INTEGRATIVE PHYSIOLOGICAL AND BIOMECHANICAL ASPECTS IN COMPETITIVE CROSS-COUNTRY SKIING

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INTRODUCTION: Cross-country skiing involves a large variety of skiing techniques. Among these double poling (DP) has markedly increased in importance during the last decade, accentuated by new racing events with higher racing velocity. The aims with the present studies were to describe DP using an integrative physiological and biomechanical approach.

METHODS: DP was examined in three studies (A-C), involving roller skiing on a treadmill. In study A (n=6), the subjects performed 10 min of DP at ~74% of their VO_{2max}. Catheters were inserted in a. and v. femoralis, v. subclavia and right atrium to measure a-v O_2 difference at systemic level as well as over the arms and legs. Blood flow in arms and legs was measured by constant-infusion thermodilution and cardiac output was calculated using the Fick principle. Moreover, lactate kinetics was examined using tracer technique. Study B and C were performed with the same group of skiers (n=11). Study B was a biomechanical analysis with the skiers DP at 85% of their maximal DP velocity (V_{max}). Electromyography (EMG) was performed on upper and lower body muscles and movement in the elbow, hip, knee and ankle joints were analysed using goniometry. In Study C the skiers performed two incremental DP tests with or without locking the knee and ankle joints (DP_{LOCKED} and DP_{FREE}) at 85% of their V_{max} during DP_{FREE}. Peak oxygen uptake (VO_{2peak}), heart rate and blood lactate concentration were determined. 2-D video analysis and measurements of pole and plantar forces were performed in both study B and C. Statistical significance was set to $P<0.05$.

RESULTS: Study A revealed VO_2 to be higher in the legs (46%) compared to the arms (37%) with blood flow following a similar distribution pattern. Furthermore, there was a net lactate release from the arms and net lactate uptake by the legs. Study B showed that pole force, in contrast to poling frequency, is directly related to DP velocity and influenced by specific muscle activation patterns and a specific characteristic flexion-extension pattern in the elbow, hip and ankle joints with the angle minima occurring around the peak pole force. Moreover, the skeletal muscles were engaged in a sequential order starting with trunk and hip flexors, followed by shoulder extensors and the elbow extensor triceps brachii. Finally, the best skiers used a special DP strategy with specific characteristics directly correlated to DP velocity. In study C the skiers showed a 7.7% higher VO_{2peak}, 9.4% higher V_{max} and 12% longer time to exhaustion during DP_{FREE} as compared with DP_{LOCKED}. There was a higher heart rate and blood lactate concentration in DP_{LOCKED} at submaximal stages, with no difference in oxygen consumption. At 85% of V_{max} corresponding to ~81% of $VO_{2peak\ FREE}$ the differences in physiological variables were accompanied by a 14% higher poling frequency, a 4.9% shorter poling phase, 13% shorter recovery phase and 11% lower relative pole force in DP_{LOCKED}.

DISCUSSION: These data demonstrate that hip and the leg region were energetically the most costly regions during DP, demonstrating DP to be more than upper body work. However, the upper body muscles have a pivotal role in producing the force and thereby DP velocity. Of note was that the best skiers used a DP strategy directly related to DP velocity characterized by smaller joint angles, higher flexion velocities and higher pole force applied during a shorter poling phase. Moreover, the intervention to impair joint movement showed that the movement of the lower body directly influences physiological and biomechanical parameters as well as DP velocity.

OVERALL CONCLUSION: Cross-country skiing has become quite complex. The findings demonstrate the value of integrating data from biomechanical studies with the energetic

demands to pinpoint the factors that are crucial to reach top DP velocities. This can then provide the basis for advice about optimal training and techniques.