BODY-ATTACHED SENSORS FOR AUTOMATIC DETECTION OF SKATING STROKE EVENTS IN SPEED SKATING

Dominik Krumm[1], Jens Buder[1] and Stephan Odenwald[1]
[1] Chemnitz University of Technology, Department of Sports Equipment and Technology, Reichenhainer Str. 70, 09126 Chemnitz, Germany

The skating motion in speed skating consists of a skating stroke divided into the glide phase, the push-off phase and the recovery/repositioning phase [1]. Since speed skating performance depends on total power generation, which in turn is composed of work per stroke time [2], the optimization of these factors leads to an improvement of athletes' speed skating velocity. The goal of this work was to provide an algorithm that detects the skating stroke events required to evaluate key performance parameters, such as skating stroke time and cadence.
Four junior elite speed skaters (age 23.3 ± 1.9 years) participated in this study. The study was in accordance with the Declaration of Helsinki. The skaters wore two pressure measurement insoles in their own skates connected to a pair of mobile measurement systems [3] attached to their ankles. A total of 14 runs with an average speed of 11.5 $m \cdot s^{-1}$, which took place during a summer training camp on an ice rink, were measured and evaluated. The runs were part of the athletes' individual training program during regular timed training sessions and the distance varied between 1,500 m and 3,000 m. Data analysis and algorithm development were performed using MATLAB (R2020b, The MathWorks, Inc., Natick, MA, USA). The voltage signals from the eight individual pressure sensors of each insole were converted to pressure signals. The converted signals were summed to pressure sums for each leg side separately. These pressure sums were smoothed using a Savitzky-Golay filter. The smoothed data were detrended to reduce the influence of possible sensor drift. Based on these data, the state levels of a two-level rectangular waveform were estimated. These two levels were used as input variables to obtain the transition metrics of the two-level waveform, i.e., pulses, cycles, transitions, preshoots, postshoots, and settlings. Three reference values, i.e., upper, middle, and lower reference, were calculated and used to narrow down the search range. The skate contacts (SC) and skate offs (SO) were determined as the linearly interpolated times at which the signal crossed the lower reference with positive and negative polarity, respectively. The initial push-offs (POi) and push-off maxima (POmax) were determined as the first post-undershoots and post-overshoots above the middle reference, respectively.
After the skating stroke events (Fig. 1a) were automatically detected, an additional distinction was made between straights and curves. The period between two

Corresponding author email: dominik.krumm@mb.tu-chemnitz.de

identical, consecutive events was used to distinguish between them, with the period for straights being larger than the mean, in contrast to curves. The events were used to determine the stroke time and cadence. The algorithm was then applied to all measurements and descriptive statistics were calculated.
The presented algorithm can be used for automatic detection of skating stroke events in speed skating. The median stroke time of straights was 2.8 s and that of curves 1.4 s. Median cadence of straights was 21.8 strokes/min and that of curves 43.9 strokes/min. The stroke times and cadences on the left and right sides of the athletes were similar (Fig. 1b). During a single run, an average of 122 stroke events occurred (range: 76 to 172 events).

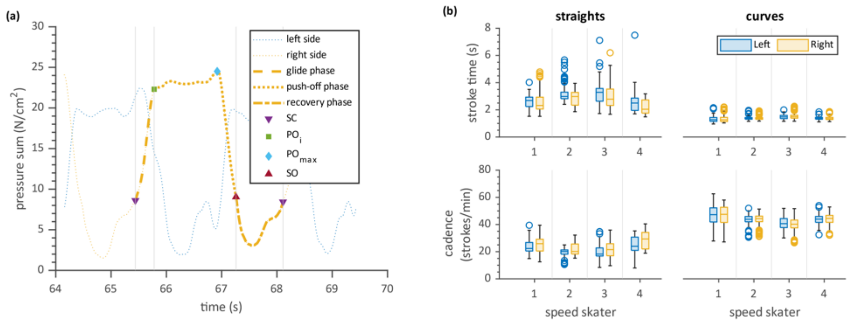

Fig. 1: (a) Pressure sum graphs of a speed skater during a single run with automatically determined skating stroke events, (b) Box plots of skating stroke time and cadence from 14 recorded runs of a total of four speed skaters as a function of rink position and leg side.

Outliers in the box plot have been confirmed to be caused by undetected events by the algorithm. Overall, however, the algorithm was applicable and robust, although the pressure insole raw data were heterogeneous both between skaters and within skaters at different runs. This approach could also be used in the future to determine push-off forces in speed skating. Corresponding work is currently taking place in our research group.

Acknowledgments: Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Project-ID 416228727 – SFB 1410 and the Sächsischer Landtag – Project-ID 100378180.

1. Allinger TL, van den Bogert AJ (1997) Skating technique for the straights, based on the optimization of a simulation model. Med Sci Sports Exerc 29(2):279–286.
2. Koning JJ de, Boer RW de, Groot G de et al. (1987) Push-off force in speed skating. Int J Sport Biomech 3(2):103–109.
3. Hill M, Hoena B, Kilian W et al. (2016) Wearable, modular and intelligent sensor laboratory. Procedia Engineering 147:671–676.

Corresponding author email: dominik.krumm@mb.tu-chemnitz.de