TOWARDS REAL-TIME FEEDBACK IN HIGH PERFORMANCE SPEED SKATING

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The aim of the current study is to evaluate several performance indicators to be used as real-time feedback in the coming experiments to enhance performance of elite speeds skaters. Six speed skaters, wearing one IMU per skate, collected data over one full training season to evaluate and pinpoint useful performance indicators. Promising performance indicators were picked in close collaboration with the coaches. One of those is the time that two skates are on the ice simultaneously, the double stance phase (DS). Coaches believe it has an inverse relation to velocity of the skater. In the curve this relationship is found for some skaters but not all. Also other factors seem to influence the DS phase as well. Data of a higher quality skating ring are inline with this finding but more profound, indicating that ice quality or anxiety, could influence the double stance phase as well.

KEY WORDS: biomechanical analysis, elite sports performance, direct feedback

INTRODUCTION: The force produced to propel a body forward in speed skating is directed almost perpendicular to the forward motion, because a skate moves nearly frictionless in the for-aft direction and more or less fixed (against the ice) in sideways lateral direction, resulting in a sliding point to push off against. This unique propulsion property makes speed skating challenging to master, the movement being quite different from propulsion methods in daily life like walking and cycling, and challenges the biomechanical(Houdijk, de Koning, de Groot, Bobbert, & Schenau, 2000). In the present study we are looking for performance indicators that will predict the quality of a stroke for a section (curve or straight) of a round and the focus will be on the double stance phase in a stroke.

In close cooperation with Dutch elite coaches some promising performance indicators have been selected for an initial examination. One of them is the time both skates make contact with the ice simultaneously, the so-called double stance phase (DS). It is hypothesized that a shorter DS phase can lead to a more effective push-off phase, especially in the curve. Skating is a cyclic movement(Koning, Groot, & Schenau, 1991). A simultaneous push of two legs would alter the cyclic behaviour of the movement. In the curve every half cycle one leg/skate is placed to the left of the supporting and push-off leg at the moment the first leg is almost extended in order to continue push against gravity and the centrifugal force of the curve. The skate placed left of the supporting skate will be closer to the centre of gravity (CoM) horizontally and thus has a larger push-off angle or effectiveness(Noordhof, Foster, Hoozemans, & de Koning, 2013; van Ingen Schenau, de Groot, & de Boer, 1985) (Angle ice-skate-CoM perpendicular to the CoM velocity)(Boer, Schermerhorn, Gademan, Groot, & Schenau, 1986), resulting in a smaller horizontal force component on the ice, the effective power delivering force. So in the DS phase an extra support leg will decrease the effectiveness of the push-off.

The data collected during a full season is used to increase the understanding of the different factors that influence this performance indicator. How stable is the DS for a skater? Is ~~a~~ there a relation between the DS and the speed of a skater? What other factors influence the DS?

The data collection is used to: 1. Develop good algorithms to obtain the DS phase automatically, and 2. to verify empirically whether the hypothesis is correct. Here we specifically focus on the DS phase in the curve.

METHODS: Six Speed skaters of a regional junior team were asked to wear IMU (Shimmer3, 2015) on a regular basis during their regular training twice a week. All speed skaters are performing on the Dutch national level or Dutch National Junior level (age 17.8±1.4, height 178.8±7.6 cm, Weight 69.1±7.4 kg, 3 men, 3 women). Data is collected over a whole season.

The IMU sensors are attached to both left and right skate shoe and synchronized before hand as described by Shimmer. Accelerometer, Gyroscope, and Magnetometer data are collected at a sample rate of 500 Hz on the sensors and downloaded after the training (of typically 1 hour).

To automatically analyse and chart a full training, several algorithms were developed. The training was cut into blocks of activity and every activity block is then cut into the straight and curve sections. For every activity block the left and right strokes are detected (figure 1). To further tailor the data for interpretation by the coach, the average DS per curve for left and right stroke was calculated as well as the time to round the curve. This already turned out to be valuable information for the coach. The algorithms were optimized for every individual skater to optimize visually the results per skater.

