, B-M., & Chu, D.P.K. (2000). The study of the optimal exchange technique in 4x100m relay. In: Hong, Y. & Johns, D.P. (eds.). Proceedings of the XVIII International Symposium on Biomechanics in Sports. pp. 810-812. Hong Kong: The Chinese University of Hong Kong.