DOUBLE-PUSH SKATING AND KLAP-SKATE IN CROSS COUNTRY SKIING, TECHNICAL DEVELOPMENTS FOR THE FUTURE?

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Two technical developments in XC-skiing, the klap-system and the double-push (DPU), were developed in the last years. Kinematic, kinetic and electromyographic measurements at maximal speed using the one-skate were performed to compare these developments towards the conventional technique or material. In both, DPU and klap-system, athletes were able to complete a 50m measurement track faster (up to 0.40 sec). DPU was characterized by higher muscle activity, higher angular velocities, and higher lateral foot forces especially in gliding phase. With the klap-system higher peak foot forces (up to 300N), higher lateral foot forces (more than 100%), and a more lateral course of the center of pressure over the whole push-off occurred. The main advantages of the DPU can be seen in the additional second push-off instead of passive gliding, and the in direct line of the forward movement set ski for the first push-off. The possibility to use a totally stiff boot with the klap system leads to less loss of force and energy, and a better distributed force applicationg during push-off.

KEY WORDS: EMG, kinematics, kinetics, sprint, maximal speed

INTRODUCTION: Sprint competitions in cross-country (XC) skiing were first established in the 90s. With sprint events becoming more popular different approaches in the field of special sprint training, testing, and skiing technique are beginning to emerge. With the higher running speeds during a sprint race (up to 10m/s in average) new developments in skiing technique and skiing material have partly emerged. Holmberg et al. (2005) was first to show up a so called “sprinter like” double poling technique which was characterized by higher maximal velocities, higher peak pole forces and a shift to shorter time of high activation and longer time for recovery.

To increase skiing speed in the XC skiing skating technique the idea was to transfer a technique of inline-speedskating, the so called “double push technique” (DPU), into XC skiing. The DPU was introduced at inline-racing by Chad Hedrick in 1993. He dominated the international racing scene for several years, and led in a new area in the inline speedskating technique. At present almost all top male skaters use the DPU (Publow, 1999). Roughly described, the DPU involves two pushes instead of one. Instead of the normally static glide period in the conventional technique, the foot, angled on the outside wheel edge, is pulled actively inward toward the body in this phase. The pending second push is in much the same manner as with the conventional technique. In XC skiing the problem occurred that the gliding direction of a ski on snow is, compared to inlineskating, hardly changeable. Hence, the transfer from the first push, where the ski is set slightly inward, to the second push, where the ski has to be set in outward direction, has to be done by a jump in order to position the ski in the right direction.

An invention in ice-speedskating, dating already from the 19th century, was the klap- or slapskate which revolutionized ice speedskating. The potential was soon extinguished as both men and women repeatedly shattered world records during the mid of the 90s (Publow, 1999). Additionally, studies have shown the significant advantage of the klapskate towards the conventional skate (e.g. Ingen Schenau, 1996; Houdijk, 2000). Several trials to use this system in XC skiing have failed in the past years, but in the skiing season 2005/06 a clap skate (FINN, Stadskanaal, Netherlands) was firstly successful introduced in the sprint world cup. The clap system consists of a totally stiff carbon or plastic boot, as used in ice- or inlineskating, and the clap mechanism produced by Finn.

The specific aims of the present study were to compare (a) the DPU with the traditional sprint skating technique, and (b) the klap-system towards conventional boots used in XC skiing.

Kinematic, kinetic and electromyographic measurements were applied to show up differences and possible advantages of the new technical developments.

METHODS: Three national elite XC skiers (members of the Austrian national and student national team), (age 28-37 yrs, weight 80-85 kg) volunteered as subjects in the study. All the skiers were familiar with the techniques and systems used in the study. Testing was done on snow on a freshly groomed flat straight skating track of 100m. Skiing time was measured over the last 50m of the measurement track via two photo sensors (Brower Timing Systems).
All subjects used carbon-fibre racing poles (EXEL). The right hand pole was specially constructed for force measurements and adjustable in length from 160 to 172 cm enabling the athletes to adjust it to their individual pole length (91 ± 0.5% of body height). The ground reaction force, directed along the pole was sampled by a strain gauge force transducer installed in a light weight aluminium body, both mounted directly below the pole grip. Vertical plantar ground reaction forces were recorded by the Pedar mobile system (Novel) at 100 Hz, consisting of two pressure distribution insoles. The total foot area was divided into fore foot, rear foot, medial and lateral part of the foot. Course of the centre of pressure (COP) was calculated during push-off. From the foot force data, cycle characteristics, impulse of force and peak force were determined for the total foot, lateral part and medial part of the foot. Angular displacement was recorded from the ankle, knee, and hip by means of goniometers. Surface electromyographic (EMG) activity was measured for nine lower body muscles. The raw analogue signals were converted to digital and stored on one pocket PC. Integrated EMG (IEMG), EMG root mean square (RMS), and median power frequency (MPV) of each muscle was calculated. All data, except for foot forces, were measured at a sampling rate of 2000 Hz.
Three trials in each technique (including klap-system) were randomly distributed for each athlete. Athletes were asked to run at maximal speed and use only the one-skate technique in each trial. Five successive cycles during the 50m measurement zone of each trial were used for data analysis. Pole forces, EMG and joint angles were measured only for the left body side, thus the major part of the results is restricted to the analysis of the left foot push-off. The push-off was divided into three sections. The first section (P_1) represents the gliding phase (except in DPU) starting with the set down of the left foot, leading to a first peak in the force curve, and ends when the knee is maximally extended and/or the skies leave ground contact during DPU. In DPU a flight phase follows where the skies are repositioned and set down again. Regarding conventional technique only an unloading of the foot occures with no change of the direction of the ski. The second section (P_2) represents the real push-off which is in both techniques alike. P_2 starts with pole plant and ends when foot force gets zero, and knee, hip and ankle joint is maximally extended. All data processing and analysis were performed using IKE-Master (IKE Software Solutions, Salzburg, Austria). The results are presented as means and ranges (min-max) over all trials and athletes.

