ANALYSIS OF IN COMPETITION SPEED SKATING USING IMU'S

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For feedback to be effective, we must first identify relevant performance indicators for speed skating. We instrumented the skating of 10 junior elite Dutch speed skaters with two inertial measurement units during two competition events. Contact time, stroke frequency and other parameters were derived from collected IMU data and related to performance (finish times). The manner and timing in which the skater initiates a race in the first 100 m, is predictive of the final finish time. A significant correlation was found between finish times and 1) a decrease in stroke frequency and 2) an increase of the contact time of the skate and the ice over the first 100 m of a race. These relations were robust against variations in race distances (i.e., 100, 300, 500 and 1500 m), while the directionality of the relation differed qualitatively between the 100 m sprint and the other distances. We concluded that progression in stroke frequency and contact time are relevant feedback parameters for enhancing performance in speed skating.

KEYWORDS: speed skating, performance Indicators, feedback, wearables

INTRODUCTION: The difference between winning or losing in modern speed skating is often a matter of milliseconds. To prepare for competition, many hours of training are invested over the season, typically 3 to 5 hours a day. During these speed skating training sessions both technique and physique are addressed on a regular basis. The question arises which technique aspects are relevant for a good race preparation? The combination of performance indicators and the newly designed system using small IMU's is expected to provide powerful feedback during both training and competition, either as concurrent (i.e., near real-time) feedback during exercise or as terminal feedback minutes after a training exercise. Moreover, after a training session the data can be analysed in greater detail to provide an overview of the session in question, and to monitor training sessions over a season, i.e. postponed feedback.
Propulsion in speed skating differs from walking or running in that during running the push-off force is directed opposite to the general velocity direction, whereas in speed skating the force is directed perpendicular to the skate blade. At high speeds the skate blade slides at a relatively small angle to the average movement direction of the COM. However, the first meters after the start are different, the skates are placed more perpendicular to the velocity, the push-off resembles a running sprint. The skater jumps from one skate to the other, the contact time with the ice is short and the force is applied almost opposite to the velocity direction, leading to an effective transfer of energy (Koning, Boer, Groot, & Schenau, 1987).
In this study we will gather information about various performance indicators of skating, including contact times, stroke frequency, and related them to finish times in order to identify feedback parameters relevant to performance.

METHODS: Twelve junior elite speed skaters (Dutch National Level age 18.9 ±1.6, mean ±SD) were asked to wear 2 IMU's, one attached to each skate during two competition events. The competition events were practise competitions with no implication for their ranking. Ten skaters volunteered to participate and 19 races were measured. Sprinters raced 100 – 300 – and 500 m, whereas long distance skaters raced 500 – 1500 and one 3000 m. One competition event was held in the Netherlands, the other in Inzell, which is a slightly faster ring, due to a higher altitude. The venue did not influence the race results, so the data were pooled for analysis.

The IMU sensors (Shimmer3 from Shimmersensing, Ireland) automatically synchronize via Bluetooth while recording data. The data were analysed with custom-made software packet (Matlab^{TM}, MathWorks) resulting in several parameters for each skate per stroke: contact time, air time, bipedal or double stance phase (DS) and stroke frequency. The manner in which these parameters were delivered from the data is described in van der Eb et al. (2017). Overall parameters calculated were: number of strokes per 100 m straightaway and turn, skate time per section of the skating ring (straightaway and turns).

RESULTS: Figure 1 shows an example of contact times and double stance times collected for a 1500 m race. The progression of the contact time for left and right skate was more or less constant on the straightaways after the second turn. In the turns a slight increase in contact time and a slight difference between left and right was observed over time. The asymmetry is not surprising since the leg movement in the turn is asymmetrical, even though the degree of asymmetry varies among skaters. Figure 2 left panel shows the lap times for the same race as Figure 1. The black and green dots are almost in line showing that the algorithm adequately distinguishes between turns and straightaways. Figure 2 right panel shows the transit times after the first 100 m for all the races, herein no clear general relation can be seen.