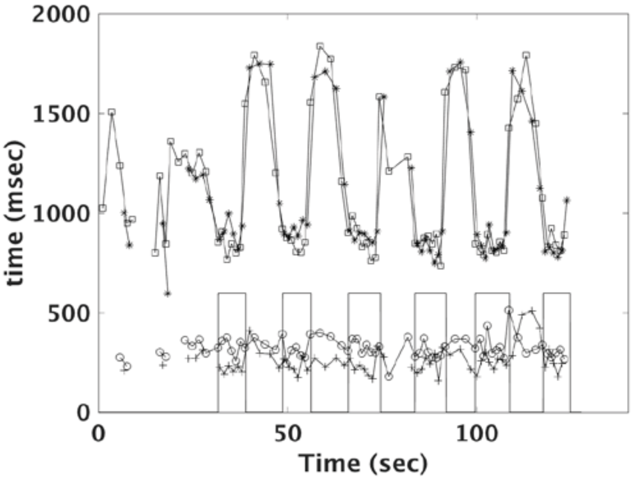

Figure 1: Example of one 'activity block', which exists of 6 curves and thus 3 rounds. (*,o) are the contact times of left and right skate. (o,+) are de DS phase per skate.

RESULTS: Figure 1 shows an example of an automatically analysed activity block were six curves were rounded. The stroke length (every dot is an individual stroke) clearly shows long strokes on the straights and much shorter strokes in the curve, as expected. The DS phase is more or less the same for the left and right stroke for this subject. Some data points seem to have errors. Two main factors contributing to these errors in the (calculated) DS and contact time are: 1. the accuracy with which the contact of the skate on the ice can be obtained from the IMU data and 2. variability introduced by the skaters due to 'external' factors. In speed skaters ride regularly in lines to shield head wind or to keep a certain pace. Riding at speeds of 40 km/h or higher with a distance to the skater in front of about 1-2 m, makes it inevitable to regularly adjust one's speed, which is most conveniently done in DS, and thus contributing to a larger spread in DS times.

Table 1

shows the average DS times (Left to Right phase (le-Ri) and Ri to Left phase (Ri-Le) and average $\overline{DS}$) for six different subjects over all analysed curves in one training season. The average duration of a curve over all analysed curves (Time/Curve), slow and fast, therefore no direct relation has to be visible between DS and average duration.

Subject	Le-Ri(std)	Ri-Le(std)	mean(std)
subj 1	331(49)	260(67)	295(58)
subj 2	410(52)	372(55)	391(53)
subj 3	323(51)	286(47)	304(49)
subj 4	348(52)	280(40)	314(46)
subj 5	374(50)	312(58)	343(54)
subj 6	298(47)	240(46)	269(47)
total:	347(50)	292(52)	319(51)

Subject	Le-Ri(std)	Ri-Le(std)	$\overline{DS}$(std)	Time/Curve
subj 1	323(51)	286(47)	304(49)	7.7(1.3)
subj 2	348(52)	280(40)	314(46)	8.0(1.0)
subj 3	331(49)	260(67)	295(58)	8.4(2.3)
subj 4	410(52)	372(55)	391(53)	8.5(1.6)
subj 5	374(50)	312(58)	343(54)	9.0(3.9)
subj 6	298(47)	240(46)	269(47)	9.8(5.0)
Mean:	347(50)	292(52)	319(51)	8.6(2.5)

The DS phase both from Left to Right and Right to left vary between skaters: on average 347 ±50 and 292 ±51 ms. For some skaters, but not all, a relationship can be seen between the time it takes to round a curve (~ speed) and the time in DS, a slower curve relates to a longer DS. Figure 2 shows a trend in DS time sloping downward as the curve time goes down. In figure 3 the DS time is plotted against the curve time for the same training showing the clear trend. In the course of the season DS patterns change somewhat.

