Relative power contributions in double poling
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Introduction
The double poling (DP) technique in cross-country (XC) skiing is a complex and dynamic whole-body movement. Although the arms and trunk are of high importance during DP, utilizing the whole body provide skiers the possibility to produce much higher external power than with isolated upper-body work. This has been explained by the utilization of total mechanical (potential/kinetic+rotational) energy of all body segments \( P_{body} = \sum_{i} E_{kin,i} \) which has a greater potential when the legs are actively utilized. During a DP cycle \( E_{tot} \) decreases during the poling phase (i.e., when propulsive forces are generated), followed by a retrieval phase (i.e., body repositioning) where \( E_{tot} \) increases. The specific role and relative contributions from the various upper and lower body joints and their interaction with \( E_{tot} \) requires further examination. Therefore, the present study performed an inverse dynamics analysis to investigate the joint-specific power and \( E_{tot} \) contributions at low, moderate, high and maximal DP intensities in a double poling ergometer.

Methods
Nine male XC skiers (age 24±5 yrs, body mass 81.7±6.5 kg, \( VO_{2\max} \) 5.45±0.64 L min\(^{-1}\)) completed three 4-min submaximal (low, moderate and high) intensities and one 3-min all-out test on a modified Concept2 SkiErg. All exercises were performed on a Kistler force platform and the SkiErg was equipped with a Futek force cell, while reflective markers (Qualisys motion capture) were positioned on anatomical landmarks. All data were collected and synchronized in the Qualysis system. By applying inverse dynamics, individual joint powers (ankle, knee, hip, shoulder and elbow) and \( P_{body} \) (i.e., rate of change in \( E_{tot} \)) were calculated for the poling and retrieval phase, and for the complete cycle. DeLeva (1996) was used for estimates of body segments mass and inertia.

Results
From low to maximal intensity the relative power from the trunk to overall external power decreased while the power from the hip increased its contribution (P<0.001). For the poling phase, \( P_{body} \) accounted for 66% of external power at the lowest and 54% at maximal intensity. \( P_{body} \) became positive during the last third of the poling phase \( E_{tot} \) increasing up to its original value), which was mainly accounted for by the hip and ankle joints. The power from the shoulder joint was continuously produced during poling while the elbow joint shifted from absorbing to producing power due to the flexion-extension movement within the poling phase. The lower limbs joints and trunk absorbed large amounts of power at around peak power output and shifted to producing power near the end of poling phase and during the retrieval phase.

Discussion
The main finding of the present study was that the ability to transfer \( E_{tot} \) effectively to external power seems highly important for DP performance. Secondly, an essential technique change occurred across DP intensities, where the relative contribution from the lower limbs (mostly hip) increased while the trunk seems to obtain a more stabilizing role thereby decreased its relative contribution. The upper limbs relative contribution was stable across intensities. However, the specific roles of the various joints varies individually in how power is absorbed and generated at different intensities. Overall, the present study’s results may help skiers and coaches to understand the different technique strategies involved at different DP intensities and thereby to better interpret and plan training to improve DP performance.

References