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3-D KINEMATICS OF DOUBLE POLING IN CLASSICAL TECHINIQUE OF ELITE CROSS-COUNTRY SKIERS ENGAGED IN WORLD CHAMPIONSHIPS RACES (1999-2003).

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INTRODUCTION

In the recent years the skating technique have received more attention from skiers, coaches, and researcher, to improve the racers performance, than the "old" classical technique. However the changes in the equipments, sometimes directly transferred from the skating technique, in the track and in the physiological aspects of the training determined great changes (CCS) also in classical technique.

In both techniques the changes were in the average velocity (Vave), cycle time (CT) and cycle length (CL) and in some other parameters. For example the elite skiers nowadays use the Double Poling (DP) or V2 skating also in moderate uphill, in spite of the Diagonal Stride (DS) or V1 skating. Furthermore the DP and V2 have a lot of resemblance and the skiers have developed their capacity to poling for larger sections, with high frequency and with greater power.

Despite the performances in elite skiers are extremely close to each other, and it not easy to understand which parameters influencing the final result of a world championships competition, we are convinced that the double poling phase, that are performed hundredths times in each race, should to received the maximal attention. Furthermore the performance are determined also by the positioning of the trunk, the shoulders, the elbows and the poles (G. Smith 1996) in the propulsive poling phase. The aim of this study was to investigate the positioning of the upper-body limbs during the poling phase in classical techniques.

METHODS

The data collection was performed on 1999, WC in Ramsau, and on 2003, WC in Val di Fiemme, during various men's CCS competition. A couples of digital camcorders (SONY 50 Hz) were located, in each races, on flat section (40 meters long). Due to the technical choice, in according with the national ski team coaches, the considered flat terrain section was located after a moderate uphill.

A dedicated software for video analysis, with free panning, tilting and zooming TV cameras was used (Baroni et al., 1998) to cover a wide working volume in according to the technical requirement. Calibration was performed by means DLT method (Aziz, Karara 1971). The maximal error was lower than 2% for coordinates and about 5% for derivated parameters. The control points for system calibration were marked out with 30-50 high rigid poles. The biomechanical model of the skier consisted of 23 landmarks, 4 of this points were used for the poles and for the skis identification. Coordinates of centre of gravity (CoG) were calculated with the algorythm of Gubitz (1978). Joint angles were calculated as the absolute angles between different anatomical landmarks; the displacements of the body's centre of mass (CG) were quantified on the average plane of track (horizontal plane) and on the orthogonal direction to this plane (vertical direction).

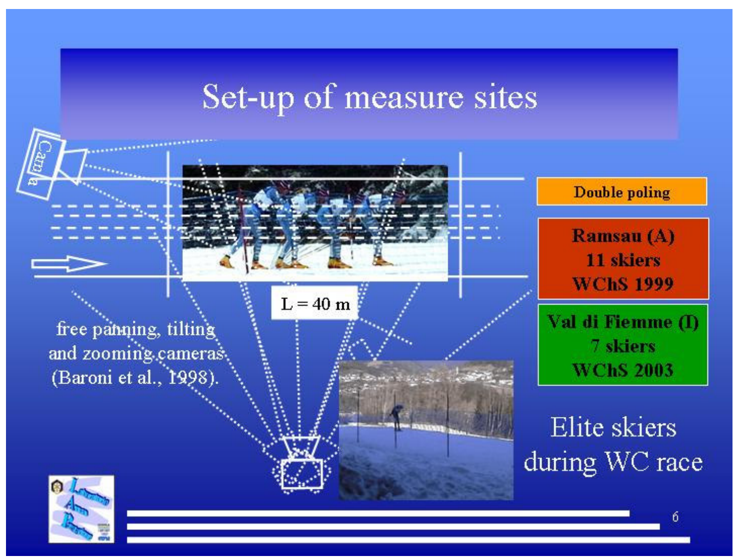

Fig. 1 – Experimental set-up

RESULTS

In the first race, 11 male skiers, from different countries, were considered for this work.

All the subjects concluded the first race with a distance just under 7 % longer than the time of the better skier included in the group. In the second race 7 male skiers were considered, included the winner. The maximal distance time of subject was 6 % longer than the time of the better one.

