1

Smart Baton: data-driven relay hand-off optimisation

Andri Feldmann[1,3], Noah Meierhans[2], Bertrand Dutoit[2], Daniel Debrunner[2], Daniel Baumgartner[1], Louis Heyer[1]

[1]Swiss Athletics, [2]Bern University of Applied Sciences, [3]University of Bern

Keywords: Relay, Athletics, Sprint, Smart Device, Hand-off , 4x100m

Introduction

The average difference between first and second place in the men's 4x100m relay at world championships over the past five years has been 0.254s (SD = 0.24s). The average difference between first and second place for the men's 100m is 0.046s (SD = 0.049s). What does this information tell us? The potential individual gains to be had in a single 100m race is extremely hard to come by. Improving a personal best by 0.01s at an elite level is very difficult and requires dedication and focused training. Improving four athletes sprint time by these kinds of margins is in itself a daunting task, in particular to have this happen congruently, and this still does not close the gap between first and second place in the 4x100m relay. This means the majority of gains in a 4x100m relay is not in the individual athletic performance but in the hand-off optimisation of the team. The purpose of this project was to develop a novel Smart Relay Baton with incorporated sensors to measure baton angle and athlete hand placement and use this tool to evaluate and optimise relay team hand-offs.

ACTION

Method

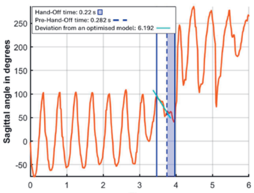

Fig. 2 Angle versus time chart for a 20m Baton hand-off with KPI indicators from the Smart Baton.

Data was collected during an official men's u20 4x100m relay practice looking at nine hand-offs between different athletes. The following KPIs (Fig. 2) were generated from the Smart Baton and analysed in relation to a five-point expert scale from *BAD* to *VERY GOOD*. In the data collection no hand-offs were evaluated as very good.

a) Hand-Off time: Time between first detection of both athlete's hands on the Baton and detected release of first athlete's hand.
b) Pre-Hand-Off time: Time before first touch of second athlete's hand on the Baton backwards to final arm swing turnaround.
c) Deviation from an optimised model: Standard deviation of the residuals from linear fit of the final arm swing to hand-off.

Equipment and Development

The project is a collaborative effort between Swiss Athletics, Swiss Olympic and the Bern University of Applied Sciences (BFH). The project started in 2021 and was executed in a multistage approach from development and prototyping to the culmination with an in-field data collection ending the project in 2024.

Fig. 1 Internal components and Smart Baton design.

Smart Baton Specifications (Fig. 1):

- a 3D print prototype: Acrylonitrile styrene acrylate (ASA) body and Polylactic Acid (PLA) interior structure
- Length 297mm
- Diameter 40mm
- Weight 110g
- Flex printed circuit board (PCB) touch sensor interface with 14 sensor panels
- Integrated IMU
- USB-C interface and charging
- 3hrs battery life, 2.5hrs charging time
- Wi-Fi module for data transmission (90Hz)

The IMU and the touch sensor interface is used to derive primary and secondary key performance indicators (KPI) including hand-off time, baton angle in the sagittal and transverse plane. Key focus was placed in design and weight management to match an official baton as closely as possible. World Athletics standards of weight min. 50g, Avg. ≈ 60g; length 280-300mm; diameter 40mm.

Results and Conclusion

The nine hand-offs evaluated for the pre-defined KPIs resulted in significant relationship between Pre-Hand-Off time and Quality Rating (Fig. 4) with a large effect size (r = 0.703, p = 0.036). The other two KPIs yielded no significant results. Hand-Off time showed no notable relationship to Quality Rating. Optimised Standard Deviation from a model (Fig. 3) showed a small effect size (r = 0.255), however qualitative analysis shows potential for strong outliers which in the case of a larger data collection could be accounted for. In addition, no hand-off was rated as very good therefore a considerable analysis gap exists.

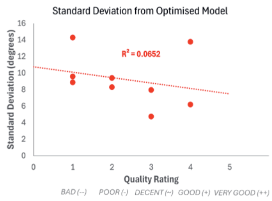

Fig. 3 Relationship plot between Standard Deviation from an optimised model and expert quality rating of a Baton hand-off.

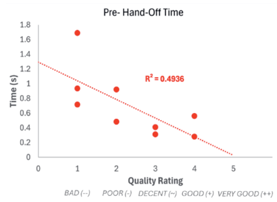

Fig. 4 Relationship plot between Pre-Hand-Off time and expert quality rating of a Baton hand-off.

Both the Pre-Hand-Off time and the Optimised model suggest that Quality rating is linked to a smooth but rapid transition of arm-swing during the sprint and Baton hand-off. The results presented are exploratory and the statistical analysis greatly underpowered and should be evaluated as such. Nonetheless, the results present viability for further technological and tool development, and secondly potential lanes of inquiry for larger data collections.

So What!?

The purpose of the Smart Baton is to act as a rapid response unit to provide both quick and actionable information during training, for example specific hand-off times. Furthermore, it can provide analysis groundwork to both inform the coach's eye and improve relay tactics and techniques.