KINEMATIC AND KINANTHROPOMETRIC RELATIONSHIPS IN ELITE ATHLETES OF SPRINT ROLLER SKI

Matteo Romanazzi[2], Renzo Pozzo[1,3], Emanuele Becchis[1,2], Martina Bianchini[2]

[1]FISI-STF, Liceo Scientifico, IIS "Alberti", Bormio, Italy
[2] School of Exercise and Sport Sciences, University of Turin, Turin, Italy
[3] Department of Biomedical Sciences and Technologies, University of Udine, Udine, Italy

The purpose of this study was to clarify the relationship between kinematic and anthropometric characteristics of elite sprint roller ski athletes. Thirteen male (age: 26±6 yrs, mass: 73.8±8.1 kg, height: 180.2±7.2 cm) were assessed at the World Cup Competition. Before the race, anthropometric and plicometric measurements were detected, subsequently a 2D recording of the entire route was made and a 3D, at running speed. A correlation of all 3D kinematic and anthropometric data was made with average skiing speed of the athletes, obtained by 2D analysis. Significant inverse relationships were found with total cycle time and time of strong leg propulsion (r<-0.8), a moderate negative relationship with time arm recovering (r=-0.7) and a positive correlations with the cycle frequency time (r=0.8). No association was reported between anthropometric measurements, body composition and performance.

Keywords: roller ski, sprint, kinematics, technique, anthropometry, correlation

INTRODUCTION: The roller ski was born as off-season training tool for athletes and cross-country skiing enthusiasts in the 1960s in northern Europe. Later, roller ski has become a sports discipline that takes place on paved roads and uses a technique similar to cross-country skiing. The first World Cup race were held in 1993 in the Netherlands. Most of the researches focused on cross-country skiing but actually there are no scientific studies that analyzed kinanthropometric characteristic and biomechanics of the roller ski technique during competition. Stöggl et al. (2010) defined that cross country skiers should have a high percentage of lean mass and a low fat mass, while it does not seem that body size are factors that influence performance. In contrast Larson & Henriksson-Larsen (2008) reported a positive relationship between the absolute value of lean mass and the performance in a 10 km skating technique of the junior category. Different researches reported that the fastest skiers in the sprint tests have a very low total cycle time (Piirainen et al., 2006; Rapp at al., 2009). Canclini et al. (2015) collected data during freestyle cross-country skiing world championship and found a positive correlation between mean velocity and cycle length and push time.
International competition in sprint roller ski (SRS) represents an interesting investigation field, also for possible comparison with the corresponding performance in sprint cross-country skiing (SCCS). Previous investigations analyzed the kinematic and kinetic characteristics of SCCS and SRS under laboratory conditions (Sandbakk et al., 2013; Stöggl et al., 2011) but not under competitions. The study of the relationships between kinanthropometric, kinematic characteristics and performance could improve the technique efficacy and the race results in this discipline. Thus, in the present study, we collected the data on the world's elite athletes at a World Cup Competition. The aim of this study was to investigate the kinematic characteristics and kinanthropometric profile and its correlation with performance in SRS elite athletes.

METHODS: The performance of thirteen male sprint elite athletes (age: 26 ± 6 yrs, mass: 73.8 ± 8.1 kg, height: 180.2 ± 7.2 cm) at the World Cup Competition in the 2016 held in Trento (Italy) were analysed. According to previous classification the technique used here corresponds to the V2-alt (also G4), i.e. where the poling movement is synchronized with the leg push-off on one side (the strong leg). Each athlete performing qualification trial was filmed with two systems: for 2-D kinematic analysis one camera (50 Hz) was positioned at 7

m height from the ground and at about the middle of the entire distance (Figure 1); this permits to calculate the average velocity and, consequently, the whole time-history of Center of Mass (CoM) velocity; for 3-D kinematic analysis two other cameras (50Hz), located ahead of the 100 m marker (i.e. at maximal velocity), recorded the lateral and frontal motion sequences along a 30 m section of the entire track (Figure 2) were taken into the analysis (Baroni et al., 1998). The kinematic coordinates and the CoM were calculated using a biomechanical model (25 points full body and poles) as reported by Zori et al. (2005). SIMI-Motion (ver. 7.2.1, SIMI, Munchen, Germany) was selected as the motion video analysis software program to compute kinematic data that included cycle length, cycle time, cycle frequency, time arm propulsion, time arm recovery, time strong leg propulsion, time weak leg propulsion, CoM average and max velocity, CoM average and max acceleration.
Anthropometric measures were also taken a day before competition for later correlation analysis. This implies six lengths and two breadths of segments and trunk shape. In particular sitting height, leg, thigh, arm, forearm, foot, biiliocristal and biacromial were measured. Additionally, to calculate the body fat percentage, triceps, subscapular, iliac crest and front thigh skinfolds were measured (Peterson et al., 2003).
To consider the relationship between the average CoM velocity across race and kinematic and anthropometric data, the Pearson's correlation coefficients (r) and 90% confidence intervals (90% CI) were calculated after the normality test of all variable was performed. Only the variables with $r>0.7$ or $r<-0.7$ were discussed (Hopkins et al. 2009). Timing of arms phases and leg propulsion side were compared with an independent *t*-test. All data are expressed as means ± standard deviation and a priori alpha level was set at $p \leq 0.05$.