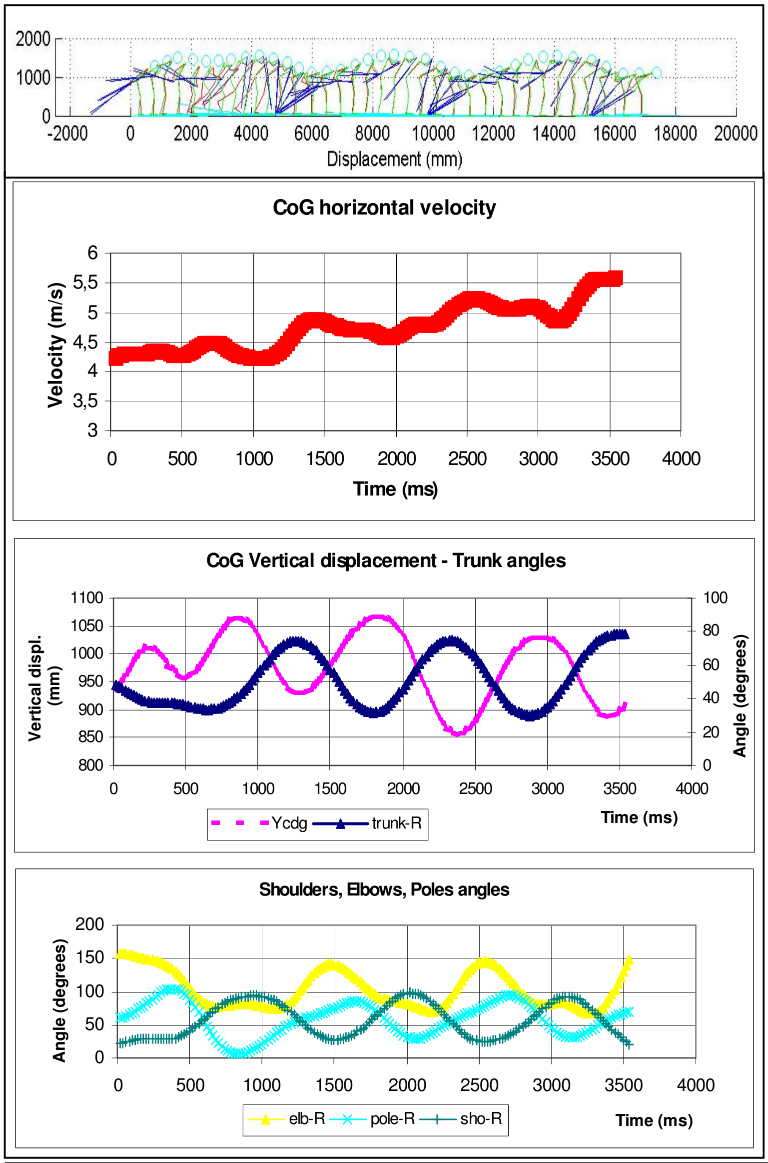

Fig. 2 - Example of Stick diagram and kinematics parameters

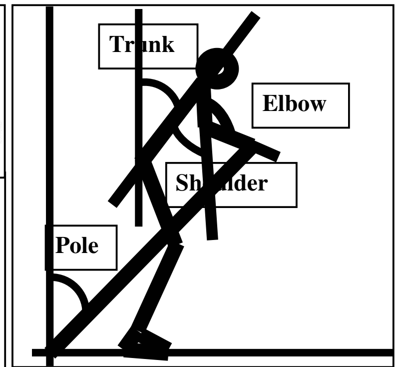

Fig. 3 – Angles definition

Fig. 2 shows a typical stick diagram, the velocity and vertical displacement of CG (second plot), in correspondence of the flat section where skiers performed DP or DP with kick stride. The analyzed Double Pole cycle begins at pole take off, continues at pole plant, when begins the most important pushing phase which causes the Velocity to increase

The next phase is a glide phase in which the arms and poles swing forward in recovery and preparation for the new pushing.

In the middle and lower graphs are plotted the typical patters of the trunk, shoulder, elbow and poles angles, we defined these as showed in the fig. 3 in according with the most used in literature, during the 3 cycles considered.

The principal kinematics parameters were measured for each competitors (tab. 1) as mean values of 2 or 3 cycles. The parameters were quite similar to each other and to the literature data. The difference in the Cycle Length (CL), and consequently in the average velocity, are related by the different snow condition.

