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Impact of dynamic friction on race times in cross-country skate skiing - a numerical simulation study

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INTRODUCTION:
Dynamic friction is an important parameter in cross-country skate skiing. A reduction of the dynamic frictional coefficient (µ) with 47% can increase the time to exhaustion with 50% when roller-ski skating [1]. With normal ski preparation µ may vary up to 15% due to the ski base texture [2]. To isolate the impact of µ on race time, numerical simulations with a power-balance model could be used as previously demonstrated [3],[4]. Field measurements have provided more detailed relationships for propulsive power and drag area with the skating sub-techniques, allowing more reliable simulations [5]. Thus, the aim of this study was to examine the impact of different dynamic frictional coefficients on the required time to complete a cross-country skate skiing.
METHODS:
A power balance model for cross-country skate skiing was implemented and solved in Matlab for skiers with body masses of 70, 80 and 90 kg respectively. Propulsive power was modelled as a function of speed, acceleration and body mass [5]. Additionally, five values of µ and three wind conditions were examined, giving a total of 45 combinations. These were all simulated on two different courses. Total race times were taken from a 15.6 km race (5 laps of the 3 km biathlon race course in Östersund) imported from GPS-data. Speeds at specific inclination angles were taken from a fictional course with sections of constant inclination angle (mean speed downhill, steady state speed on the uphill and flat). In the 15.6 km race the ambient winds were aligned to give either 4 m/s tailwind in the majority of downhill sections and headwind uphill (4SW), the opposite (4NE) or zero wind. In the fictional course wind was either 4 m/s tailwind, 4 m/s headwind or zero through the entire race.
RESULTS:
The mean total race time in the 15.6 km race was 2240.7±141.1 s, with shorter race times for the heavier skier (90 kg 19.2±1.3 s < 80 kg 22.2±1.3 s < 70 kg) and for tailwind uphill (4NE 5.0±2.0 s < zero wind 5.9±2.0 < 4SW). Changing µ from 0.013 to 0.015 increased the total race time for the 70, 80 and 90 kg skiers with 33.6 s (1.53%), 34.0 s (1.57%) and 34.0 s (1.58%) respectively. Changing µ from 0.025 to 0.027 gave 34.6s (1.44%), 34.2s (1.44%) and 35.1s (1.49%) increased race time for the 70, 80 and 90kg skiers respectively. The changes in speed from the 70 to 80 to 90 kg skiers were all below 0.43% on the uphill and between 0.70 and 1.53% on the flat and downhill. Changing µ gave largest change in speed for moderate downhill (e.g. 2.15%, µ 0.015 to 0.013) followed by flat (1.29%) and moderate uphill (1.22%).
CONCLUSION:
An absolute change in µ of 0.002, e.g. a different preparation of the skis, have slightly larger impact on faster (µ~0.014) than slower snow (µ~0.026) but in both cases could turn the tide in a close race. This change in race time is generated mostly in sections with moderate or no inclination angle.
1. Ainegren et al. (2009) 2. Budde & Himes (2017) 3. Sundström et al. 2013 4. Moxnes et al. 2014 5. Gloersen et al. (2018)

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