CHANGE IN SPATIOTEMPORAL CYCLE VARIABLES & MUSCLE ACTIVATION DURING CLASSIC ROLLER SKI DOUBLE POLING TECHNIQUE

Kitae Kim[1], In-sik Shin[1], Siddhartha Bikram Panday[1], Jin-hae Kim[2]*, Hye-young Kim[3], Gwang-jae Yu[4], Ji-hyun Kim[5]

Department of Physical Education, Seoul National University, Seoul, Korea[1]
Department of Physical Education, Korea National Sport University, Seoul, Korea[2]
Division of Liberal Arts and Science, Korea National Sport University, Seoul, Korea[3]
Department of Industrial & Systems Engineering, KAIST, Daejeon, Korea[4]
Korea Institute of Sports Science, Seoul, Korea[5]

The purpose of the study was to assess the effects of distance covered while roller skiing using the double poling technique. Five national team members and college elite cross-country skiers were chosen to participate in this study. EMG system and digital camcorder were used to measure spatiotemporal cycle variables, muscular fatigue, and activation patterns. There were no significant differences on cycle variables. However, the result shows accumulation of fatigue and decrease of muscle activation on triceps brachii and tibialis anterior muscles across skiing distance.

KEY WORDS: cross-country ski, roller ski, double poling, EMG, fatigue

INTRODUCTION: Cross-country skiing is one of the winter sporting Olympic event which requires a high level of power output and characterized by repeated dynamic contraction of both upper and lower limbs. One of the foremost technique in cross-country skiing is the double poling (DP) technique that is mainly performed on flatter terrain in the classical event (Lindinger, Holmberg, Muller, & Rapp, 2009). There is a noticeable increase in use of DP technique by skiers during the races, however few studies have focused on the kinematic and kinetics factors that influence this technique (Hoffman, Clifford, & Bender, 1995; Millet, Hoffman, Candau, Buckwalter, & Clifford, 1998; Smith, Fewster, & Braudt, 1996). However, how spatiotemporal cycle factors, as well as muscle activation patterns, are affected during a full race with the accumulation of fatigue has rarely been studied. Several studies have utilized roller skis to analyze and understand the characteristics of the double poling (DP) technique of cross country (Cignetti, Schena, & Rouard, 2009; Holmberg, Lindinger, Stoggl, Bjorklund, & Muller, 2006; Lindinger & Holmberg, 2011; Lindinger et al., 2009; Stoggl, Lindinger, & Muller, 2006, 2007; Vesterinen, Mikkola, Nummela, Hynynen, & Hakkinen, 2009; Zory, Vuillerme, Pellegrini, Schena, & Rouard, 2009). As roller skis are being used by skiers as an alternative off season training to enhance and maintain their physical as well as technical abilities. Quantifying DP technique on roller ski in an actual course could provide scientific data to cross-country skiers and winter sports instructor to plan and evaluate skiing strategy for enhancing the performance. Therefore, the purpose of the current study was to assess the effects of distance (12 km) on muscular fatigue, activation patterns, and spatiotemporal cycle variables while performing double polling technique.

METHODS: Five national team members and college elite cross-country skiers (Age: 20.4±1.1 years, Height: 177.2±3.3 cm, Weight: 69.0±2.4 kg) who have won in competitions of a national or higher level were chosen to participate in this study. We used a partial course (2 km) of a regular biathlon course that mixed both flat and inclined sections.
The electromyography (EMG) and spatiotemporal cycle variables (e.g. cycle time, cycle length, cycle rate, the time ratio of each cycle phase, and mean velocity) were measured while the subject ran the full 12 km course. In total, the measurements were taken four times (right after the start and after each subsequent 4 km of skiing). The measurement section was located 20 m to 50 m after the starting point. In each measurement section, the subjects were asked to use exclusively the double poling (DP) technique. Prior to each experiment, all subjects were allowed 10 minutes of warm up time followed by attaching electrodes for the EMG

measurement. They were attached to two upper body muscles (TB: triceps brachii, LD: latissimus dorsi) and four lower body muscles (VL: vastus lateralis, TA: Tibialis anterior, BF: biceps femoris, GL: gastrocnemius lateralis).