Tab. 1

Parametres	Ramsau WC 1999	Fiemme WC 2003
CL (m)	7.9 ± 1.1	5.9 ± 0.3
CT (s)	1.30 ± 0.14	1.27 ± 0.10
Vave (m/s)	5.7 ± 0.25	4.70 ± 0.24
% Time-Poling / CT	23% ± 1%	30% ± 1%
CoG Vertical Displacement (m)	0.19 ± 0.04	0.16 ± 0.04
Elbow Angle (°) at Pole Plant (PP)	111 ± 10	99 ± 12
Elbow Angle (°) min	91 ± 13	84 ± 12
Shoulder Angle (°) at PP	94 ± 11	95 ± 15
Poles Angle (°) at PP	17.5 ± 6.4	25 ± 5

About the angular parameters, we are pointing our interesting at the crucial poling phase: we measured the trunk, shoulders, elbows and poles angles at the poles plant time, to try to understand the different strategy to perform the poling. A characteristic pattern of the CoG's Vertical Displacement and the trunk flexion are showed in the Fig. 4; during the poling phase the CoG drop about 20 cm, which was largely a result of trunk flexion that was about 40°: it start at 30° and reach about 70°.

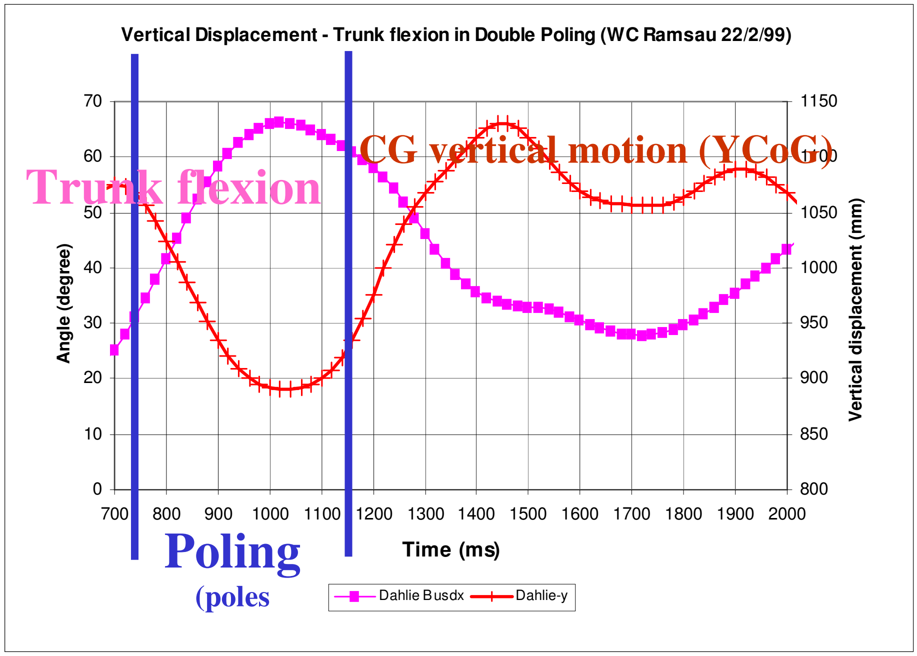

Fig. 4 - Example of CoG's Vertical Displacement and the trunk flexion

In order to reach the goal the trunk angle versus shoulder angles was plotted for the poling phase, for the 11 skiers in the Ramsau race and for 7 skiers in Val di Fiemme race; in the last case we analyzed the 3 double poling cycles performed by each skiers.

The graph of Fig. 5 shows an example of the patterns of one poling phase (the second in the Val di Fiemme race); poling begin at the right of each curve and proceeded to the left as showed in the stik diagram above in the Fig. 5.