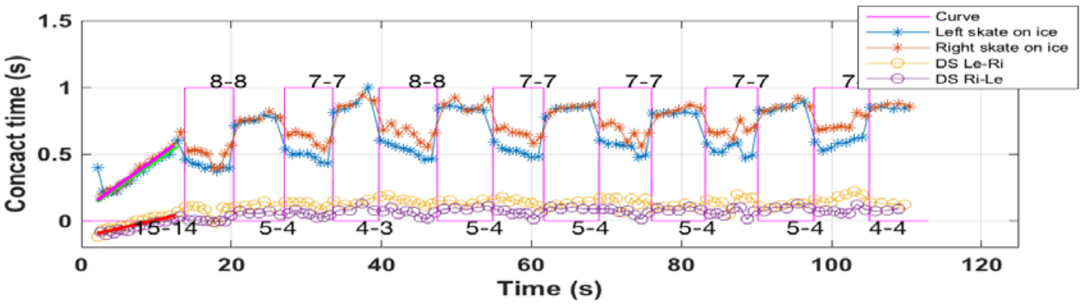

Figure 1. Contact time and double stance time for a 1500 m race. Male, finish time 1:49.69 s. The purple square line shows the turns, where the contact time is much lower than on the straightaways. The circles show the double stance phase which is more or less constant throughout the race for this athlete. The numbers in the graph are the number of strokes per section, separately for straightaways and turns.

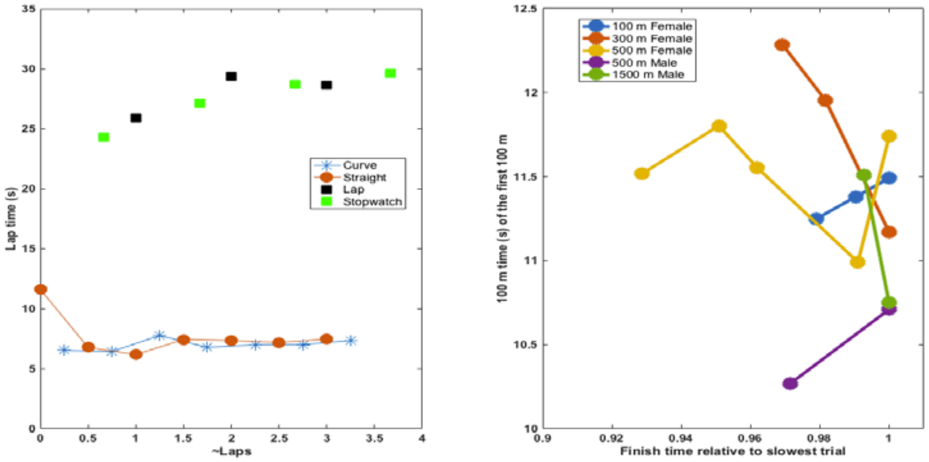

Figure 2. Left panel: The same 1500 m race as in Figure 1. The left graph gives an indication of how well the software calculates the lap times: black dots compared to the stopwatch times (green dots). Right panel: 100 m pass time versus finish time, per distance and gender.

In Figure 1 a gradual increase is visible in contact time over the first 100 m (up to the first turn), and the double stance (DS) time increases from negative to positive. A negative DS indicates the skater is jumping from one skate to the other, just like running. i.e., the skates are simultaneously in the air. At some point in the first 100 m the skater transitions from ‘running’ to more gliding movements and to skating. The gradual increase in stroke contact time and decrease in stroke frequency show a relationship with the finish time on all but one distance measured (100, 300, 500 and 1500 m) (Figure 2). The 100 m (female) data showed an opposite trend.

