A DIRECT MEASURING METHOD FOR THE DETERMINATION OF THE EDGING ANGLE AND THE GROUND REACTION FORCE IN ALPINE SKIING

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The purpose of this study was to clarify the advantages and disadvantages of a combined dynamic and body mounted kinematical measurement system in alpine skiing. A high profile former world cup athlete of the German national team performed a test-run equipped with a bilateral insole and an inertial measurement system. In particular the edging angle and the ground reaction force were of interest. The measured values were comparable to previous findings. The main benefit can be seen in the application in the training process for an enhanced objectified technique training. The weight and the mechanical characteristics of the measuring system may slightly affect an athlete adversely.

KEY WORDS: alpine skiing, technique training, inertial measurement system

INTRODUCTION: Besides dynamic measurements the analysis of the skiing techniques in alpine skiing is mainly limited to the use of optical kinematical methods (Babiel et al., 1997; Müller, 1986; Raschner et al., 1996; Spitzenpfeil et al., 2005). Disadvantages of these methods (at infrared-, ultrasound- and video basis) can be seen in the practicability in the training process and the expenditure of time and equipment (Mayagoitia et al., 2002; Witte et al., 2004). Hence, an application of these methods in the training process is not common. In contrast, the use of body-mounted kinematical systems enables the measuring of biomechanical parameters almost without a limitation of the site. Additionally body-mounted systems require often less equipment compared to the optical methods. Due to the weight and the mechanical characteristics such systems tend to affect the athlete adversely. However, in the skiing training process the use of body-mounted systems is mainly limited to the use of goniometers for the determination of the knee angle and dynamic measurements.

The aim of the study is the combined use of a dynamic and a body-mounted kinematical measuring system for the analysis of the skiing technique in the training process. In particular the skis edging angle and the ground reaction force are of interest. A combined measuring of the edging angle and the ground reaction force for complete training runs would have a great benefit for trainers and athletes. By means of a pilot measurement of a carving test-run the advantages and disadvantages will be illustrated.

METHOD:

Research Design: The investigation was carried out at the “Rettenbach” glacier in Soelden, Austria. A high profile former world cup athlete of the German national team performed a test-run with the carving skiing technique on a well prepared slope. The inclination for the upper part of the slope was approx. 26°. At the end of the run the slope had an inclination of approx. 11°. The distance between the starting and the end point of the giant slalom run was approx. 390 m. The snow conditions were icy and hard particular for the upper part of the slope.

Data Collection: Pressure distribution on the plantar surface was measured by the use of the bilateral insole measurement system “Parotec” (Paromed, Germany) with a frequency of 150 Hz. Each insole included 24 sensors and was inserted in the athlete’s ski boot. Additionally the system includes two amplifiers, one data logger unit and a power supply.

Due to the incomplete covering of the boot sole by the sensors and the deflection of forces over the leg of the ski boot a systematic error occurs. The maximum error of measurement can be specified by approx. 20% (Spitzenpfeil et al., 2005). Hence, an analysis of the acting ground reaction force seems to be practicable comparatively only.
The kinematical parameter edging angle was measured by the use of an inertial measurement system (Xsens, Netherlands). The system consists of 2 sensor units, a transmission unit, a data logger and a power supply. Both sensor units include gyroscopes, accelerometer and magnet field sensors and were mounted directly behind the safety binding of the skis. The recording frequency was 50 Hz. The root mean square of the measurement error concerning the accuracy of the sensor unit's orientation is approx. 3° (Xsens, 2004).
Data loggers and power supplies of both systems were stored during the test-run in a waist belt worn by the athlete. The weight of the complete measurement system was in total approx. 1,4 kg. The adverse effects to the athlete caused by the measurement systems were almost negligible referring to the athlete. Data synchronization of the dynamic and the kinematical system was established by a distinctive movement of the athlete. The test-run was additionally filmed.

Data Analysis: Ground reaction forces were calculated from the pressure distribution data. In the following the force data were filtered by use of a 10 Hz low pass filter (Butterworth). The edging angle is defined as the angle between the ski and the horizontal of the earth fixed coordinate system. Positive values of the edging angle illustrate a clockwise rotation around the longitudinal axis of the ski and therefore a right turn. The measured edging angle data were interpolated to a frequency of 150 Hz.

RESULTS AND DISCUSSION: The edging angles of both skis for the carving turn run are shown in figure 1.

