PUSH-OFF FORCE IN IN-LINE SPEED SKATING: MAGNITUDE, LOCAL DISTRIBUTION UNDER THE FOOT AND POINT OF APPLICATION

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In-line speed skating (ISS) is a rather new competitive discipline. Besides previously shown similarities in kinematics with ice speed skating (1), it remains unclear to date whether dynamics and push-off mechanics of highly skilled athletes in ISS show similar characteristics compared to those obtained in several studies with ice speed skaters (2,3,4). The objective of this study was to assess magnitude, local distribution under the foot and point of application of push-off forces in ISS for several skating speeds.

Six in-line speed skaters of international top level (age: 21,3 ± 3,6 years, weight: 75,7 ± 10,2 kg, height: 181,0 ± 3,9 cm) performed a standardised indoor test of graded speed levels (4,56-8,72 m/s) on a large motor driven treadmill. Magnitude, local distribution under the foot and point of application (COP) of push-off forces were measured for all speeds with a Foot Pressure Distribution System (Novel-Pedar, bipedal, 50 Hz). Force-time histories of sixteen consecutive steps were averaged for each side, normalised in % of BW and analysed for nine different areas of the foot. Additionally, sagital plane kinematics of hip, knee and ankle joint (electrogoniometry) were assessed.

All obtained total force-time histories were similar in shape, showing two peaks with a local minimum in between. One peak occurred at the time of weight transfer and one during the first part of the lateral push-off. Peak magnitudes of total push-off forces were always in between 120-150 %BW and usually occurred during the lateral push-off at about 80 % of stance. In some cases the first force peak at 20 % of stance exceeded the second one and coincided with a moderate increase in knee extension velocity. The second peak of total push-off forces increased significantly ($p<0,05$) with increasing speed and coincided with explosive joint extensions. The highest force values could be localised in three anatomical regions of the foot: middle metatarsal heads (MidM) with values up to 45 %BW and medial and lateral part of the heel (MH, LH) with values around 30 %BW. For all speed levels a similar significant ($p<0,001$) forward and medial shift of the COP with respect to the sole of the foot was present. Starting from a position of about 60 % in width and 30 % in length of the foot the COP moved to a position of approximately 40 % in width and 70 % in length, covering a distance of up to 11 cm in forward and 2 cm in medial direction. For all athletes the Peak total push off force occurred when its point of application was more or less in the middle of the foot.

Elite in-line speed skaters show specific dynamics and push-off mechanics. Our data show that during ground contact the COP is kept on a straight line (heel to MidM) directly above the position of the skating frame and wheels, with maximum local push off forces occurring at the endpoints where the frame is mounted. This and the fact that Peak total push-off force is applied when its point of application is in the middle of the foot indicate that the athletes try to realise an optimal force transfer between foot, frame and wheels. During gliding and push-off the COP is continuously moving forward and slightly inward along the frame. This forward shift as well as shape and magnitude of the measured total push-off forces are in agreement with data found in previous studies with competitive ice speed skaters (2,3) indicating that the centre of mass is shifted forward during the stride. Besides these similarities, inline speed skaters use the push-off force as a main factor for speed regulation. Some athletes even apply some extra force on the frame during the first part of the gliding phase inducing a second "push" on the outside edge of the wheels to the medial body side. This so called double-push technique (5) may represent a wheel-specific variation of the traditional gliding technique.

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