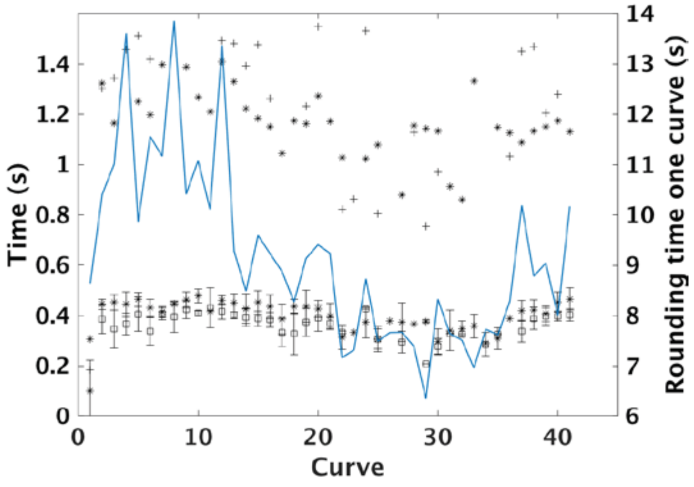

Figure 2: Example of the average DS per curve for left to right (o) and for Right to left (☐) weight transfer during a full training. Average contact time per skate per curve (Left *, Right +). The line gives an estimate of the rounding time of a curve. The ragged shape of this line indicates the training schedule rather then the quality of the data.

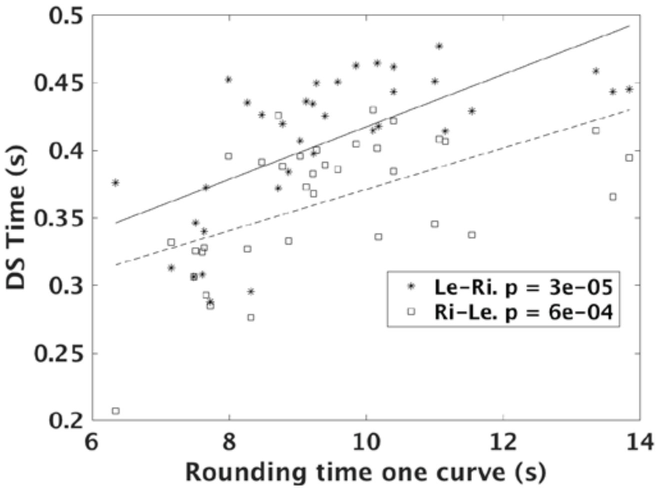

Figure 3: Relation between rounding time and average DS per. The same training as used in figure 2.

DISCUSSION AND CONCLUSION: The first performance indicator investigated shows clear differences between skaters and changes somewhat over the course of the training season. The method applied to retrieve the timing of the strokes seems adequate and already provides useful information for the coach and skaters. After showing the results of a specific training (e.g. figure 2), several weeks later a skater reflected on her performance related to symmetry of her skating movement that training (more symmetric), which corresponded with the findings of the analysis. This suggests that the DS timing can be influenced by the skater and possibly with direct feedback.

Results (e.g. fig. 3) suggest a relation between the DS and curve speed, supporting our hypothesis, but is not jet conclusive. To investigate this in more detail we intent to measure elite skaters of an even higher level and during competition. It is worth to note that a relation between DS and speed is not necessarily visible for every athlete. This only holds if the skater can adapt the DS timing with higher speeds, at some point the movement can not be performed faster. Not only skill level but also ice quality seems to influence the DS times. Direct feedback experiments will be executed shortly with a variable baseline design. In this way we intent to overcome the variation due to possible cofounders like ice quality, and training or competition schedule. The feedback will be processed real-time and converted to a simple measure of performance; this will be presented in the glasses of the skater. The currently developed instrumented Klapskate (Kruk, Schwab, Helm, & Veeger, 2016) will further broaden the possibilities to provide feedback in real-time on the ice.

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