RESULTS:
DPU vs. conventional sprint technique :
Compared to the conventional sprint technique the DPU was 0.20 - 0.41 s (3.0 - 5.5%) faster over the 50m measurement section. Peak foot force using DPU was 8.9 –27.5% higher in P_1 and around 5% lower in P_2. Regaring the whole cycle, impulse of total foot force was around 3.4% lower whereas lateral foot force was 9.3 % higher in DPU. Especially in P_1 the loading of the lateral part of the foot was around 18.4% higher in DPU (Fig. 1). A comparable pattern can be seen in the course of COP during P_1. The maximal value was 16.5% (11.3-21.5%), and the mean value during P_1 8% further towards the lateral edge of the foot during DPU (Fig. 2). Regarding EMG values, muscle activity was higher in all measured muscles during P_1. Especially the muscles adductor longus and gastrocnemius lateralis had much higher IEMG and RMS values during DPU (40-92% higher). The difference in MPF was much lower (0-17% higher). Angular velocity during extension in P_1 (min value to max value at end of P_1) was higher in all measured joints for DPU. Angular extension velocity was 114%, 37%, and 25% higher in the ankle, knee and hip joint, respectively. Flexion velocity in P_2 (from set

down to min) was 31% higher in the DPU trials. No remarkable differences in the pole force variables were found.

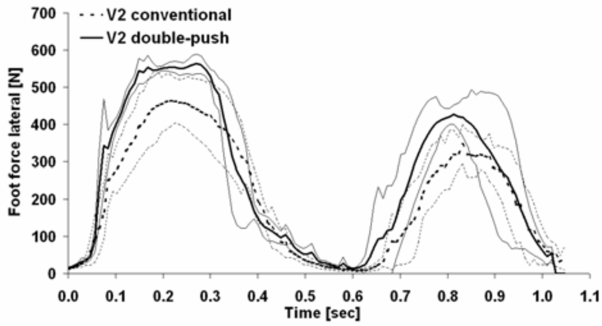

Figure 1: Representative time course of lateral foot force of DPU (bold line) and conventional (dashed line) one-skate technique. Time courses are mean ± SD.

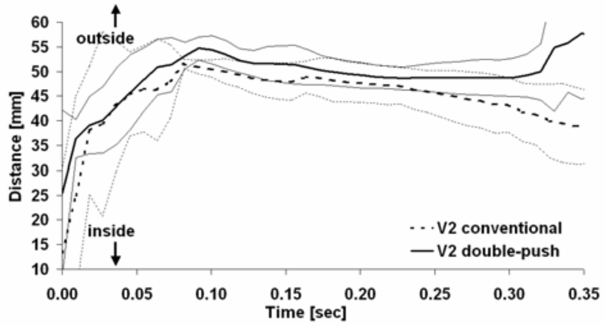

Figure 2: Course of the center of pressure (outside-inside) during P1 (gliding phase in conventional technique, and first active push in DPU) for the left foot using one-skate technique. Time courses are mean ± SD.

Klap-sytem vs. conventional sprint technique :

The klap-system was 0.1-0.32 s (1-4%) faster over the 50m measurement section. Peak foot force was around 10% (7-13%, up to 300 N) higher when using the klap-system. Impulse of total foot force (Fig. 3), and lateral foot force (Fig. 4) was 16% and 64 % higher, respectively, for the klap-system. Regarding the course of COP (Fig. 5), the maximum in P1 and P2 was 2% and 16.5% higher, respectively, when using the klap-system. The mean value over the whole P1 and P2 was 8 – 24% further to the outside edge. EMG values of gastrocnemius (lateralis and medialis) were lower (9-28% lower) during P1 and higher (6-31%) during P2, regarding IEMG and RMS. Maximal values were higher for the ankle (5.6%) and knee joint (3%) with the klap system. Peak pole force and impulse of pole force was around 6% lower for the klap-system trials.

