NEW ADVANCES IN RACING SLALOM TECHNIQUE

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NOVA NAPREDOVANJA V TEKMOVALNI SLALOMSKI TEHNIKI

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Abstract

In the past years, the radical changes in the shape and materials of the slalom skis affected the skiing technique. This area is the subject of intensive investigations. Our previous work in measurement of kinematic and dynamic parameters in the alpine skiing initiated new advances in slalom racing technique. The changes are so significant that we propose the new racing technique. In this study we present several biomechanical advantages of the new technique according to the current one. Substantial dynamic analyses have been performed and have been proven with the Kolmogorov-Smirnov statistical tests. Up to now, all performed measurements, even with the elite ski racers, show the superiority of the proposed technique.

Keywords: alpine skiing, slalom, technique, dynamics, measurement

Izvleček

V zadnjih letih se je zelo močno spremenila geometrija slalomskih tekmovalnih smuči. Naglemu razvoju mora slediti tudi tehnika, ki mora čimbolj izkoristiti novo opremo. Predhodne meritve kinematičnih in dinamičnih parametrov pri alpskem smučanju ter študij tekmovalne tehnike so nas privedli do novih izboljšav tekmovalne slalom tehnike. Spremembe so tako značilne, da predlagamo novo tekmovalno tehniko. Opravljena je bila izdatna analiza dinamike, ki so jo potrdili tudi Kolmogorov-Smirnov statistični testi. Vse meritve do sedaj, tudi tiste z vrhunskimi tekmovalci, so se izšle v prid nove tehnike.

Ključne besede: alpsko smučanje, slalom, tehnika, dinamika, meritve

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INTRODUCTION

Many changes in the shape and materials of the alpine skis have happened in the last few years. That is why skiing technique is also under radical changes. Especially in racing new improvements in equipment and technique contribute to better results. These are the reasons for several biomechanical studies that have been introduced in skiing. For example mathematical modeling have been used for better understandings of the skiing techniques and proposing new, more efficient techniques (Renshaw, & Mote, 1989; Hirano, & Tada, 1994; Hirano, 1996). On the other hand optimum controlling procedures were used for minimization of the total time needed (Maronski, 1990) and for maximization of the speed (Hertzen, Hollund, & Ranta, 1997) in the downhill racing. Also, variation calculus was used to obtain optimum trajectories in giant slalom (Supej, & Kugovnik, 2000). Several research groups measured and analysed different kinematical parameters that also help to improve the skiing technique (Kugovnik, Nemec, Pogačar, & Čoh, 2000; Pozzo, Canclini, Cotelli, Martinelli, & Roeckmann, 2001; Supej, Kugovnik, Nemec, & Šmitek, 2001; Seifriz, & Mester, 2001). According to new carving skis and consecutively different turn trajectories many dynamic analyses of forces and vibrations have been performed (Kugovnik, Nemec, Pogačar, & Čoh, 2000; Kugovnik, Nemec, & Supej, 2000; Nemec, Kugovnik, & Supej, 2001; Tscharner, & Schwameder, 2001).

However, the most radical changes in the men's world cup races have happened in slalom skis. Racers started to use skis from 155 to 170 cm long instead of over 190 cm in the last two years. New skis are significantly different also in the side cut and radius, which was decreased from approximately 35m to 11m. Such change results in the evolution of the racing technique (Supej, Kugovnik, Nemec, & Šmitek, 2001). The main goal of our work is to propose new advances in slalom technique. Due to the significant changes compared to the current technique we decided to call the proposed technique »new technique«.

