SPRINT ACCELERATION BIOMECHANICS

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Sprint start performance (SSP) is of prime importance in short sprint races. The purpose of this workshop was to present a method for the evaluation of SSP in a typical training environment. For this purpose, starting blocks, instrumented with 3D force sensors in the front and the rear block were utilized in combination with high-speed video cameras and light barriers. Performance related parameters could be extracted immediately from the captured force signals. Individual values were compared to a large reference database. Comparisons were made to reference values of athletes with similar sprint performance capacity. Optimisation potentials in technical and strength related aspects of SSP were highlighted for each start, based on the actual overall sprinting performance level of the athlete.

KEY WORDS: sprint start performance, force measurement, sprint mechanics

INTRODUCTION: The importance of sprint start performance (SSP) is inversely related to the distance of the sprinting race. Particularly in 100 m sprint races (outdoors) or even more in 60 m sprint races (indoors) SSP is of critical importance for overall race time. Consequently, analysing SSP has frequently drawn the attention of researchers in the past (e.g. Harland, Kyröläinen & Komi, 2006, Bezodis, Salo & Trewartha, 2010, Mero, Kuitunen, Taboga, Grabowski, di Prampero & Kram, 2014 Bezodis, Salo & Trewartha, 2015) For the coach on the track it is important to know which biomechanical parameters are related to SSP in order to optimize the starting technique and related training programs (e.g. strength training, jumps, etc.). Force measurements in the starting blocks are of great importance in this context, as block reaction forces are directly linked to centre of mass acceleration of the athlete based on Newton’s second law of motion. Two of the most basic parameters to describe starting performance are the average normalized horizontal block power (NAHBP, Bezodis, Salo & Trewartha, 2010) and the ratio of horizontal to resultant ground reaction force impulse (RHRI, Morin, Bourdin, Edouard, Peyrot, Samozino, & Lacour, 2012). Furthermore, using both feet to create propulsive impulse has been shown to be related to SSP (Willwacher, Herrmann, Heinrich & Brüggemann, 2013).
If these performance-related parameters are known, comparisons can be made between results of the individual athlete and reference values. In lots of cases these reference values are the results obtained from the best athletes in the sport, e.g. world record holders or world and / or Olympic champions. Nonetheless, in young or developmental athletes this comparison might be less useful, as the anthropometric characteristics, strength and technical capacities of these athletes might be too different to derive valid inferences for the design of training programs. A comparison with respect to athletes of similar or slightly higher performance level might be more appropriate in this case.

METHODS: Instrumented starting blocks were used to collect block reaction forces separately for the front and the rear starting block. The details of these blocks are described in Willwacher, Küsel-Feldker, Zohren, Herrmann & Brüggemann (2013). Then, a substantial amount of parameters were immediately extracted from the force waveforms. The most important ones are NAHBP, RHRI, peak forces and impulses in the front and rear blocks and push times. In addition to the instrumented starting blocks, dual light barriers were used in order to collect 5 m and 10 m times. Furthermore, high-speed video cameras were used to qualitatively analyse the motion of the athletes in the sagittal and frontal planes of motion.

When calibrated, these videos could be used for the subsequent analysis of spatio-temporal or joint kinematical parameters.

The force parameter analysis was based on the linear regression analysis detailed in Willwacher et al. (2015). Regression lines were calculated between 100 m personal record times and selected force parameters in a dataset of 142 male and female athletes ranging from regional to world record level.

