Maximal strength in upper-body segments as determinants of double poling performance in female cross-country skiers

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Introduction
Upper-body strength and endurance capacity is of high importance for cross-country skiing performance and especially relevant in the double poling movement. This study aimed to investigate how maximal strength in the elbow, shoulder and trunk segments (measured in isolation) influence double poling efficiency, endurance and sprint performance in female cross-country skiers. To provide further insight into the mechanisms related to these relationships, poling technique and body composition was analyzed.

Methods
13 well trained female cross-country skiers (age 22±3yrs, body mass 61±5 kg, VO₂max running 65±4 ml/kg/min) tested maximal strength (1RM) in elbow extension, and shoulder and trunk flexion exercises. Double poling was performed on a Concept2 SkiErg where all skiers completed three 4-min submaximal stages, as well as 3-min and 30-sec all-out tests. Work rate and cycle rate were measured with the ergometer’s internal software which had been validated with force and velocity measurements. Average work rate determined performance, whereas gross efficiency (GE), calculated as work rate divided by aerobic metabolic rate, was estimated at 90 W. Body composition was measured using dual-energy X-ray absorptiometry.

Results
Both the 30-sec test and the 3-min test showed significant correlations with 1RM in elbow, shoulder and trunk (30-sec r=0.85, 0.88, 0.64, all P<0.001; 3-min r=0.54, 0.58, 0.66, all P<0.05). Submaximal GE correlated significantly only with trunk 1RM (r=0.55, P=0.03). Stepwise multiple regression analyses revealed that elbow and shoulder 1RM together were the best predictors of 30-sec performance (R²=0.88,) and that trunk 1RM alone was the best predictor of 3-min performance (R²=0.39). The average work produced per cycle during the 30-sec test showed significant correlation with all strength tests (r=0.61-0.85, P<0.05) but not with 3-min performance or gross efficiency, whereas total arm and trunk lean body mass both correlated with the 1RM strength and performance (r=0.55-0.87, all P<0.01).

Discussion
This study demonstrates that the impact of maximal strength in elbow and shoulder segments increase with increasing demands of work rate production, whereas maximal trunk strength has a similar importance for poling efficiency and performance across the whole intensity spectrum. Since both poling performance and maximal strength were associated with high lean body mass in arms and trunk, enhanced upper-body muscle mass may be advantageous for female skiers.