METHODS

Sample

We took under the investigation the current and the new proposed slalom racing technique. In the current race technique, there is evident double up and down body motion during the ski turn. Consequently, this results in very high ground reaction forces just under the ski gate. Because of the double body motion, the ground reaction forces are the sum of the radial, gravitational and on-weighting forces. Additionally, double motion results also in non-optimal motion of the skier mass centre. Detailed analyses of the current technique can be found in (Supej, Kugovnik, Nemec, & Šmitek, 2001). In order to overcome mentioned problems, we propose a new slalom technique. The key points of the new technique are:

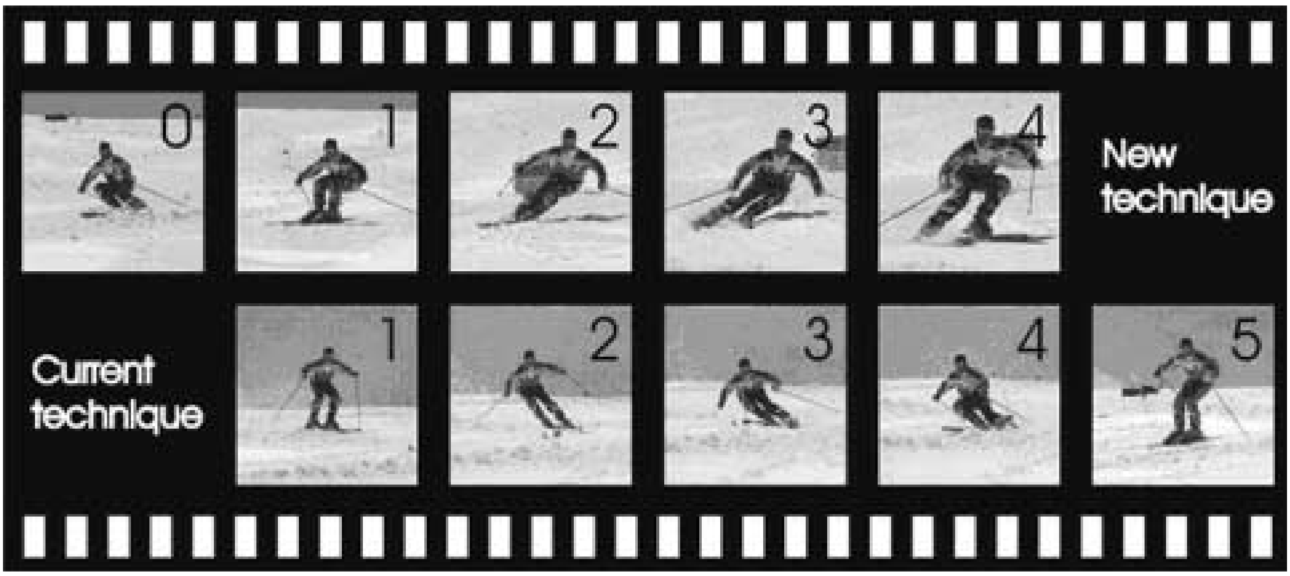

Fig. 1: The pictures on the »film« represents one turn in the new technique (top) and one turn in the current technique (bottom).

- there is no double up-down body motion during the ski turn. The skier is in the most bent position at the time of the weight change. This is the beginning of the new turn. The upright position is around the ski gate.
- The resulting skier mass center trajectory is shorter with the new technique.
- The radial, gravitational and on-weighting forces do not reach the maximum values at the same time in the same direction. This results in decreased ground reaction forces.

The comparison between new and current technique is shown in the Fig 1.

A high-skilled ski instructor, member of the national demonstration ski team (Ski Demo Team Slovenia) and former ski racer, performed 18 slalom runs. In the first 10 runs the gates were placed with the absolute distance d_S=13m between each other and rapt by d_r=4m (Fig. 2). For the other 8 runs the gates were placed with the absolute distance d_S=11m between each other and rapt by d_r=2.5m. The skier alternately used once the current and once the new technique. Both setting-ups were placed on the well-prepared ski slope (18.5° at the beginning and ending with 13°). There were 14 gates for the each setup. The first and the last ski turn were excluded from the analyses. The snow was in the first runs hard, but due to the high temperature conditions (+6°C) it was slowly getting wet. The skier was using race extreme carving skies (Head Cyber XTi, 160cm) with 11m radius that suits FIS (International Ski Federation) requirements. The weather was sunny and the visibility was excellent.

