**Downhill turn techniques and associated physical characteristics in cross-country skiers**

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**Introduction**

The courses used for cross-country skiing races, consist of uphill, flat and downhill sections distributed across the entire distance. In this context most research to date has focused on performance on uphill and flat terrains, where the most pronounced temporal differentiation between skiers occurs. However, in connection with mass-start and sprint events in particular, valuable positions achieved during downhill turns can decide the outcome. To the best of our knowledge, downhill turns during cross-country skiing have not yet been examined in detail. Accordingly, in this study, kinematic, kinetic and temporal characteristics of downhill turn techniques are described and related to skier strength and power.

**Methods**

Twelve elite female cross-country skiers performed six consecutive turns of standardized geometry as fast as possible. Initially, the typical and predominant turning techniques employed in World Cup competitions in cross-country skiing were identified by observation. Subsequently, an appropriate course involving six consecutive turns of standardized geometry was developed (Fig. 1). Data were collected using a real-time kinematic Global Navigation Satellite System (RTK GNSS), photocells and camcorders. Performance was defined as the time required to complete the course of six turns. The techniques utilized in each turn were identified and relevant mechanical parameters calculated. Peak strength and power were determined in the laboratory.

**Results**

- Snow ploughing, parallel skidding and step turning were utilized for all turns.
- Faster skiers employed less snow ploughing and more step turning, more rapid deceleration and earlier initiation of step turning at higher speed ($P<0.05$).
- Better performance was most strongly correlated to higher velocity ($r=0.99; P<0.05$).
- Better performance was significantly correlated to counter-movement jump characteristics of peak force, time to peak force and rate of force development ($r=0.71/0.78/0.83$; all $P<0.05$).

**Discussion**

This first investigation of downhill turns during cross-country skiing has revealed an initial deceleration phase involving skidding and snow ploughing, followed by acceleration by step turning. The faster skiers used snow ploughing less extensively, performed shorter and more effective periods of skidding for deceleration, and initiated the acceleration by step turning earlier in the turn and at a higher velocity. High maximal leg power was correlated to these abilities, which in combination with good coordination and balance, might have enabled skiers to employ both high speed and short trajectories during turns. Finally, we recommend cross-country skiers to reach a certain level of strength and power and do more downhill training to improve their downhill turning performance.