Contribution of arm swing on the kinematics and energy characteristics of V2A ski skating in elite cross-country skiers

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Introduction & Goal

Arm swing plays an active role in maintaining balance and providing propulsion in different human movements. It is especially pronounced in V2A skating, a cross-country (XC) skiing technique performed on level terrain involving one poling push for two leg strokes. Although in V2A arm swing effect has been already discussed focusing on biomechanics and physiology (1; 2), no study has investigated its contribution to the center of mass (COM) kinematics.

The study aimed to discover how arm swing contributes to the COM kinematics in V2A with consequences on the mechanical energy and its fluctuations. We hypothesized that arm swing would enhance the vertical oscillation, speed and acceleration, influencing the mechanical energy.

Methods

Participants & protocol:
Seven male XC skiers performed a 18-m-long trial in the Vuokatti ski tunnel (Finland) without poles. The subjects skied at moderate speed (5 m/s), paced with light cells, and at maximal sprinting speed keeping the coordination of V2A without arm swing (0A), with one arm swing (1A) and two arms swing (2A). In condition 0A and 1A, the athletes skied with the hand positioned on the hip and, in 1A, choosing the preferred arm to swing (Fig.1).

Data collection & analysis:
A motion capture system (Vicon Nexus) with passive reflective markers (Plug-in-gait and skis) recorded the performance, permitting the COM kinematic analysis and the calculation of mechanical energies using Matlab.

Fig.1: Athlete performing V2A in 0A condition

Results

Arm swing:

- Influenced cycle characteristic at maximal speed,
  i.e., cycle time 0A: 1.37±0.18 s, 1A: 1.28±0.13 s, 2A: 1.25±0.14 s (P<0.05)
- Increased COM lift, as vertical and sagittal COM speed and acceleration
  sagittal maximal speed 0A: 5.76±0.48 m/s, 1A: 5.91±0.54 m/s, 2A: 5.99±0.58 m/s (P<0.05)
- Increased mechanical energies and their ranges at 5 m/s and maximal speed
  Max TE/body mass (with equipment) at 5 m/s 0A: 13.81±1.61, 1A: 14.33±1.71, 2A: 15.30±1.84 J/kg (P<0.05); at maximal speed 0A: 18.42±2.80, 1A: 19.86±3.35, 2A: 21.23±3.90 J/kg (P<0.05)

Mechanical energy fluctuations were out-of-phase in V2A (Fig.2).

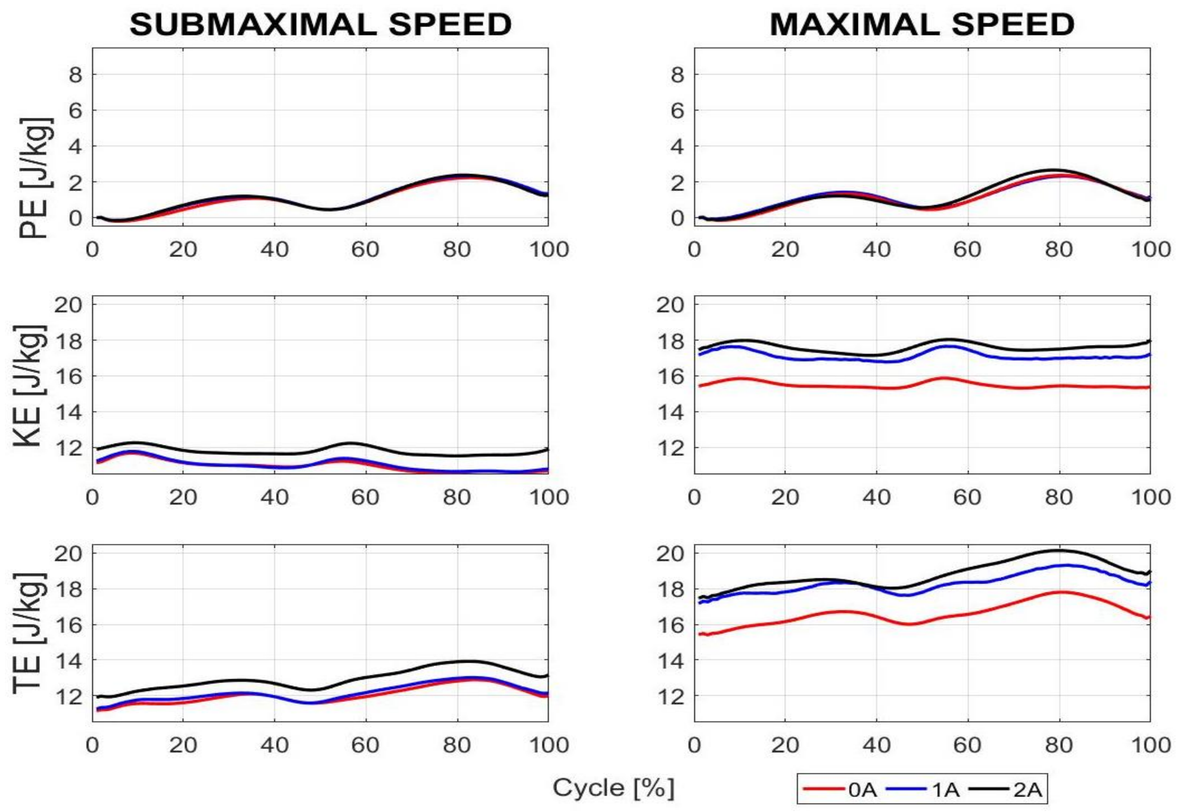

Fig.2: Potential (PE), kinetic (KE) and total (TE) energy fluctuations per kg of body mass (with equipment) in different arm swing conditions 0A: no arm, 1A: one arm, 2A: two arm swing at moderate and maximal speeds

Discussion & Further research

The research shows that arm swing is relevant in XC skating propulsion. The swing contributes to the overall V2A cycle movement and enhances kinematics and energy in particular at maximal speed, as happens in running (3). The out-of-phase energy fluctuations (inverse pendulum behaviour) confirmed a previous study (4), while the phase was not influenced by arm swing conditions and speeds.

Further researches should investigate the influence of arm propulsion and maximal speed on the COM energy fluctuations.

References

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