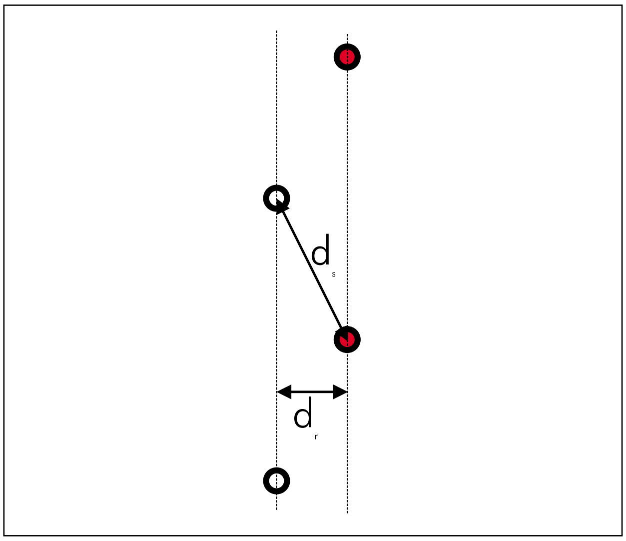

Fig. 2: The schematic shows the absolute distance between neighboring gates ds and the rapture dr between the gates.

Measuring device

The forces during the runs were measured with four strain-gauge sensors with 50 measurements per second on each ski build in ski boots and synchronized with a mini DV digital camcorder. Detailed description of the device is presented in the article (Kugovnik, Nemec, Pogačar, & Čoh, 2000).

Data analysis

For analysing the performance of the skier runs we used the AviComp 3.0 program and for analysing the recorded data combined with the video signal XSki 1.0 (Fig. 3).
The forces measured during each run were analyzed with histograms, where the measuring area from 0N to 4000N was divided into 100 intervals. The norm of histograms was set to 100 and the data was smoothed by Butterworth digital filter subroutine in Matlab 6.0. The effect of the filtering is shown in Fig. 4.
The Kolmogorov-Smirnov statistical test is used for zero hypotheses whether certain two histograms belong to the same statistical population. All combinations of each population and between the populations were made. Two histogram regions were especially considered. The first region from 0N to 120N determines the low contact forces between the skis and the snow. According to this, we introduce a new parameter p_C, which describes the portion of the ski turn in percentage that was performed with the low contact forces. The second region with forces over 2000N determines undesired forces that contribute to the dissipation of the kinetic energy. Additionally, the mean histogram values in each population were smoothed with Butterworth digital filter for easier analyses.

RESULTS

From 18 runs we made four different populations of results. Two runs from the first population were excluded due to bad skier performance. That is why we have two populations of four runs for the current technique and two populations of four runs for the new technique. The associated histograms and the filtered mean values to these four populations are presented in Fig. 5.
Statistical significance (5%) has been proven with the Kolmogorov-Smirnov test. When we tested whether the samples in one population are the same (combination of tests), the tests were positi-