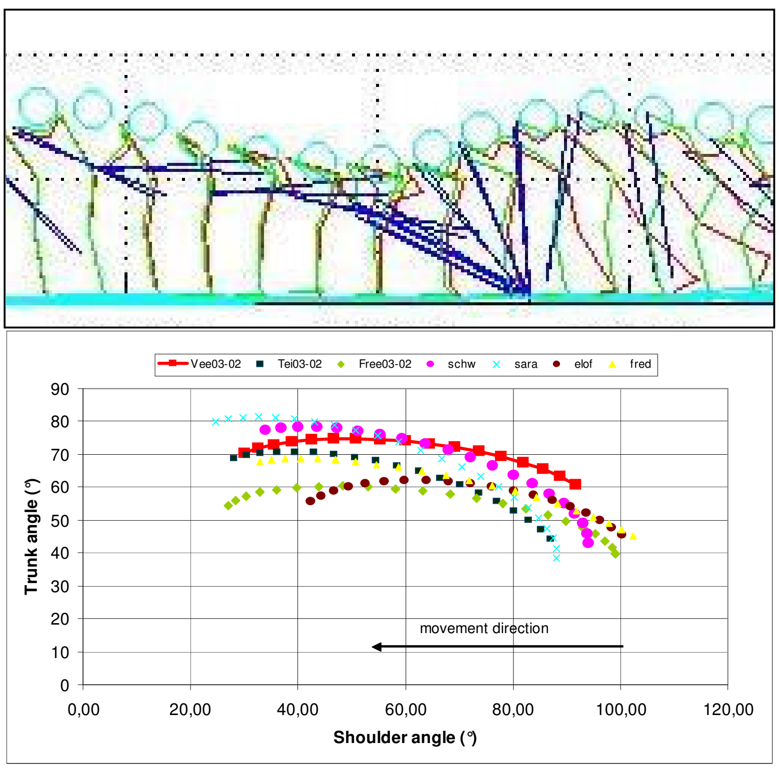

Fig. 5 – Stik diagram and trunk angle versus shoulder for poling phase for 7 skiers (Fiemme 2003)

Due to the relatively homogeneous group analyzed, the curve are quite similar and you can note that all athletes perform a large shoulder rotation from 80°-100° to 20°-30°.

The trunk flexion angle start at similar values about 30° and reach different values ranging from 60° to 90°.

As well we can note some different patterns also when two subject present similar values in the trunk flexion angle.

It's not easy to classify the behaviours, but in the plot we evidence almost 2 different curves which correspond to 2 strategy involving the trunk angle rotation versus shoulder angle motion: Free02-03 (♦) and schw (●) curves.

Nevertheless its start at similar values, the second skier (schw) reach a greater trunk angle than the first (Free02-03).

In the same manner the elbow angle are plotted versus shoulder angle for the single cycle in the Ramsau race and for the 3 cycles in the Fiemme race. We can do analogues considerations about the curves. In particular we can note the relatively different patterns for the previous skiers considered (Free02-03 (♦) and schw (■)) as it shows in the graph (under left) of Fig. 6.

Finally the elbow angle was plotted versus pole angle, which determine the magnitude of the horizontal propulsive force. The poles inclination for all athletes at the begin is quite similar, about 20°-25°, and quickly increase, which put pole in advantageous angle to generate larger components force in forward direction than in vertically. You can see how poling can be affected by the elbow positioning during the poling phase. For the 2 considered case (Fig. 6 graph above right) we note 2 different strategy: in the first skier (Free02-03 (♦)) we found a relative little flexion of the elbow; instead the other subject (schw (■)) flex the elbow in the first part of the poling about 20° .

