Treadmill simulation of Olympic cross-country ski tracks.

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1 Introduction

Cross-country skiing is a sport in which it is possible to perform sport-specific training, testing and research on a treadmill (Holmberg, Lindinger et al. 2005; Lindinger, Stoggl et al. 2009). In addition, it is possible to simulate a cross-country skiing racing course on a treadmill using roller skis in order to train for upcoming competitions. Stöggl and colleagues (Stoggl, Lindinger et al. 2006; Stoggl, Lindinger et al. 2007) created a test protocol to simulate sprint skiing on a treadmill, based on the classic World Cup-sprint in Stockholm, Sweden. However, the protocol used by Stöggl and colleagues (Stoggl, Lindinger et al. 2006; Stoggl, Lindinger et al. 2007) used constant speeds for the different sections of the course which limited the skiers to ski at their own individually preffered speeds. Different skiers have different racing speeds depending on inclination, distance and sub-technique and these differences affect each skier's race tactics. Hence, it is desirable to have a wireless self-adjusting speed system when roller skiing on a treadmill; this allows skiers to ski at their own pace and using their own tactics depending on course length and topography. Also, a self-adjusting speed system creates a more realistic skiing environment which is good for training or research purposes as well as for competition preparations on competition-specific tracks. Minetti et al. (2003) developed a self-selected speed system using an ultra-sonic range finder. However, the ultra-sonic solution is sensitive to lateral drift and movements and movements should follow the usual walking and running patterns, which makes it unsuitable for roller skiig.

Elite cross-country skiers train and compete on the physiological limit of the human body. Optimization and preparation of equipment and training facilities therefore play an important role in the quest for medals. The 2010 Winter Olympics were held in Vancouver, Canada with the cross-country and biatholn events taking place in Whistler in an arena not well known for the Swedish skiers. Familiarity with the competition tracks and terrain can be an advantage in the pursuit for medals in the Olympics. The purpose of this project was thererfore to create a virtual indoor training facility for roller skiing, simulating the 2010 Winter Olympics tracks for the purpose of training using a treadmill, video feedback and accurate track profiles.

2 Methods

Global Navigation Satellite System (GNSS)-data with ±1 cm horizontal and ±2 cm vertical accuracy were collected, from all the Olympic ski tracks located at the Whistler Olympic Park, using a Real Time Kinematic GNSS system (RTK GNSS) (Leica Geosystems AG, Heerbrugg, Switzerland). The RTK GNSS unit was mounted to a snowmobile that drove around each track of a velocity between 10 - 20 $km \cdot h^{-1}$ and surveyed positions at 20 Hz sampling rate. A video camera (Canon XH A1e, 50 Hz HDV, Canon Inc., Tokyo, Japan), handheld by a person on the snowmobile was used to capture video footage from each track. The RTK GNSS antenna, mounted on a geodethic pole, was rapidily lowered down to the ground and raised back up while being filmed in order to get a synchronization point between the RTK GNSS and the video camera. This procedure was performed before each data capture for all tracks. RTK GNSS positioning data was first interpolated in order to match the video frequency and thereafter transformed from time to space domain using Matlab (MathWorks Inc., Natick, MA, USA) and subsequently used to establish treadmill protocols. An oversize treadmill (RL 3500E, Rodby Innovation AB, Vänge, Sweden) was to simulate tracks for both classic and skate skiin. All tracks were divided into small sections where only small terrain variations occured. A nominal speed, dependent on inclination and length of the section, was set for each section. A self-adjusting speed system, based on the nominal delivery speed, was developed to facilitate a more realistic ski-feeling. A laser scanner (SICK LMS111, SICK AG, Waldkirch, Germany), positioned at the rear corner of the treadmill scanned the area of the treadmill, at 50 Hz and detected the position of the skier. The treadmill was divided into three zones: rear, middle and front, in which the skier could position him/her-self, Fig 1. The front zone and rear zone increased and decreased the speed, from the nominal speed value, whereas the middle zone remained a constant speed.