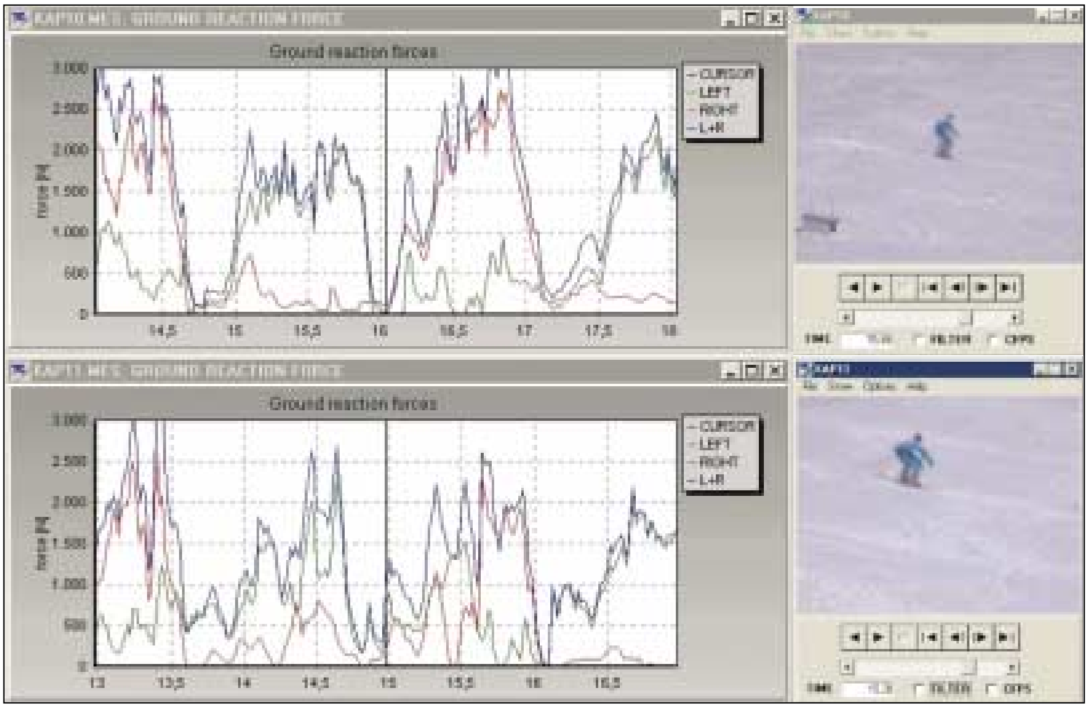

Fig. 3: Analyzing the current (top) and the new (bottom) slalom ski technique with XSki 1.0. The diagrams shows the forces during the runs for the left ski, right ski and the sum. Both pictures on the right side present the skier during the weight change (marked with the black line in the middle of the diagrams) once with the current (top) and once with the new technique.

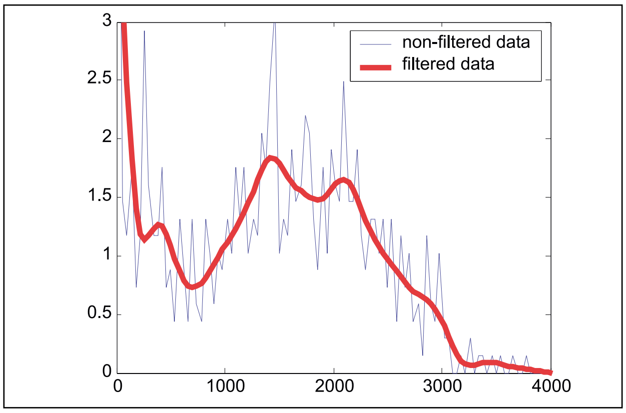

Fig. 4: Histogram of the skier first run using the current slalom technique. The curves show non-filtered data and smoothed data with Butterworth digital filter.

ve in 5 of 6 in both first populations and 6 of 6 in both second populations. When we tested the inequality between the first two populations, the tests were positive in 10 of 16 and between the second two populations in 11 of 16.

The determination of the poor snow contact brought the following results. On the first gate combination the factor pc was 8.8% in average with the current technique and only 0.5% with the new technique. On the second gate combination factor was 14.5% and 2% respectively.

From Fig. 5 it can be seen that the force distribution is different in the new technique compared to the current one. Detailed analysis of undesirable forces over 2000N shows that the density of these forces is greater with the current technique. The average value with the current technique in the first and second gate combination exceeds the new technique for 20% and 35% respectively.

DISCUSSION

From the measurement of the ground reaction forces we can notice that the average force does not change with the new technique. However, we have statistically proven that the force distribution is significantly different.

From Fig. 3 different force distribution in one turn can be noticed. With the new technique, the skier compensates the radial and gravitational forces with the down body un-weighting motion (see ground reaction force graph between 14.7 and 15 sec of the ski run performed with the new technique).

The force distribution is even more evident from the force histograms (Fig. 5). The ratio p_C is 17 and 7 times greater with the current technique for the first and the second gate combination respectively. Please note that large p_C factor denotes poor contact between the skis and the snow. This reduces steering ability of the skier. However, very high forces in the ski turn usually mean increased dissipation of the kinetic energy and increased friction. Therefore, the portion of the very high forces during the ski turn should be as small as possible. Also