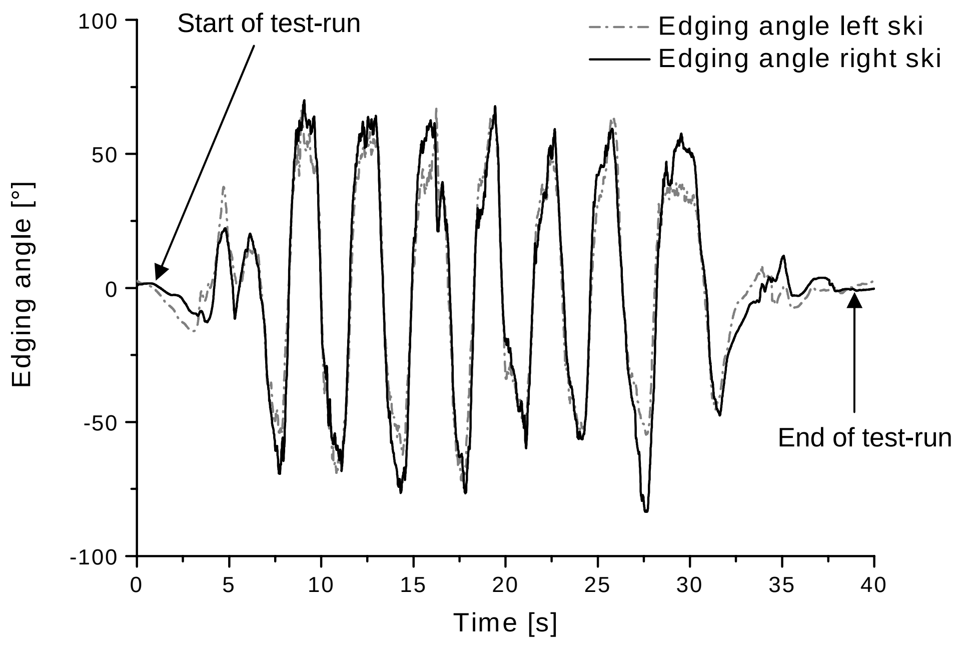

Figure 1: Edging angle of the left and the right ski for the carving turn run

For the carving turn run edging angles between 55°-75° were measured except the last left turn, where the edging angle of the right ski shows a maximum of -83°. No higher values of the outer ski compared to the values of the inner ski could be found. These findings correspond to previous surveys. RASCHNER et al. (2001) found maximum values between

65°-70° and almost identical edging angles of the inner and the outer ski regarding two turns of the carving technique. The differences between the left and the right ski in particular in the first half of the test-run and the last turns need to be closer analysed. To verify the accuracy of the measuring system under the conditions in alpine skiing, a simultaneous use of an optical kinematical system will be strived for. Beside negligible interferences the curve progression can be considered as harmonic. These interferences are caused by occurring vibrations at the ski (Niessen et al., 1996). A decrease of the maximum values is observable from approx. 18 s of the test-run. A reason for that might be the reduction of the slope inclination. Figure 2 shows therefore the edging angle and the ground reaction forces of a left-right-carving turn combination for the upper (slope inclination approx. 21°) and the lower (slope inclination approx. 13°) part of the slope of the same test-run. The skied speed and the distances between the poles and therefore the radius of the left-right turn combinations were almost identical.

