New aspects of double poling technique in cross-country ski racing - a biomechanical approach
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Introduction
The importance of double poling (DP) as a main classical technique has increased in modern cross-country ski racing during the last two decades. Better track preparation and better ski and pole material has increased the fractional use of DP during a race. The introductions of the skating technique in the 80’s and the sprint discipline during the last years have put more emphasis on upper body strength and endurance training. The consequence of this training has lead to physiological adaptations, which are of importance in DP. But only few biomechanical studies have been analyzed DP. Hoffman et al. (1995) showed that increases in submaximal intensities were associated with increases in cycle rate with unchanged cycle length. Smith et al. (1996) demonstrated that faster skiers showed a greater range of elbow motion with initial flexion immediately followed by extension, with higher angular velocities. Millet et al. (1998) showed that increases in speed were achieved by increasing pole force and cycle rate accompanied by a shortening of both poling and recovery time in each DP cycle. No earlier study has used EMG in order to study DP. The purpose of this study was 1) to perform a complex biomechanical analysis of the DP technique in cross-country skiing at racing speed to highlight complex mechanisms, 2) to advance hypotheses, which biomechanical aspects contribute to DP performance and 3) to biomechanically analyze the interaction between upper and lower body during DP, already shown from a physiological point of view (Van Hall et al, 2003).

Methods
Eleven elite XC skiers (Swedish U-23 and Junior National Team) performed DP at 85% of their maximal DP velocity (V85%) during roller skiing at 1º inclination on a treadmill. Ground reaction forces directed along the pole were measured for nine upper and ten lower body muscles at a sampling frequency of 2000 Hz (Biovision, Ernst, Germany). Standard statistical methods were used for calculations of correlations and statistical differences.

Results
1)The basic characteristic of the pole force curves showed a distinct impact force followed by a peak pole force (PPF). Absolute peak pole force (PPFabs) was 235 ± 63 N and relative peak pole force (PPFrel) 32.1 ± 7.5 %BW. Absolute impulse of pole force was 36.4 ± 5.9 N·s, corresponding to a relative impulse of pole force of 4.9 ± 0.5 %BW·s. 2) The absolute velocity at 85% of Vmax (V85%), was correlated to PPFabs (r = 0.70), PPFrel (r = 0.66), angular velocity in elbow flexion during PP (r = 0.80), knee angle minimum during PP (r = -0.72) (all P < 0.05) and elbow angle minimum during PP (EAmin PP) (r = -0.88, P < 0.01). 3) PPFrel Correlated to EAminPP (r = -0.71), relative poling time (r = -0.72), recovery time in the elbow joint during PP (r = -0.79) (all P < 0.05) and hip angle at the start of PP (r = -0.89, P < 0.01).4) Two different DP strategies (A and B), where strategy A (best skiers) was characterized by higher angular elbow and hip flexion velocities, smaller minimum elbow (P < 0.01) and hip angles (P < 0.05) and higher PPF (P < 0.05). 5) EMG activity in trunk and hip flexors, shoulder and elbow extensors, and several lower body muscles followed a specific sequential pattern with changing activation levels, and 6) EMG activity in lower body muscles showed DP required more than upper body work.

Discussion/Conclusion
The better an athlete was performing using DP (V85%) the higher relative peak pole forces, the smaller minimal knee and elbow angles and the higher elbow flexion velocities were reached. Additionally PPFrel was positively influenced by shorter relative poling times and consequently longer relative recovery times, an aspect that might positively influence DP economy. The smaller hip angle at pole plant was the higher PPFrel was, what leads to the idea to “fall” into the poles starting from a “high hip-high heels” position. This pattern also partly described the found strategy A in DP and was shown by the best skiers in the group. Altogether this DP pattern was already discussed and described among coaches in elite cross-country ski racing as a sprint like DP technique and it is shown by the best also in world cup. Probable correlations of those DP strategies to strength abilities (neural aspects) in elite cross-country skiing athletes have to be investigated in further studies on DP. The found results enable coaches and athletes to be able to be more specific regarding technique and strength training. Future research on DP should further investigate specific biomechanical aspects of the different strategies, the relationship to physiological variables and elaborate specific strength and technical models to increase pole force and DP performance.

References