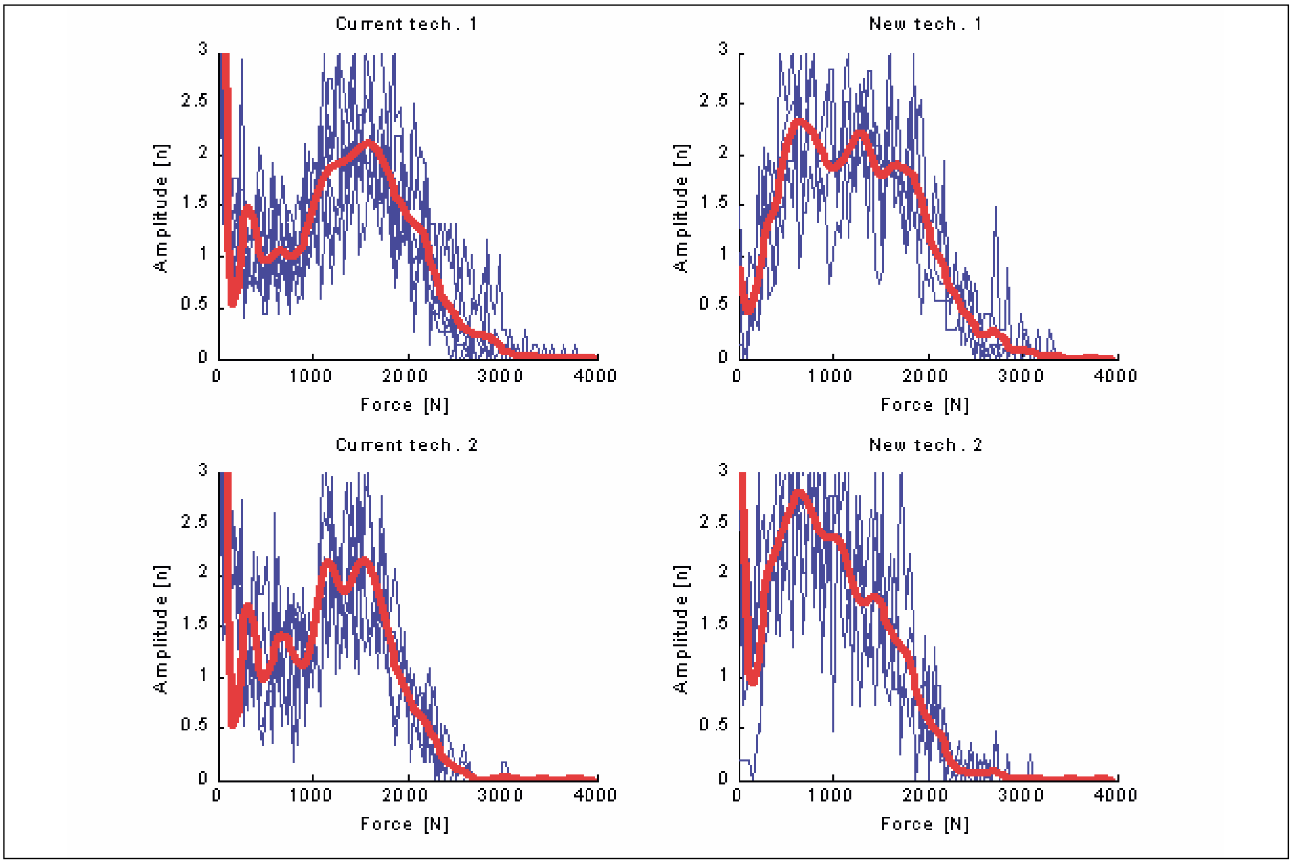

Fig. 5: Each of the diagrams presents four of the non-filtered histograms and the filtered mean value drawn with bold line. Both left diagrams show the populations of the current technique and the right two show the new one. One of the diagrams in each pair belongs to the first gate combination and the other one to the second gate combination.

in this parameter we can see the benefit of the new technique. The average value of the high force with the current technique in the first and second gate combination exceeds the new technique for 20% and 35% respectively.

Although the total time of the ski runs were not under the investigations, we obtained a 0.2 to 0.4 sec shorter time in average on ski runs of 12 sec. Encouraged with these results we performed tests with elite ski racers, where we obtained significantly shorter total times with the new technique.

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