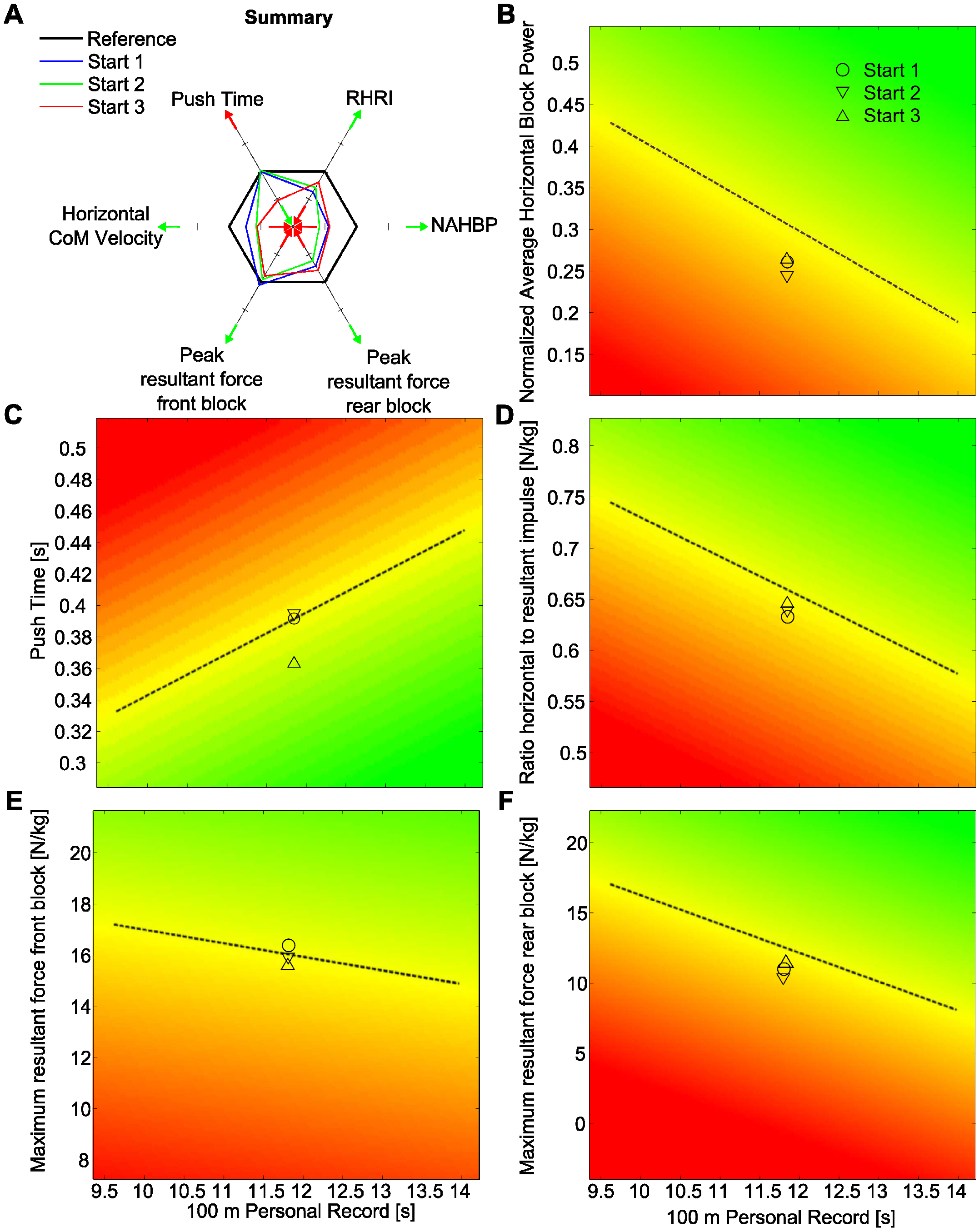

Figure 1: Graphical representation of block force characteristics of a regional level German decathlete. A summarizes the results of the specific parameters visualized in B – F. In A, the black line represents the average performance of an athlete with similar 100 m personal record time. For each start the z-normalized deviation from the average performance is represented in the radar chart.

The SSP of an individual athlete was evaluated by the distance of his or her results with respect to the linear regression line. A novel visual representation of the results has been developed in order to allow for a quick interpretation of the results. Therefore, the distance to the regression line was normalized to the standard deviation of the residuals in the linear regression model. Based on this normalized distance, a colour value was assigned to each point in the regression plot background, ranging from red (poor performance) to yellow (average performance) to green (excellent performance). Figure 1 displays an example of this graphical representation of a regional level German decathlete. In addition to the graphical representation, exact numbers of each individual start and the reference dataset are provided.