The electrodes were exclusively attached to the right side of their respective muscles. The Telemyo DTS Wireless system (Noraxon, USA) was used to collect EMG data along with the maximum voluntary isometric contraction (MVIC) to normalize each muscle (Konrad, 2005). The sampling rate of the EMG measurement was set to 3000 Hz. All the subjects were given the same models of aluminium roller skis (XLA 900 Series, V2, USA) and boots (model RC Carbon, Salomon, USA). The subjects used their own carbon poles fit to their respective body dimensions and preferred style. When subjects skied over the measurement section it activated a digital camcorder (HDR-PJ380, Sony, Japan) that was placed 50 m away on the right side to collect additional data. The sampling rate of the digital camcorder was set to 30 Hz.

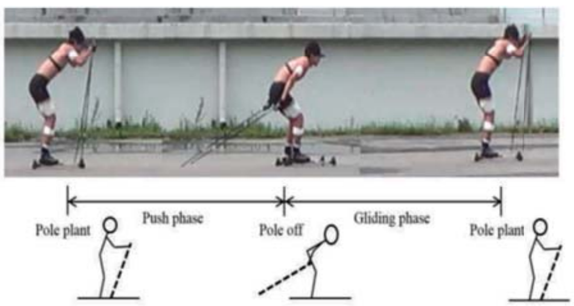

Figure 1. Definition of events and phases during a double poling motion

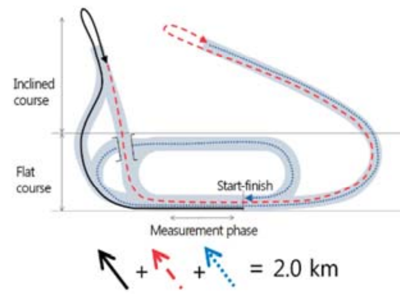

Figure 2. Experimental Course

Three cycles of double poling were analyzed over 30 m of a measurement section in each lap. Spatiotemporal cycle variables included cycle time (time measured from pole plant to pole plant), cycle length (distance covered after 1st pole plant to 2nd pole plant), cycle rate (frequency of poling), the time ratio of each cycle phase (figure 1), and mean velocity. The EMG variables included mean power frequency and mean amplitude. In order to calculate spatiotemporal cycle variables, the average value of three cycles of DP were used throughout the measurement section. The EMG raw data was band-pass filtered at 80 to 250 Hz. To calculate mean power frequency, data was processed using the Fast Fourier Transformation method. The mean frequency of each measurement trial (each 4 km) was converted to percentage value by the first trial. The mean amplitude of the filtered data was rectified and averaged across three cycle duration spent on each measurement section and normalized by the MVIC value of each muscle. All EMG data was processed by MR3.6 (Noraxon, USA) software.

A Non-parametric test (Friedman) was used, and the Bonferroni post hoc test was carried out to verify differences across all four trials in spatiotemporal cycle variables and three trials without the last trial in muscle activation and Mean power frequency analysis. For muscle activation and Mean power frequency analysis, a statistical test was carried out for only three trials assuming skiers could use a different strategy in the final lap because there is no need to maintain physical condition for another lap, Statistical significance was set to $\alpha=0.05$. SPSS ver. 22 (IBM, USA) software was used for statistical verification.

RESULTS & DISCUSSION: No statistical significance was observed in lap time across trials (minutes); start to 4km: 13:57 ± 00: 38, 4km to 8km: 13: 17 ± 00: 34, 8km to 12km: 13: 04 ± 00: 38 ($p=.066$). In cycle variables, there were no significant differences across first to third trials (Table 1). Zory et al. (2009) reported that in cross-country sprint, cycle rate was decreased whereas push and gliding duration was increased as a result of fatigue. Despite evidence that cycle time was maintained, push time ratio was increased. The current study's results showed similar patterns of data, but it did not reach statistical significance.

Table 1. Results for the non-parametric test (Friedman) for spatiotemporal cycle variables in each trial.