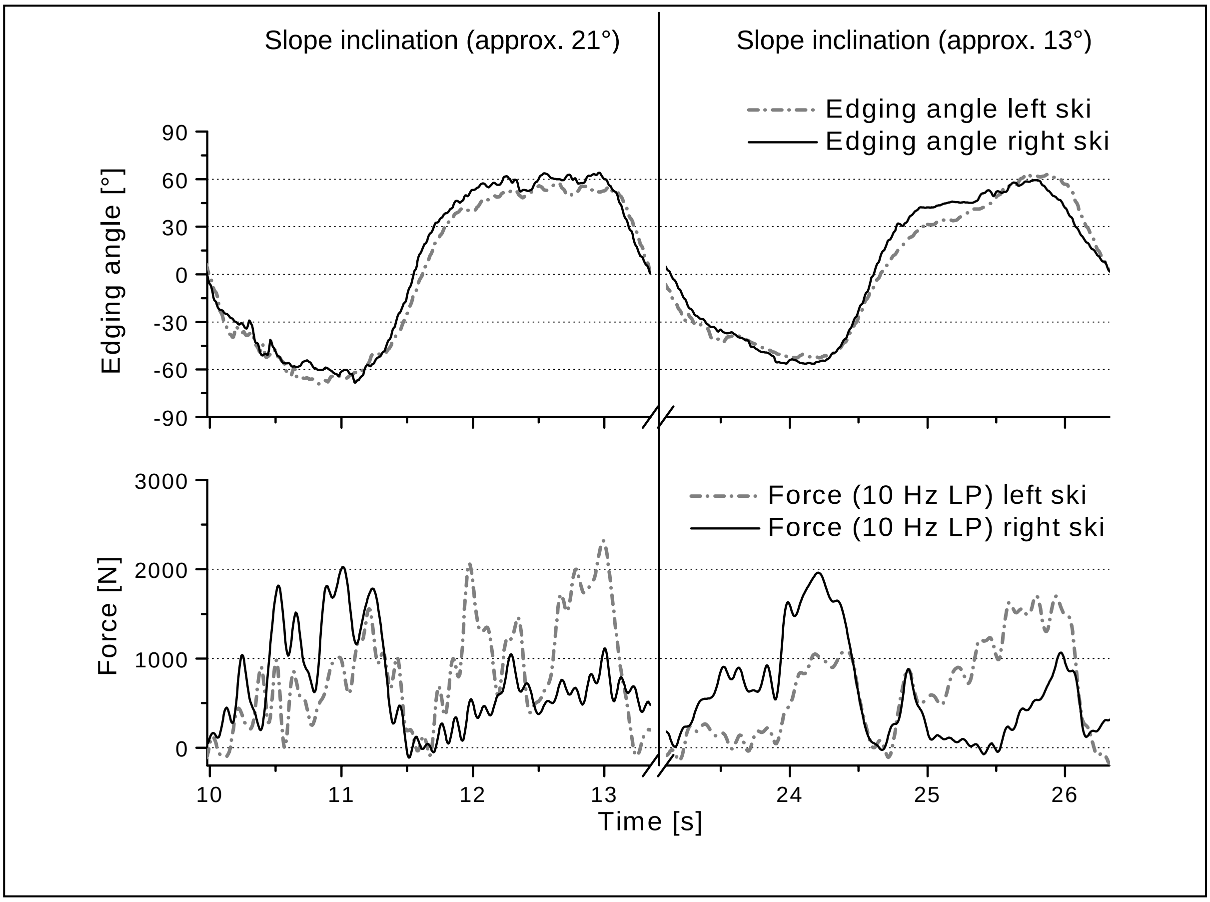

Figure 2: Edging angle and ground reaction force of the left and the right ski for different slope inclinations

The edging angles of the right ski of the left-right turn for the upper part of the slope are -68° and 64° respectively. For the lower part reduced edging angles of -56° and 63° respectively can be found. Acting ground reaction forces show similar characteristic. Measured forces of the outer ski for the upper slope part are between 2000 N and 2300 N. Due to the error of measurement it is important to notice that the force values are approximated values. Decreased forces between 1700 N and 1950 N can be found for the less inclined part of the slope. This corresponds to the findings of MUELLER (1986), who measured higher ground reaction forces on steep and icy slopes. Furthermore, differences concerning the inner ski load can be observed. The inner ski is less loaded at the reduced slope inclination compared to the steeper slope part, especially in the first part of the steering phase of the turn.

Associated with the increase of the edging angle to the maximum value an increase of the force from 50 N to 1050 N can be measured in the second part of the steering phase.

CONCLUSION: This study illustrated the combined use of a dynamic and a body-mounted measurement system for the analysis of the skiing technique in alpine skiing. The advantage of the method can be seen in the application in the technique training process due to the direct measurement of the edging angle and the ground reaction force without a limitation of the site. Additionally the data analysis is not time-consuming. The values of the measured parameters correspond to previous findings. Although the weight and the mechanical characteristics were negligible to the athlete, the effects may influence the athlete adversely.

The combined use of the described measurement systems in the technique training is therefore considered as useful. Due to an application in the technique training the system could be used to provide the trainer and athlete useful parameters. Hence, the analysis of the skiing technique in the training process could be further objectified.

REFERENCES:

Babiel, S., Hartmann, U., Spitzenpfeil, P. & Mester, J. (1997). Ground-reaction forces in alpine skiing, crosscountry skiing and ski jumping. In Müller, E., Schwameder, H., Kornexl, E. & Raschner, C. (Eds.) *Science and Skiing* (pp. 200-207). London: E & FN Spon.

Mayagoitia, R.E., Nene, A.V. & Veltink, P.H. (2002). Accelerometer and rate gyroscope measurement of kinematics: an inexpensive alternative to optical motion analysis systems. *Journal of Biomechanics,* 35, 537-542.

Müller, E. (1986). *Biomechanische Analyse alpiner Schilauftechniken – Moderne alpine Schilauftechniken in unterschiedlichen Schnee-, Gelände- und Pistensituationen*. Innsbruck: Innverlag.

Raschner, C., Müller, E. & Schwameder, H. (1996). Kinematische und dynamische Technikanalyse im Slalom- Vergleich ausgewählter Parameter zwischen Spitzen- und Nachwuchsrennläufern. In Müller, E. & Schwameder, H. (Eds.) *Aspekte der Sportwissenschaft* (pp. 211-221). Salzburg: Universitaet Salzburg.

Raschner, C., Schiefermüller, C., Zallinger, G., Hofer, E., Müller, E. & Brunner, F. (2001). Carving turns versus traditional parallel turns – a comparative biomechanical analysis. In Müller, E., Schwameder, H., Kornexl, E. & Raschner, C. (Eds.) *Science and Skiing II* (pp. 203-217). Hamburg: Kovac.

Spitzenpfeil, P. Hartmann, U. & Ebert, C. (2005). Techniktraining im alpinen Skirennlauf – Der Einsatz von Druckmesssohlen zur Objektivierung der Technikanalyse. In Krug, J. & Minow, H.-J. (Eds.) *Messplatztraining* Band 2 (pp. 193-198). Sankt Augustin: Academia.

Witte, K.; Edelmann-Nusser, J. & Campe, S. (2004). Movement analysis systems and their applicability to karate techniques. 9th Annual Congress of the European College of Sport Science, Clermont-Ferrand, 03-06 July 2004.

Xsens (2004). *Motion Tracker Technical Documentation*. Enschede.