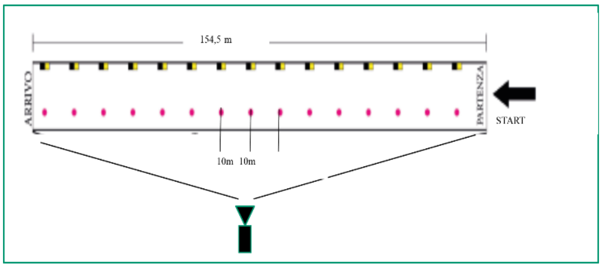

Figure 1 Experimental set-up for 2-D race analysis

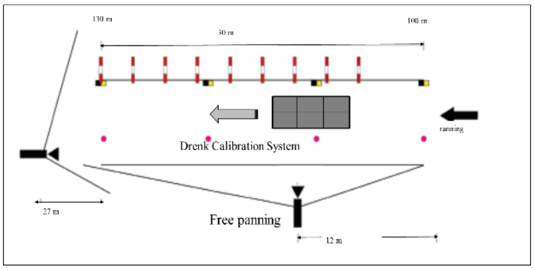

Figure 2 Experimental Setup for 3D analysis. The volume calibration was marked out with 15 rigid poles and moving 3D calibration frame

RESULTS: Classical parameters describing the overall performance (2-D analysis) and the single cycle structure (3-D analysis) are presented in Table 1. Significant difference for the time of leg propulsion was found between the strong and the weak leg (0.61±0.10 s and 0.40±0.11 s respectively; $p<0.05$), whereby the time of arms propulsion and recovery (pole swing) were 0.21±0.08 s and 0.72 ±0.11 s respectively ($p<0.01$). Kinanthropometric data were reported in Table 2.
Among the relevant kinematic data (Table 3), we found significant correlations between the average CoM velocity measured across the full race and some main parameters: a negative correlations with total cycle time ($r=-0.9$, $p=0.0001$), recovering arm time ($r=-0.7$, $p=0.01$) and time strong leg propulsion ($r=-0.88$, $p=0.003$) were detected; a positive correlations with the cycle frequency ($r=0.88$, $p=0.0003$), CoM max velocity($r=0.92$, $p=0.0001$) and CoM max acceleration ($r=0.79$, $p=0.003$).
No correlations was found between anthropometric characteristic and average CoM velocity identifying a low level of relationship between kinanthropometric data and performance (Table 3).

DISCUSSION: The present study investigates correlation between the kinematic structure of technique and kinanthropometric profile and performance of elite SRS athletes during a World Cup competition. This competition can be classified as pure maximal speed

performance (total distance 154 m) confirmed by average cycle length and cycle frequency that represents high values compared to similar technique applied in SCCS (Canclini et al., 2015, Sandbakk et al., 2013). Positive correlations with the cycle frequency time, identifying a linkage between velocity of execution and average CoM velocity during race were confirmed in previous research (Piirainen et al., 2006). Athletes have to manage two main tasks: a) high acceleration of CoM while starting from standing position and this is achieved in the early 40-60 m; b) maintain and possibly increase a high level of steady state maximal CoM skiing velocity. A significant correlation with CoM max acceleration identifies that the first condition is met. Correlations between 3D variables and average CoM velocity showed that there was a strong inverse relationship between total cycle time and time of strong leg propulsion. This identifies a dependence of the performance on the speed of the movements in particular maintaining a high linear velocity of CoM during race.
These results may be confirmed by significant inverse correlation with the time arm recovery and difference in timing of propulsion where the lower the recall time of the limbs the greater the number of propulsions.

Table 1: Most relevant 2-D and 3-D kinematic parameters of all the subjects

Variables	Mean ± SD
CoM average velocity (m/s)	10.2±0.60
CoM max velocity (m/s)	12.1±0.80
CoM average acceleration (m/s^2)	0.5±0.10
CoM max acceleration (m/s^2)	2.4±0.40
Cycle length (m)	10.0±0.7
Cycle time (s)	0.90±0.11
Cycle frequency (Hz)	1.10±0.10
Time arm propulsion (s)	0.21±0.08
Time arm recovery (s)	0.72±0.11
Time strong leg propulsion (s)	0.61±0.10
Time weak propulsion (s)	0.40±0.11

Table 2: Kinanthropometric measurements of all the subjects

Variables	Mean ± SD
Height (cm)	180.2±7.2
Weight (kg)	73.8±8.1
Sitting height (cm)	94.2±3.1
Lower Leg (cm)	46.7±1.9
Thigh (cm)	47.3±2.9
Arm (cm)	32.1±1.4
Forearm (cm)	28.2±1.3
Foot (cm)	26.2±1.4
Biiliocristal (cm)	30.7±0.8
Biacromial (cm)	39.7±1.6
Body fat (%)	12.8±3.3

Table 3. Correlation analysis results for CoM average speed with kinematic and kinanthropometric data.

