INSTRUMENTED START BLOCKS: A QUANTITATIVE COACHING AID

M.J. Harland, M.H. Andrews and J.R. Steele.
University of Wollongong, Wollongong, Australia.

Baumann (1976) claimed a good start was characterised by great forces exerted in the horizontal direction. Despite obvious kinematic differences exhibited by elite sprinters while starting, a common denominator of superior start performers has been the ability to create maximum force in minimum time. In learning the complex skill of starting, immediate kinetic feedback to the coach and performer therefore allows instruction as to appropriate application of force on the blocks.

The purpose of this study was to develop a system with which to collect kinetic data from the block start, a system applicable in a training or competition setting, and to be able to provide immediate quantitative feedback to coach and performer.

Design Criteria

Design of the starting blocks was based on several criteria:

1. forces applied to the blocks were to be resolved into horizontal and vertical force components,
2. calibration of the strain gauge elements within the blocks had to be accurate,
3. spacing and obliquity of the foot pedals had to be adjustable to each subject's normal foot placement in the start position,
4. independent force recordings for right and left foot pedals during the start were required, and
5. block pedal arrangement could not deviate significantly from the standard international starting block positioning in terms of dimensions and rigidity.

Block Components

The starting blocks consisted of two standard adjustable cast aluminium block pedals, each suspended clear of the ground via an instrumented axle. The block face obliquity was adjustable to four settings: 75, 65, 55 and 45 degrees to the horizontal. The two axles were identical in construction and milled from a 45 mm diameter mild steel rod billet.

A 70 mm long section of the axle was used for instrumenting, as this presented sufficient area to separate the strain gauges mediolaterally along the length of the axle which, in turn, enhanced accuracy of the chosen gauge arrangement. From calculations using maximum expected loads on this cantilevered beam arrangement, the determined diameter of the axle was 25 mm.

Large (44 mm) collars surrounded the instrumented section of each axle to restrict flexing to this section only. Attachment of the block pedals to the axles was done using two 25 mm holes drilled centrally through the medial and lateral walls of the pedal and rigidly affixed using a fitted sleeve within the pedal.

Each axle was attached to a 230 mm wide mild steel parallel flange channel by drilling 25 mm holes through the lateral channel wall, through which the threaded end of the axle was inserted. The base plate provided a large stable base because of its mass (10.5 kg) and was affixed to the synthetic track surface by six 12 mm commercial shoe spikes. All athletes using the blocks reported no perceived difference in the stability or rigidity of the instrumented blocks compared to standard competition blocks.

Eight 3 mm strain gauges were adhered to each axle using the configuration where four gauges were aligned to each orthogonal axis. Gauge cross-talk between the axes was minimal. The gauges were incorporated into a Wheatstone Bridge circuit, and arranged to measure the shear force on the axle by utilising the bending moment difference method (Berme, 1990). Using this method, the signal recorded is unaffected by the position of force across the block pedal. The signal will only change with force magnitude variation.

This gauge arrangement, however, does not allow for temperature compensation to be built into the circuitry. Therefore, self-temperature compensated gauges were used. Further protection from the elements was provided by sealing the instrumented section with silicon rubber and sheathing it in a thick PVC plastic tube. The strain gauge circuitry was powered by the computer hardware.

Amplifiers were constructed to enable the small differential signal created by deformation of the strain gauges to be amplified to a quantifiable level. Each orthogonal channel (left and right horizontal, and left and right vertical) contained a separate amplifier. The amplifiers incorporated two potentiometers, one to adjust the zero offset, and the second to adjust the gain of the signal for calibration purposes. The amplifiers also contained programmable high and low pass filters on the signal to reduce the noise of interfering frequencies.

After amplification, the differential signal developed from the strain gauge circuitry under load was fed into a personal computer using a WIN 30-D analog to digital converter card. The raw data were sampled at 1000 Hz and saved to disk as a text file.

Using custom software a number of kinetic variables were able to be immediately presented on screen following a start performance from the blocks. These included:

1, peak horizontal and vertical force for front, rear and combined feet,

2. time to peak force,
3. reaction time,
4. block velocity and block acceleration, and
5. front, rear and total block time

Results

Examples of kinetic feedback parameters collected from two block starts of an elite 100 m sprinter (Table One) and an elite 110 m hurdler (Table Two) are presented. All data were collected using the instrumented starting blocks.

Table One: Comparison of two starts of a World Champion 100 m sprinter

	START ONE	START TWO
Block Velocity ($m.s^{-1}$)	3.94	3.74
Peak Force Front Block (N)	1030	1010
(BW)	1.14	1.12
Peak Force Rear Block (N)	1285	1100
(BW)	1.42	1.22
Block Time (ms)	385	371
Block Acceleration ($m.s^{-2}$)	10.23	10.08

Table Two: Comparison of starts by a World Champion 100 m sprinter and a World Champion 110 m hurdler

	100 m SPRINTER	110 m HURDLER
Block Velocity ($m.s^{-1}$)	3.94	3.56
Peak Force Front Block (N)	1030	730
(BW)	1.14	1.03
Peak Force Rear Block (N)	1285	730
(BW)	1.42	1.03
Block Time (ms)	385	349
Block Acceleration ($m.s^{-2}$)	10.23	10.20

Discussion

Considering the two starts made by the 100m performer (Table One) it can be seen that Start One had a superior block velocity at 3.94 $m.s^{-1}$ compared to 3.74 $m.s^{-1}$ for Start Two. This extra velocity was a result of a larger force production on the rear block, 1285 N compared to 1100 N for the lower velocity start. Minimal difference was exhibited in front block force production between the two starts (1030 N to 1010 N).

Before it can be said that Start One is a better start than Start Two, it can be seen that the sprinter took an extra 14 ms (385 ms to 371 ms) to produce the extra force. In a temporally decided event, this additional time is detrimental to performance. Some researchers have advocated acceleration as the single most appropriate value to quantify the sprint start as it includes both velocity and time. Start One has a slightly greater acceleration (10.23 $m.s^{-2}$) compared to Start Two (10.08 $m.s^{-2}$).

Comparing the starts of the two performers (Table Two) it can be seen that the hurdler displayed a reduced block velocity at 3.56 $m.s^{-1}$ as a result of less force applied to the blocks per body weight (around 1 BW for both front and rear legs compared to 1.1 to 1.4 BW respectively for the 100 m performer). However, the hurdler produced this force to leave the blocks in a noticeably shorter time than did the 100 m sprinter (349 to 385 ms) and this was a significant temporal advantage to the hurdler. The acceleration data did not differentiate the two starts of these performers.

Conclusion

It is evident that an analysis of common kinetic parameters of the block start can lead to distinct differentiation of the start, not only between performers, but also within consecutive performances by the same individual. The use of this portable instrumented start block arrangement was found to quickly quantify an athlete's block start performance, and provide immediate and relevant kinetic information to the coach and performer.

This is useful in terms of correcting faults in force application that may exist or to support the coach in his or her teaching of a preferred start technique. Such feedback may also be used to quantify the effects of making adjustments to the set position or adjusting key thoughts of the athlete while executing the start.

Bibliography

Baumann, W. (1976). Kinematic and dynamic characteristics of the sprint start. In P.V. Komi (Ed.), Biomechanics V-B, (pp. 194-199). Baltimore: University Park Press.

Berme, N. (1990). Measurement of force, pressure, and muscle activity. In N. Berme & A. Cappozzo (Eds.), Biomechanics of Human Movement: Applications in Rehabilitation. Sports and Ergonomics (pp. 140-146). Worthington, Ohio: Bertec Corporation.