The effects of the arm swing on biomechanical and physiological aspects of roller ski skating

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Introduction

In sports such as jumping and running, it has been demonstrated that the arm movement contributes to enhanced performance. These improvements are mainly explained by higher ground reaction forces resulting in an increased take-off velocity of the body’s center of mass. Although the upper body movement is regarded highly important for cross-country skiing, with poling demonstrated to enhance skiing performance, the influence of the arm swing has not yet been investigated. In order to understand the contribution of the arm swing in cross-country skiing with the skating technique, the present study compared the G4 leg-skiing technique using a pronounced arm swing (SWING) with leg-skiing using locked arms (LOCKED) when roller ski skating on a treadmill. It was hypothesized that the arm swing supports the leg work which would enhance the propulsive forces, lead to longer cycle lengths and reduce the metabolic costs.

Methods

Sixteen male elite cross-country skiers (age 24±4 years, body mass 74.4±7.6 kg, VO₂max 71.5±3.8 ml kg⁻¹ min⁻¹) completed six 4-minute sub-maximal stages in SWING and LOCKED at 10, 15 and 20 km h⁻¹ on a 2% inclined treadmill. SWING was performed as leg-skiing without using poles, but with an active arm swing while simulating the G4 skating technique, such that the backward arm swing imitated the poling action during the leg push-off on the strong side followed by a forward arm swing during the leg push-off on the weak side. LOCKED was performed as leg-skiing with locked arms. Ventilatory variables were assessed by open-circuit indirect calorimetry, three-dimensional kinematics were analyzed using the Qualisys Pro Reflex system and kinetic variables were measured using roller skis instrumented with full bridge strain gauges (Hoset et al. 2013).

Results

SWING demonstrated higher peak push-off forces and a higher force impulse at all speeds, but a longer cycle length only at the highest speed (all P<0.05). Additionally, the flexion-extension movement in the lower limbs was more pronounced for SWING, with differences between the strong and weak side here. With LOCKED, the flexion-extension movements did not differ between both sides. Oxygen uptake was higher for SWING at the two lowest speeds (both P<0.05), without any differences in blood lactate. At the highest speed, oxygen uptake did not differ between SWING and LOCKED, but the respiratory exchange ratio, blood lactate concentration and ventilation were lower with SWING (all P<0.05).

Discussion

Overall, utilizing the arm swing provided the possibility to use greater flexion-extension movements of the legs and increased the total force production in roller ski skating. This resulted in reduced physiological stress and longer cycle lengths at high speed, but did not alter cycle length at low and moderate speeds. This indicates that the force effectiveness was higher with LOCKED at the two lowest speeds. In contrast to what was expected, adding the arm swing increased oxygen uptake at the low and moderate speed, while blood lactate values were similar. At the highest speed however, differences in oxygen uptake between the two techniques disappeared and the lower blood lactate concentration, respiratory exchange ratio and ventilation indicated a lower anaerobic energy contribution with SWING. Thus, it can be concluded that utilizing the arm swing is energetically more costly at low and moderate speeds, but physiologically and biomechanically beneficial at high skiing speeds.