	r	90% CI	p
Cycle time	-0.90	-0.97-0.67	0.0001
Cycle length	-0.56	-0.86-0.05	0.07
Cycle frequency	0.88	0.59-0.96	0.0003
Time arm propulsion	-0.59	-0.87-0.01	0.05
Time arm recovery	-0.7	-0.91-0.17	0.01
Time strong leg propulsion	-0.88	-0.96- -0.89	0.0003
Time weak leg propulsion	-0.50	-0.84-0.13	0.11
CoM max velocity	0.92	0.71-0.97	0.0001
CoM average acceleration	0.50	-0.13-0.84	0.11
CoM max acceleration	0.79	0.37-0.94	0.003
Height	-0.18	-0.70-0.46	0.59
Weight	0.24	-0.41-0.73	0.46
Sitting height	0.35	-0.31-0.78	0.28
Leg	-0.05	-0.63-0.56	0.87
Thigh	-0.19	-0.71-0.45	0.56
Arm	-0.35	-0.78-0.30	0.27
Forearm	-0.15	-0.69-0.49	0.65
Foot	-0.43	-0.81-2.28	0.18
Biiliocristal	0.21	-0.44-0.72	0.52
Biacromial	-0.31	-0.76-0.35	0.34
Fat mass	0.33	-0.32-0.78	0.30

The second aim of this study was identify a correlation between kinanthropometric profile of athletes and performance. This investigation didn't find any relationship confirming that a reference body model in this competition doesn't exist. This is confirmed by other studies where body dimensions do not appear to be a predictive factor (Stöggl et al., 2010) in SCCS races. Also, percentage of body fat hasn't reached a high level of correlation, unlike the results of Niinimaa et al. (1979) that analyzed long distance cross country athletes where a low level of fat and weight can influence performance.
Our work shows SRS is essentially an anaerobic all-out performance where body weight, composition and shape is secondary to the high level of power deliver. This study confirm that the improvement of the technique seems to be a priority factor compared to the anthropometric factors in achieving the best results in high level SRS athletes.

CONCLUSION: This study resulted in sport-specific findings during a maximal trial by elite SRS athletes. Performance was highly correlated with kinematic parameter related to propulsion and execution time but kinanthropometric parameter was not statistically significant identifying that influence of technique prevails over anthropometric characteristics. Future researches will be needed on biomechanics in SRS athletes to detect further relationships with performance.

REFERENCES
Baroni, G., Ferrigno, G., Rodano. R., Canclini, A., Cotelli, C., Fantino, M., Minotti, D., Pozzo, R. (1998). 3D sport movements analysis by means of free floating TVC with variable optics. *Proceedings of 16th ISBS*, Konstanz, Germany.
Canclini, A., Canclini A., Baroni, G., Pozzo, R. (2015). 3D Kinematic in freestyle cross country skiing (xcs) technique during world championships (Val di Fiemme 2013). *Proceedings of 3rd ICSNS*, Vuokatti, Finland.
Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, 41(1), 3-12.
Larsson, P., & Henriksson-Larsen, K. (2008). Body composition and performance in cross-country skiing. *International journal of sports medicine*, *29*(12), 971-975.
Niinimaa, V., Shephard, R. J., & Dyon, M. (1979). Determinations of performance and mechanical efficiency in nordic skiing. *British journal of sports medicine*, *13*(2), 62-65.
Peterson, M. J., Czerwinski, S. A., & Siervogel, R. M. (2003). Development and validation of skinfold-thickness prediction equations with a 4-compartment model. *The American journal of clinical nutrition*, *77*(5), 1186-1191.
Piirainen, H., Papinaho, A., Nuorala, S., Niemelä, E., Härkönen, T., Hämäläinen, H., ... & Jozefiak, Z. (2006). Effect of stride frequency on the maximal velocity and skiing time in classical sprint skiing. In Linnamo, Komi, Muller (Eds), *Science and Nordic Skiing* (pp. 130-38). Oxford: Meyer & Meyer Sport.
Rapp, W., Lindinger, S., Müller, E., and Holmberg, H.C. (2009). Biomechanics in classical cross-country skiing-past, present and future. In Muller, Lindiger, Stogll (Eds), *Science and Skiing* IV (pp. 630-40). Maidenhead: Meyer & Meyer Sport.
Sandbakk, Ø., Ettema, G., & Holmberg, H. C. (2013). The physiological and biomechanical contributions of poling to roller ski skating. *European journal of applied physiology*, *113*(8), 1979-1987.
Stöggl, T., Enqvist, J., Müller, E., & Holmberg, H. C. (2010). Relationships between body composition, body dimensions, and peak speed in cross-country sprint skiing. *Journal of sports sciences*, *28*(2), 161-169.
Stöggl, T., Müller, E., Ainegren, M., & Holmberg, H. C. (2011). General strength and kinetics: fundamental to sprinting faster in cross country skiing?. *Scandinavian journal of medicine & science in sports*, *21*(6), 791-803.
Zory, R., Barberis, M., Rouard, A., & Schena, F. (2005). Kinematics of sprint cross-country skiing. *Acta of Bioengineering and Biomechanics*, *7*(2), 87.