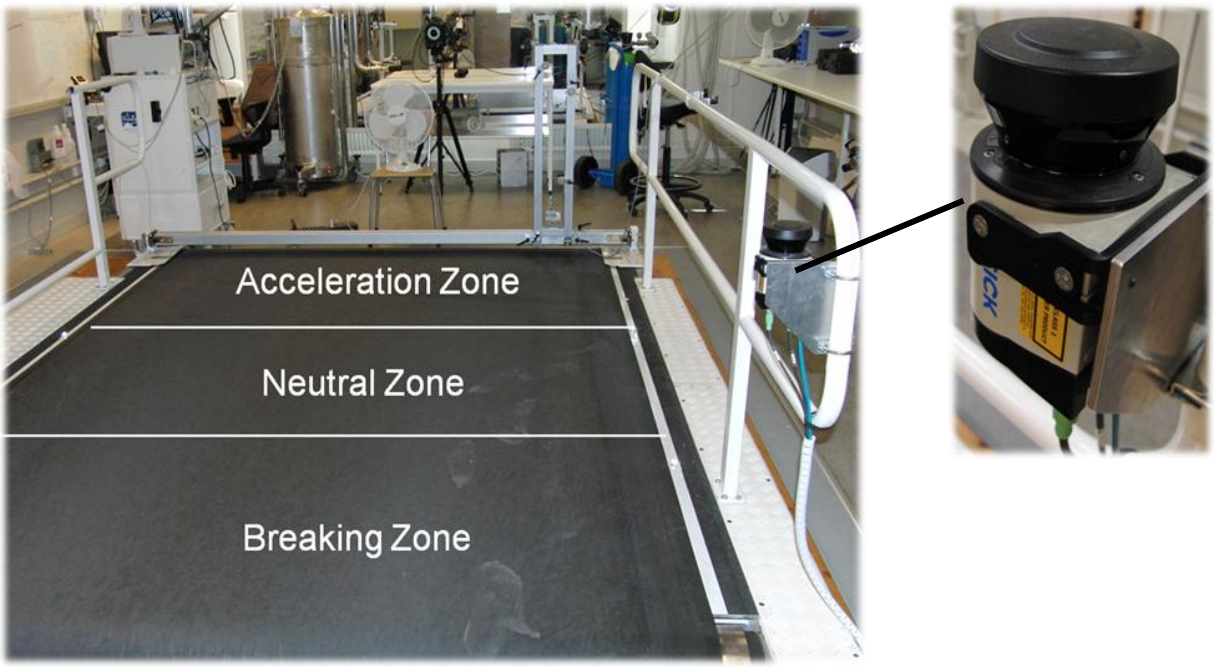

Fig. 1: Treadmill setup with the three different speed adjusmtent zones. The laser scanner, sensing the skier's position is located in the right rear corner.

A percentage of the speed increase/decrease was added to the subsequent section of the track protocol in order to get smooth speed transitions. Zone size, acceleration/deceleration rate, reaction time and laser sensitivity were adjusted for each skier. Three 42" TV screens were placed in front of the treadmill so that the skiers were able to see the video from the current track, as well as a graphical display of the track profile, heart rate and/or live footage from any of the four cameras mounted around the treadmill, Fig 2.

3 Results

The developed self-adjusting speed system allowed skiers to accelerate and decelerate with at up to 0.6 $m{\cdot}s^{-2}$, by themselves, at speeds between 0 and 36 $km{\cdot}h^{-1}$ and up to 15° of inclination. In the downhill sections the skiers assumed the crouched position that is used on real downhill parts, and held on to a fixed pole tip as often is seen during cross-country ski races. A total of 24.4 km, comprised of 8 different tracks, from the 2010 Winter Olympics were programmed into the treadmill and used by the Swedish cross-country and biathlon ski teams prior to the 2010 Winter Olympics. The videos from each track were an important factor in the familiarization process. Each video had to be manually synchronized for each track and skier due to limitations in data transfer between the treadmill-control program and the video-visualization program.