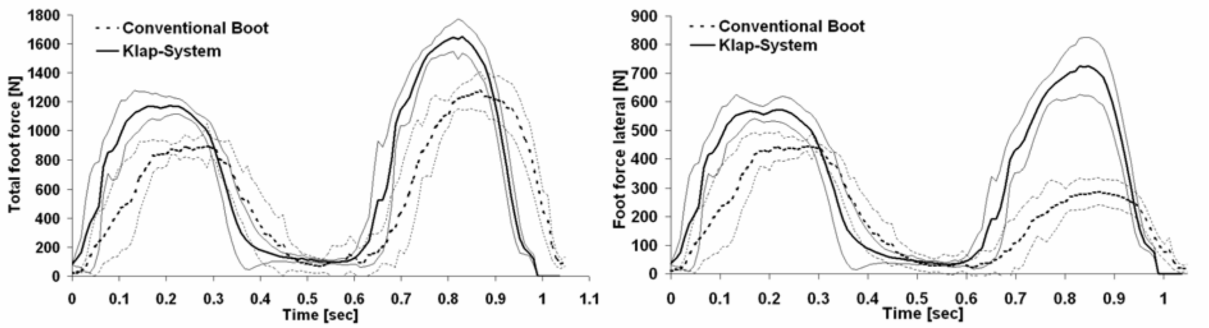

Figure 3 & 4: Representative time courses of total- and lateral foot force comparing double push (bold line) vs. conventional (dashed line) one-skate technique. Time courses are mean ± SD.

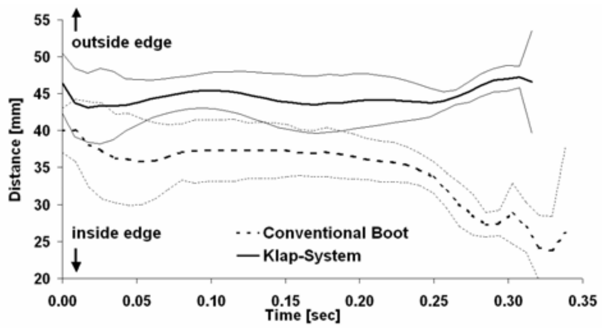

Figure 5: Course of the center of pressure (outside-inside) during push-off-phase (P2) for the left foot using one-skate technique.

DISCUSSION: Especially for the sprint discipline, the most important variable to show up if a new technical development might be an improvement is maximal running speed. Both technical developments, klap-system and DPU, showed faster running times over the 50m compared to the conventional technique and material. However, due to the amount of subjects we can speak here just of tendencies. The reason for the faster running speed when

using DPU might be explained by three aspects: (a) the set-down of the ski at the beginning of P_1 is placed straight or even slighly inward angled to the forward direction, compared to outside angled skies in the conventional technique. Hence, the ski is moving in direct line of the forward movement; (b) In addition to the more optimal ski angle in P_1, an additional propulsion was produced instead of just a gliding phase in the conventional technique. This can be seen by the higher lateral foot forces, the more lateral course of the COP, with a distinct increase to the end of P_1, the faster extension velocities towards the end of P_1, and the higher muscle activity of adductor longus and gastrocnemius lateralis; (c) Owing to the flight phase for repositioning the ski, faster flexion velocities to the joint minimas in P_2 occurre. This might lead to a higher pre-activation and occurrence of a more distinct stretch shortening cylce during P_2. Although the DPU is faster, that technique should be further investigated on running economy. Due to the higher muscle activation in P_1 and the more explosive form of movement, the use of the DPU might lead to faster fatigue.
Concerning the klap-system the main advantages are: (a) the possibility to use a totally stiff boot (mostly carbon), comparable with ice- or inline speedskating, (b) the higher freedom in movement in the ankle joint due to the lower boots, and (c) less activation of lower leg muscles, as seen in the lower activation of gastrocnemius. Compared to a conventional XC-skiing boot athletes were able to produce push-off forces up to 300N higher with the klap-system. Additionally, the foot forces were more equal distributed over the total push-off. This can clearly be seen by the much higher loading of the lateral part of the foot, and the more stable and more lateral course of the COP. Thus, during push-off no force and energy is lost due to movements and twisting of the shoe, as occurres with conventional boots.

CONCLUSION: Both technical developments have led to an increase in maximal running velocity, and both aspects have already shown their efficiency in other sports. However, due to the higher demanding technique, the DPU might be restricted to start and finishing spurts in sprint events. Additionally, new aspects in training should be considered with this new technique. The klap-system shows many advantages, that might lead in a new technical revolution in XC-skiing. Although it should be further developed to make it easier applicable.

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