DISCUSSION: The proposed method to analyse SSP has several advantages. Firstly, it allows a direct feedback to the athlete, because the force parameters are available a few seconds after the athlete has left the blocks. Therefore, this method is highly valuable not only for performance diagnostics, but also for feedback training. The addition of high-speed video footage further helps to identify technical deficits of the athlete during the block phase and subsequent steps. The proposed methods allow for an immediate comparison of several starts, for example for the evaluation of different starting positions, different block separations, tilt angles or distances to the starting line. The potentially biggest strength of the approach is the comparison to a very large reference database, which includes starting performances of athletes ranging from regional level to the current world record holder and Olympic champion. The newly developed graphical representation eases the quick interpretation of the results. The comparison to athletes of a similar performance level further allows to draw conclusions with respect to the developmental stage of an individual athlete in different phases of the sprint race (start and acceleration phase, constant velocity phase or sprint endurance phase). The decathlete in figure 1 for example shows a below average SSP with respect to athletes of similar 100 m personal record time. This seems to be mostly related to a weak force production in the rear blocks (Fig. 1F), a too vertical oriented general force production (low RHRI, Fig. 1D), resulting in a low NAHBP (Fig. 1B). This implies that this athlete must perform relatively better in the constant speed phase of the 100 m race and / or in the speed endurance phase, because otherwise he would not be able to create his 100 m personal record time. Therefore, the results of this SSP analysis will help the coach in setting priorities in the training program of an individual athlete.
A severe limitation of the instrumented starting blocks used for the collection of the reference database (Willwacher et al., 2015) is that these blocks are very heavy and changing block settings takes a considerable amount of time. In order to make the proposed SSP analysis method feasible for on track performance diagnostics and feedback training, a more lightweight, easier to use version of instrumented starting blocks needs to be developed. In this process, care must be taken that the improvement of user friendliness does not come at the price of weak force signal detection quality.

REFERENCES:

Bezodis, N. E., Salo, A. I. & Trewartha, G. (2010). Choice of sprint start performance measure affects the performance-based ranking within a group of sprinters: which is the most appropriate measure? *Sports Biomechanics,* 9, 258-269.

Morin, J. B., Bourdin, M., Edouard, P., Peyrot, N., Samozino, P. & Lacour, J. (2012). Mechanical determinants of 100-m sprint running performance. *European Journal of Applied Physiology*, 112, 3921-3930.

Willwacher, S., Herrmann, V., Heinrich, K. & Brüggerman, G. P. (2013). Start block kinetics: what the best do different than the rest. In T. Y. Shiang, W. H. Ho, P. C. Huang, and C. L.

Tsai (Eds.), Proceedings of XXXI International Conference on Biomechanics in Sports, Taipei, Taiwan.

Willwacher, S., Küsel-Feldker, M., Zohren, S., Herrmann, V. & Brüggemann, G.P. (2013). A novel method for the evaluation and certification of false start apparatus in sprint running. *Procedia Engineering,* 60, 124-129.

Willwacher, S., Herrmann, V., Heinrich, K., Funken, J., Potthast, W., Bezodis, I., Strutzenberger, G., Irwin, G. & Brüggerman, G. P. (2015). Sprint start kinetics: Comparison of amputee and non-amputee sprinters. Paper accepted for the presentation at the XXXIII International Conference on Biomechanics in Sports, Portiers, France.

Mero, A.,Kuitunen, S., Harland, M., Kyröläinen, H., & Komi, P.V. (2006). Effects of muscle-tendon length on joint moment and power during sprint starts. *Journal of Sports Sciences,* 24(2), 165-173.

Bezodis, N.E., Salo, A.I., Trewartha, G. (2015). Relationships between lower-limb kinematics and block phase performance in a cross section of sprinters. *European Journal of Sport Sciences.* 15(2), 118-124.

Taboga, P., Grabowski, A.M., di Prampero, P.E., Kram, R. (2014). Optimal starting block configuration in sprint running: A comparison of biological and prosthetic legs. *Journal of Applied Biomechanics.* 30, 381-389.