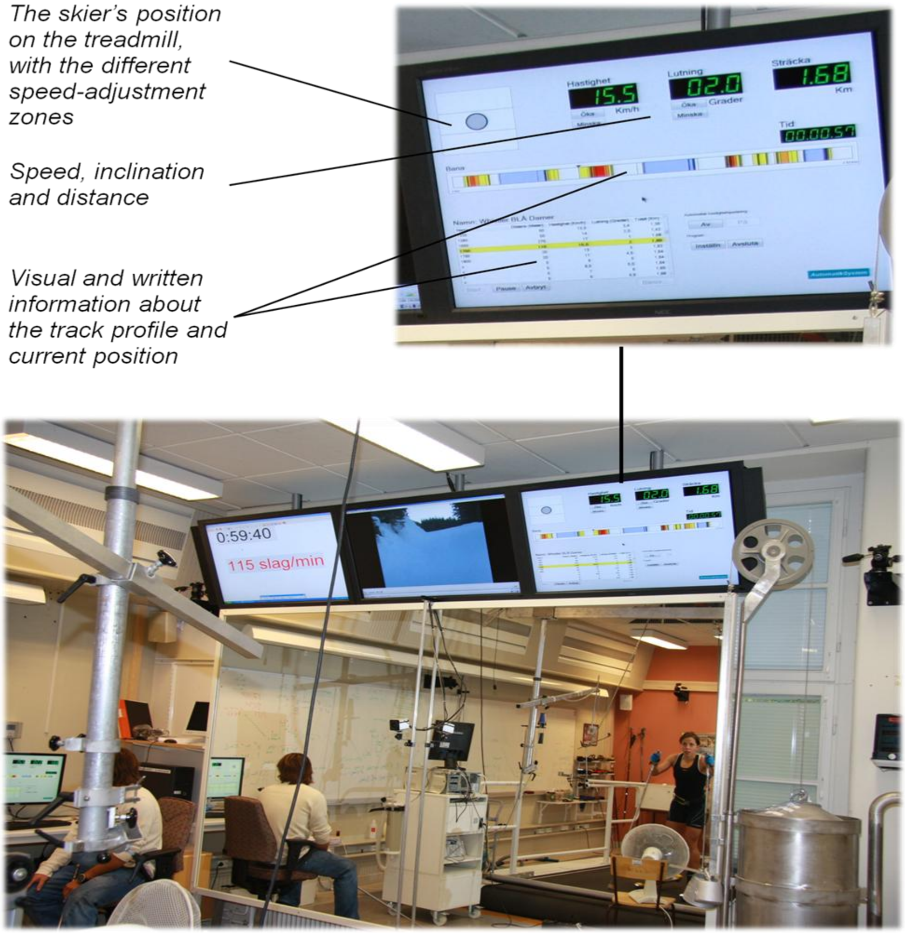

Fig. 2: The visual feedback system for the skiers. Consisting of three 42" TV-screens showing (from left): Time and heart rate, video from the current track and course/protocol information

The developed system enables crude programming of any ski track based on GNSS data for the track profile.

4 Discussion/Conclusion

Good training facilities and preparations are essential to be able to perform at elite level. The new virtual indoor training facility with wireless self-adjusting speed provides realistic training and preparation conditions for cross-country skiers. However, one limitation with this system is that the skiers are not affected by airdrag and do not have any kinetic energy as they are stationary on the treadmill. This means that a correctly adjusted nominal speed and smooth inclination transitions are essential for achieving realistic and skiable tracks on the treadmill. The ability to adjust zone size, acceleration/deceleration rate and sensor sensitivity is crucial in helping different skiers and creating a more realistic feeling, whether it is a skate, classic, distance race or sprint race. Another limitation is that negative inclinations are not possible due to the construction of the treadmill. Although skiers do not experience the same type of fatigue on a treadmill as during long and technical downhill sections, the solution used in this study (crouch position holding on to a pole tip) is a reasonable substitute.

The developed system works well for any type of course with known topography and distances. GNSS-coordinates with an accuracy of ± 1cm are not necessary due to the need to adjust and smooth out the inclination transitions for the skiers. Also, the treadmill is limited in how fast it can adjust the inclination, which affects the minimum distance for each section of the protocol. Track simulations will thus be even more realistic when using treadmills that can change inclination rapidly and have high acceleration capacity for the velocity of the belt.

Further developments should include options for recording when and how each skier altered velocity in each section, in order to be able to analyse differences between skiers and their tactics. Also, for training purpose a solution, where the skiers can adjust the inclination by themselves is desirable. However, a solution with self-adjusting inclination requiers a solution where the speed of the treadmill also changes, so as to prevent the skiers from going to fast or to slow depending on the inclination.

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