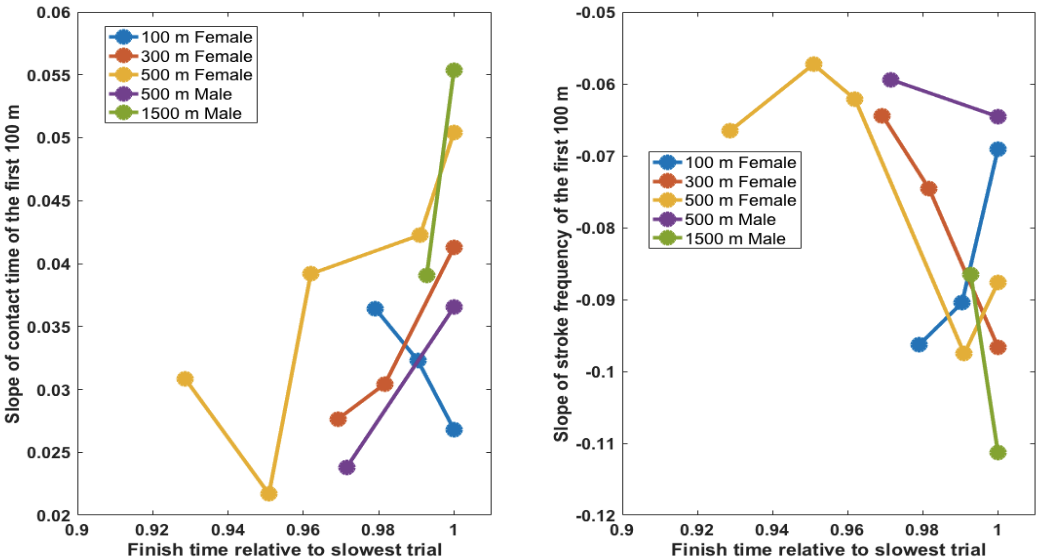

Figure 3. The slope of the contact time (left) and stroke frequency (right) of the first 100 m is plotted against the finish time for different distances and gender.

Although the results presented here are only of two competition events and with the same junior elite skaters (three skaters performed three times, three performed two times) the results suggest a clear trend. Ignoring the 100 m results the correlation for the frequency slope is significant (Pearson’s r = -0.68, p = 0.016). With the 100 m results included, the correlation is weak (Pearson’s r = -0,5 p = 0.057). For the slope of the contact time the relation is weak (Pearson’s r = 0.057 and p = 0.054) without the 100 m results and with (Pearson’s r = 0.046 and p = 0.083). The data suggest that for a faster finish, the decrease in stroke frequency and increase in contact time the over the first 100 m should be kept as low as possible. The reason why the 100 m female data shows the opposite trend is not entirely clear. The major differences are: pacing strategies are important for races longer then 100 m, and a 100 m race has no transitions from a straightaway to a turn which influences the last part of the 100 m straightaway.

DISCUSSION: The present research indicates that skaters finishing with a better time keep a higher rhythm during the first 100 m with shorter contact times per stroke. Apparently running or jumping is more beneficial than gliding during the initial stage of the race. That is, the definition of external power defined by Van Ingen Schenau and Bakker (1980) shows the relation between external power and work per stroke times frequency for speed skating. Thus, keeping the decrease in stroke frequency lower over the first 100 m could imply that a higher external power was delivered with the same amount of work per stroke. At the same time, the fastest skaters kept the increase in contact time per stroke lower for the first 100 m compared to the slower finish times. To deliver the same (or greater) amount of work per stroke in a shorter time, a skater either has to be more 'explosive' in delivering power to the ice, or the work has to be delivered more 'effectively' to the ice. Especially during a start, the force applied to the ice can be directed more in line with the velocity of the skater (centre of mass), due to the fact that the skates are placed at a higher angle, relative to the direction of movement, on the ice compared to the more gliding phase later in the race. Thus the resultant force producing positive external power is higher during the start than during the gliding phase. The question now arises whether it is more efficient to 'run' or 'glide' at relatively low velocities.

CONCLUSION: The slope of the stroke frequency and with a lower correlation the slope of the contact time during the first 100 m of a race appear to be promising performance parameters since they are related to finish times. Although the number of measurements in the race was limited, the observed relations were robust against race distances and gender, except for the 100 m females. The results are promising and warrant further measurements during competition. This research also raises new questions, such as: is 'running' or skating at relatively low speeds energetically favourable?
The IMUs are small enough to be worn during training, and even in competition, without interfering with performance. The IMU's in combination with the developed tools to analyse the data becomes an interesting avenue to provide feedback during training and for off-line research purposes. The identified performance indicators will be used in the near future to provide feedback to the skaters while they are training, either concurrent or as terminal feedback.

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