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LATERALITY OF LOWER LIMBS DURING V2 ALTERNATE IN NORDIC COMBINED ATHLETES

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SOŇA JANDOVÁ *, JAN CHAROUSEK
Technical University of Liberec, Liberec, Czech Republic

ABSTRACT
Purpose. The aim of this study was to analyse the foot pressure distribution by cross-country skiers during the push-off phase when using the V2 Alternate skating technique depending on lower limb preference. The study also focused on whether push-off during V2 Alternate would be performed more quickly and in a shorter time interval by the dominant leg than the non-dominant leg. **Methods.** Data were collected using a pedographic system together with synchronised video recording. Conventional dialogistic methods used in kinanthropology were used to detect the lower-limb lateral preference. **Results.** Statistically significant differences in the vertical component of force produced by the right/leg lower limbs was observed. However, no statistically significant differences were present in the duration when weight was transferred to one of the lower limbs. **Conclusions.** Although V2 Alternate is a movement task that is considered to be symmetrical (where left and right leg push-off should be practically identical), the results of the study proved otherwise. In practice, this implies that the explosive force capabilities of cross-country skiers should be trained especially for the non-dominant leg so as to ensure that a fully adequate push-off can be conducted during two-sided skating.

Key words: dynamometry, skiing technique, pressure distribution, dominant and non-dominant leg

Introduction

The occurrence of right and left-sided dominance has been known for a number of years, with research on speech disorders in the 19th century first documenting this phenomenon. It was discovered that movements of the right side of the body are governed by the left hemisphere of the brain while those of the right side of the body are governed by the left hemisphere of the brain due to the crossing of the main pathways of the brain cortex. However, the cause of laterality, or the preference of humans to use one side of their body over the other, and the factors influencing the ontogenetic development of laterality have been difficult to determine. Blakeslee [1] believes that the most important factors in the development of laterality are biological (the functional asymmetry of the left and right hemispheres) and social. Sovák [2] distinguishes four different categories of laterality, being undetermined, determined right-preference, determined left-preference and crossed laterality, whereas Kováč and Horkovič [3] recognize extreme right-preference, strong right-preference, weak right-preference (ambidexterity) and left-preference laterality. However, due to specific exercises it is possible to overcome determined laterality in some sports [4]. Some individuals are able to exhibit two-handedness or two-footedness as the result of long-term intensive training. Porac and Coren [5] defined lateral preference as being significant during the selection and use of paired body organs during specific activities. According to Vaverka [6], one side of the body in movement activities exhibits better developed coordination, with it being of higher quality and more skilful than the other side. A number of tests were developed to determine laterality. Ruisel [7] proposed a battery of six tests to ascertain the lateral preference of the lower limbs, while Oberleck [8] determined the lateral preference of the lower limbs based on how accurate one is able to kick a ball. Starosta [9], Kollarovits and Gerhát [10], Kasa [11], Šimonek [12] and Hellebrandt et al. [13] have all used standardized tests to estimate laterality.

Generally, lower limb activity is less asymmetrical than the upper limbs as the legs work similarly during such activities as walking and running [14]. Of considerable interest is how lateral preference is expressed in sports, with the literature on the subject paying significant attention to skiing. Vaverka and Vodičková [15] examined alpine skiing and found indicators of lower limb laterality in relation to the carved ski arc by dynomometrically measuring differences in foot pressure distribution. A study by Rapp et al. [16] focused on the biomechanical aspects of cross-country skiing by analysing the historical development of skiing technique. Several authors [17, 18] have also emphasized that performance in cross-country skiing is influenced by the force generated at push-off as well as the stamina of the skier. These authors reported that there were higher values of vertical ground reaction force during push-off in the classic skiing style than when skate skiing. A study by Canclini et al. [19], conducted during World Cup races in the

* Corresponding author.

1990s, found large differences in the techniques of world-class cross-country skiers and those who compete at a lower level, especially in terms of slide length, and also observed intra-individual variability of skiing technique. Additional studies by Canclini et al. [20] noted differences in stride frequency, push-off speed and slide length of athletes competing in the World Championships. However, after studying the aforementioned literature, it seems that the interaction of force between the foot and insole during classic and skate skiing has not been fully addressed.