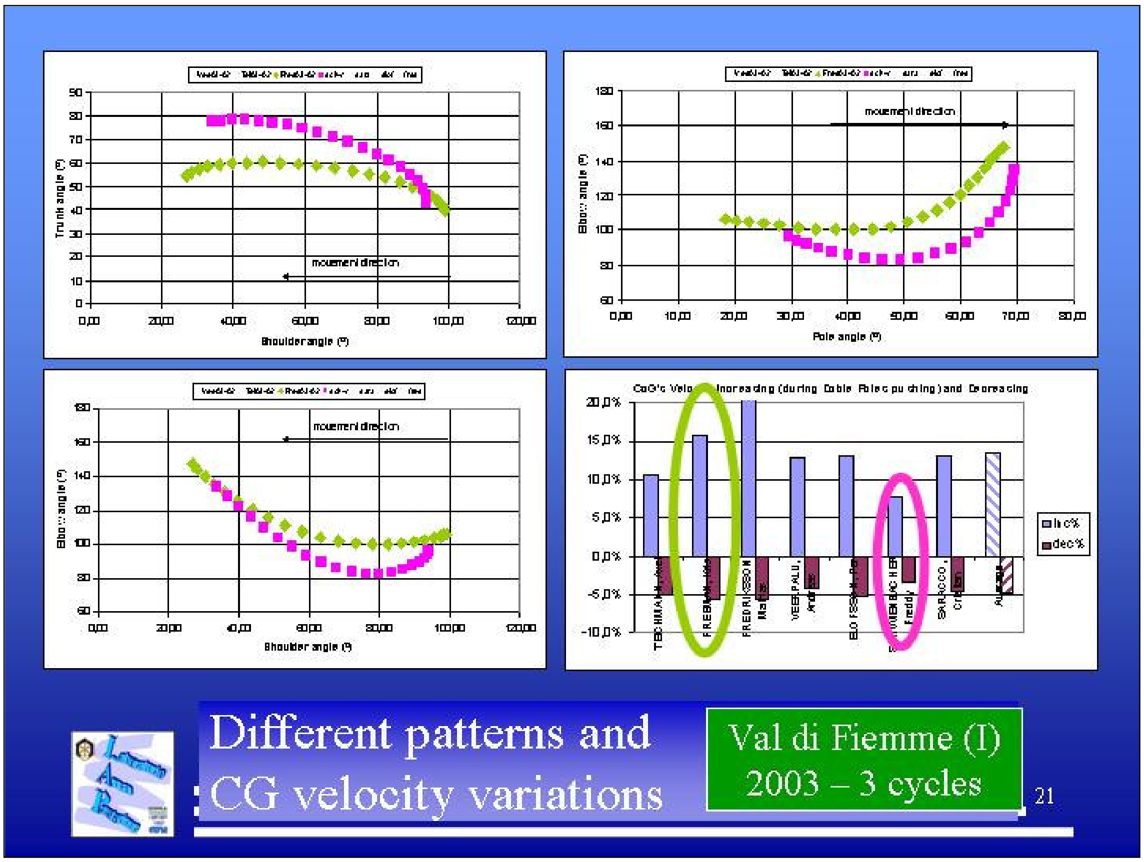

Fig. 6 – Different patterns of angular positioning of the upper-body limbs during poling phase (begin at the poles plant and stop at the poles take-off) for 2 skiers (Fiemme 2003), which perform DP, and CoG velocity variations.
Graph above left: Trunk angle versus shoulder angle
Graph under left: Elbow angle versus shoulder angle
Graph above right: Elbow angle versus pole angle
Graph under right: Mean values of increment for each skiers with the averages of the groups analyzed.

Although is not easy to predict why the fastest skiers increasing theirs velocity by different positioning of upper body limbs, we measure the relative velocity variations due to the double poling.

The mean values of increment for each skiers and for both races are presented in the bar graphic of Fig. 6, with the averages of the group analyzed which are about and 13% for the Fiemme race (10% for Ramsau race).

It seem that the greater velocity variation (the second subject from left which correspond to Free02-03 (♦) curves) are associated with the strategies which involved less trunk flexion, quite no elbow flexion and greater rotation of the shoulder. Also the poles angles quickly increase to reach the advantageous propulsive inclination.

SUMMARY AND DISCUSSION

Two groups of top level skiers during their maximal performance, 2 World Championships races, were analyzed. In this study we considered three cycles of Double Poling with and without kick performed by each subject on a flat section of race about 40 m long.

In according with previous study (Marino 1977, Komi 1987, Bilodeau 1995, Smith 1996, Canclini 2000), we found that the faster skiers have longer cycle lengths (r=0.53 Ramsau, r=0.48 Fiemme).

The kinematics patterns of shoulder, elbows and poles angles were found to be quite similar to literature data, but the values of the angle shows no correlation with the CoG velocity. However it seems that the key point of the poling is the relative positioning of the upper-body limbs to each others and the angles of the poles. For example a Elbow Angle at the PP is quite 90° in all case and not change in the first part of the poling.

However the skiers adopted different strategy to perform the poling with respect to the trunk, shoulder and elbow rotations. Inclination of poles and force generation should be "tuned" in order to achieve great horizontal impulse on CG. Nevertheless the difficulty to refer the better performance to the different upper limb angular motion, it seems that the faster skiers show less trunk flexion, quite no elbow flexion and greater rotation of the shoulder.

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