Variables	Mean ± SD of each trial (*n=5*)				Sig.	Post hoc (sig)
	1st	2nd	3rd	4th		
Cycle Time (s)	0.85±0.1	1.01±0.38	0.94±0.11	0.79±0.06	.012*	
Cycle Length (m)	5.36 ±0.57	6.24 ±0.76	6.16 ±0.50	5.26 ±0.38	.050	3rd/4th (.042*)
Cycle Rate (hz)	1.21 ±0.14	1.04 ±0.14	1.08 ±0.14	1.29 ±0.10	.041*	3rd/4th (.040*)
Push Time Ratio (%)	31.37 ±3.79	29.18 ±3.93	30.43 ±2.91	34.63 ±3.65	.059	
Mean Velocity (m/s)	6.42 ±0.28	6.41 ±0.27	6.60 ±0.45	6.75 ±0.25	.306	

* significant difference at p<0.05 in cycle length (m) and cycle rate (Hz) at 3rd and 4th measurement trial (Friedman followed by Bonferroni post hoc testing)
1st trial: start trial, 2nd trial: 4 km trial, 3rd trial : 8 km trial, 4th trial: final finishing trial

The statistical difference observed only on 3rd and 4th trial for cycle length (m) and cycle rate (Hz) variable ($p<.05$). It is considered that skiers presumably use the different strategy in finish section because there is no need to maintain physical condition for another lap.

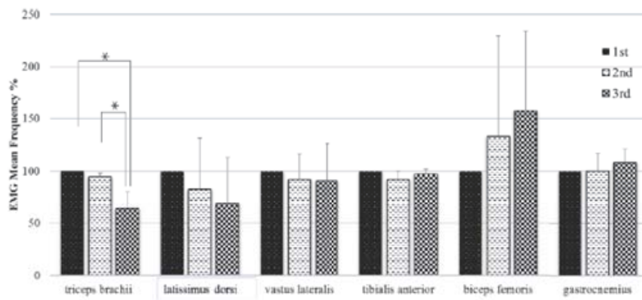

Figure 3. Mean frequency ratio (±SD) of power spectrum of right side muscles during 1st, 2nd and 3rd trial (start, 4km, and 8km trial respectively) *n=5*

The results display a pattern that decreased the mean frequency of upper body muscles. A particularly significant difference was observed in the triceps brachii muscle ($p<.05$) (figure. 3). Latissimus dorsi was generally thought to be an agonist muscle in the DP technique, but there was no significant difference observed. Similar results were revealed within the study of Vesterinen et al. (2009). Triceps brachii muscle are relatively composed with a higher ratio of Type IIa fibers which are prone to fatigue (Peltonen et al., 1997; Vesterinen et al., 2009).

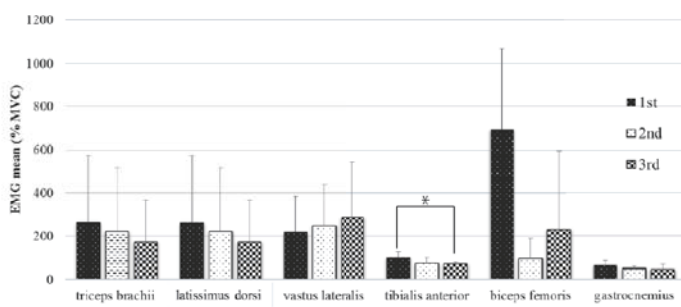

Figure 4. Normalized MVC % (±SD) EMG amplitude for the six muscles of right side during 1st, 2nd and 3rd trial (start, 4km, and 8km trials respectively) *n=5*

There was a significant decrease in the activity of the tibialis anterior muscle in the Mean amplitude %MVC value ($p<.05$) (figure. 4). Prior research only demonstrated minimized activity of the lower body using the DP technique (Smith, 2003). Holmberg et al. (2006) reported that even using the DP technique, active movement of the lower body could increase performance and decrease energy consumption as well as muscle activity of the upper body. Particularly in cross-country, the heels of ski boots are independent from the ski plate. The use of the tibialis anterior muscle which is related to the ankle dorsiflexion is frequently observed and fatigue or decrease of activity of the tibialis anterior muscle is related to the overall performance.

CONCLUSION: There were no differences in the cycle variables across the skiing distance over 12 km. However, in EMG variables, accumulation of fatigue in triceps brachii and tibialis anterior muscle were observed. Triceps brachii is related to elbow extension, and tibialis anterior is related to the ankle dorsiflexion. Hence, these two muscles play critical role in double poling (DP) technique. Elbow extension is the main movement while poling and performing push techniques whereas, tibialis anterior is related to control of ski plate. Fatigue in those muscles can explain that they are frequently used in DP technique and can effect performance also.

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