The aim of this study was to therefore analyse foot pressure distribution by analysing a group of experienced cross-country skiers by monitoring insole pressure distribution during the push-off phase when using the V2 Alternate skating technique in terms of their lower limb preference on flat terrain at race speed. In relation to the stated objective, this study also focused on whether push-off during V2 Alternate would be performed more quickly and in a shorter time interval by the dominant leg in comparison with the non-dominant leg. A certain uniformity in the values of the vertical component of force during push-off was expected as measurements were performed on high-level athletes and that the long-term training such competitors undergo would offset their determined laterality [4].

Material and methods

The study was performed on five male Nordic combined athletes (age: 26.4 ± 5.57 y; height: 1.79 ± 0.03 m; weight: 67.8 ± 2.32 kg) that officially represent the Czech Republic. The study was conducted at the Harrachov ski resort in the Czech Republic.

Four of the five cross-country skiers featured right leg dominance while the fifth individual had no preference for which foot he used for push-off. The participants were asked to complete eight runs on flat terrain using various skating techniques. Along a selected 100-metre section they were asked to use the V2 Alternate style (symmetrical push-off) at race speed.

Data were collected by dynamographic measurement with simultaneous video recording so as to allow for a more detailed analysis. Measures of the applied force and its duration during the push off-phase was performed using the Pedar in-shoe dynamic pressure measuring system (Novel, Germany) at a frequency of 100 Hz. This system records the pressure of the foot on a sensor insole placed inside the participant's cross-country boot. Recordings of maximum ground reaction force were wirelessly transmitted to a PC, where this data was synchronized to the video recordings using the bundled Novel software. The Wilcoxon test was used to statistically analyse the obtained results. A symmetry index was also used to analyse the differences between the left and right leg.

Results

Maximum ground reaction force at push-off and its duration during the weight transfer from the left to right leg is presented in Table 1 (an example of the recorded force measurement using the Pedar system is shown in Figure 1). Differences between the dominant and non-dominant lower limb were observed for both ground reaction force and its duration. Three of the four cross-country skiers who prefer to push off with their right leg achieved a higher Fz_{max} (N) value with their dominant (right) leg. The situation was different for the fifth participant with no leg preference for push-off, who achieved similar Fz_{max} (N) values with both the left and right legs. The duration of weight transfer between the dominant to non-dominant lower limb was longer in three of the four skiers who prefer to use their right leg for push-off, while for the remaining two it was shorter.

The Wilcoxon rank sum test rejected the null hypothesis for push-off measures of all five competitors except for the duration of weight transfer to the left leg. Significant differences in Fz_{max} values were found, although no significant differences were observed in the duration of weight transfer between the right and left leg (Tab. 1).

Overall, although the V2 Alternate skating technique is defined as a symmetrical motor task (where the push-off from the left and right legs should be practically identical), the use of a symmetry index for the measured values found otherwise. The symmetry index (where a value of 1.0 denotes functional similarity of the limbs) for maximum ground reaction force and the duration of weight transfer was 1.242 and 1.025, respectively.

Discussion

Due to the fact that few studies have addressed the occurrence of lower limb laterality in cross-country

Table 1. Basic statistical characteristics of maximum ground reaction force (Fz_{max}) registered at push-off and its duration (t) during the weight transfer between left and right leg

Variable	Right leg		Left leg		Difference		Symmetry index	Correlation coeff.	Defferences	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD			Wilcoxon p value	Significant
t (s)	1.008	0.133	0.989	0.140	0.019	0.098	1.025	0.740	0.235	No
Fz_{max} (N)	1064.9	350.0	857.6	158.7	207.3	251.3	1.242	0.761	0.003	Yes

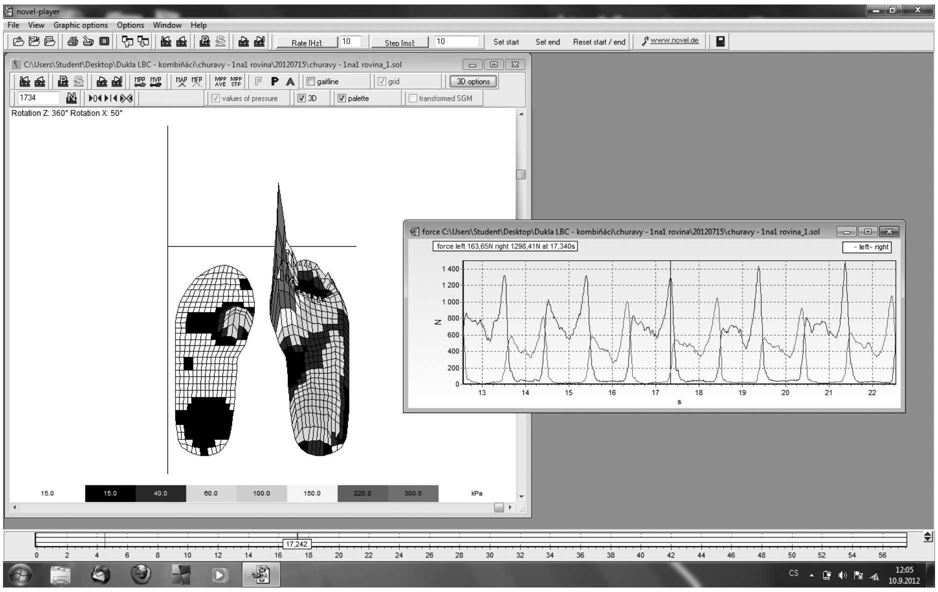

Figure 1. Example of the pressure distribution between the left (non-dominant) and right (dominant) leg observed using the Pedar system

Table 2. Correlation coefficients expressing the relationship between duration and force at push-off

Correlation	t_P (s)	t_L (s)	Fz_{maxR} (N)	Fz_{maxL} (N)
t_P	1	0.74	–0.691	–0.772
t_L	0.74	1	–0.761	–0.638
Fz_{maxR}	–0.691	–0.761	1	0.761
Fz_{maxL}	–0.772	–0.638	0.761	1

t_R – duration when weight transferred to the right ski; t_L – duration when weight transferred to the left ski; Fz_{maxR} – maximum value of vertical ground reaction force for the right leg; Fz_{maxL} – maximum value of vertical ground reaction force for the left leg

skiing, a comparison of the results was performed with those of Vaverka and Vodičková [15], where amongst other findings they claim that during downhill skiing the duration of weight transfer on the preferred lower limb is longer and with larger values of force. The correlation coefficients (Tab. 2) calculated in the present study, expressing the relationship between the duration when weight was shifted between one ski and the other and the maximum registered force, found a high negative correlation between these variables. This argues in favour of the hypothesis that a lower value force is replaced by increased duration. In practice, this signifies that for skiers one leg is stronger for push-off while one is more skilful for sliding. In order to confirm this theory it would be necessary to conduct further research on a larger group of participants with both right- and left-sided lower limb dominance.

When comparing the results of this study to those of Stöggl at al. [21] on peak pressure during V2 skating, the participants of this study achieved slightly lower values. This may have been caused by the selected group of participants, as in the present study these were skiers who competed in the Nordic combined and were not a group of exclusively cross-country skiers.

Future studies should explore this issue with skiers with a clearly determined preference for using the left leg for push-off and also include a larger group of skiers with an undetermined lower limb preference.

Conclusions

Based on the results, it can be postulated that even for movement regarded as symmetrical there exist statistically significant differences, as was found in the values recorded for maximum vertical ground reaction force in this group of skiers. However, no statistically significant differences were found for the duration when weight was transferred to the preferred foot at push-off. Overall, although V2 Alternate is a movement task that is considered to be symmetrical (where left and right leg push-off should be practically identical), this was found to be otherwise. In practice, this implies that the explosive force capabilities of cross-country skiers should be trained especially for the non-dominant leg so as to ensure that a fully adequate push-off can be conducted during two-sided skating. This gives rise to the notion that such athletes should engage in unilateral training [22, 23].

This present study has shown that applying dynamometric measurement is suitable for monitoring the quality of push-off while skate skiing, with additional research needed on a larger group of cross-country and Nordic combined skiers

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Correspondence address
Soňa Jandová
Technical University of Liberec
Institute of Health Studies
Studentská 2
461 17 Liberec, Czech Republic
e-mail: sona.jandova@tul.cz