LATERALITY OF THE LOWER LIMBS AND CARVING TURNS

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ABSTRACT: The aim of this study is to discover whether the lateral preference of the lower limbs influences the execution of successive carving turns or not. Six skilled skiers (men, right lower limb preference, age 26.5±1.61 years old, height 1.80±0.04 m, body weight 78.83±5.46 kg) executed 30 (18 left, 12 right) symmetrical carving turns. Kinetic analysis of the final vertical component of reaction force FZ(t) measured dynamometrically provided the information about the time of initiation and steering phases of the turn and the maximum force, average force and force impulse. Differences between right and left turns are not statistically significant. Factual analyses of the magnitude of measured variables confirmed that left turns were found to have a longer duration, a shorter initiation and longer steering phase, and higher level of produced force and force impulse in comparison with right turns. Based on the results it can be concluded that the turns where the outer leg is the preferred limb are preferentially used to regulate the speed of the ride. The study of laterality in symmetrical carving turns has proven that lateral preference of lower extremities influences the execution of the turn also by expert skiers.

KEY WORDS: dynamometry, kinetic analysis, laterality, lower limbs, ski turn

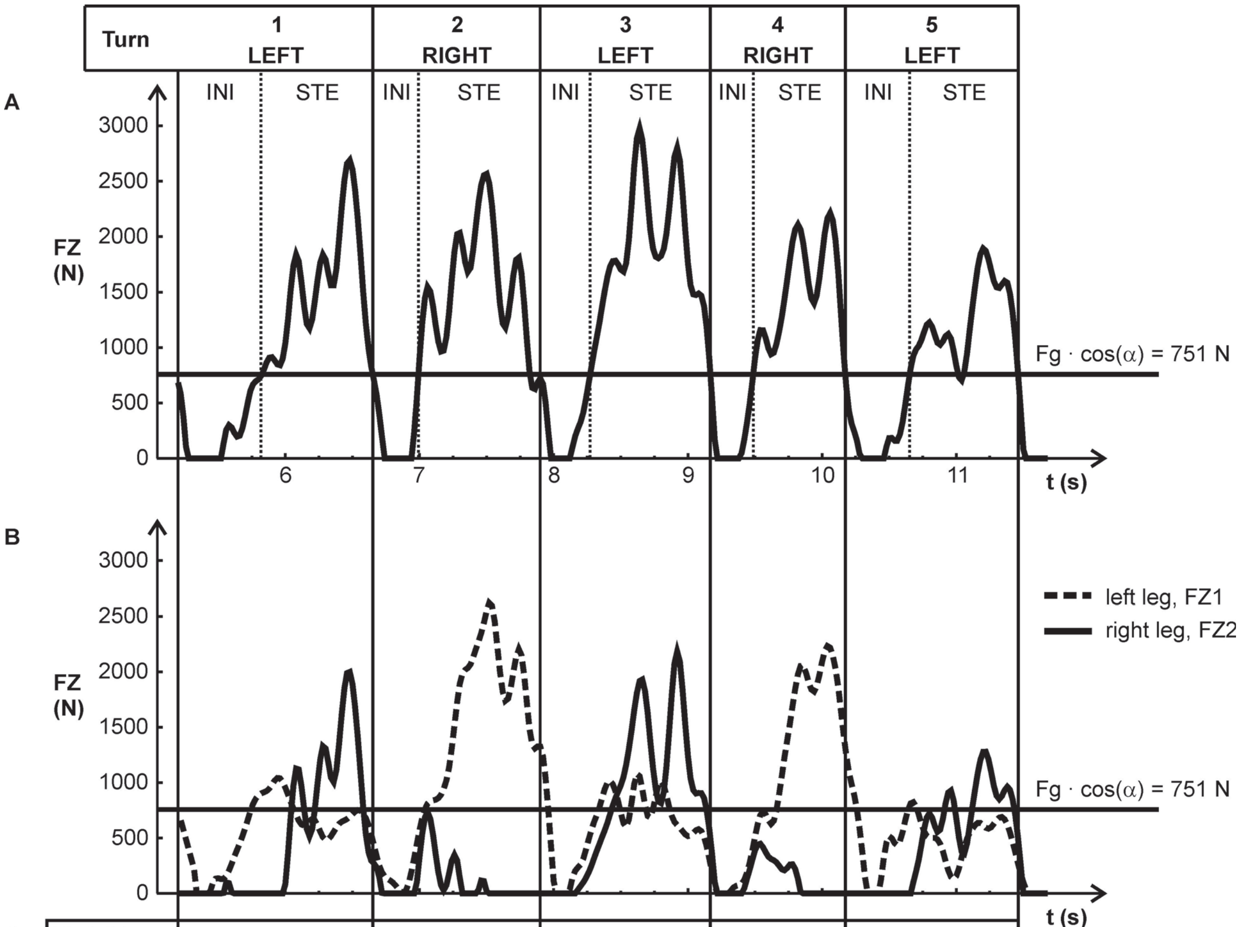
INTRODUCTION

The lateral preference of the upper or lower limbs influences the motor activity of a person in unilateral and bilateral actions [18]. Lateral preference can be defined as priority in the choice and usage of paired limbs of the human body in specific activities [11]. Anatomic symmetry (paired organs, two arms, two legs) is not compatible with functional symmetry and one side of the body is usually more developed and more skilful than the other. We are referring to the lateral preference in motor actions, which basically involves the dominance of either the left or the right side of the brain [11]. The left hemisphere controls the action of the right side of the body and vice versa. The ratio of people who prefer one side of the body in motor activity has remained constant for a long time and oscillates in terms of the upper limbs between at 90% for right-handed people, 8-9% for left-handed people and 2-3% for ambidextrous people [6]. As far as alpine skiing is concerned, we are interested in the percentage expression of laterality in the lower limbs in the general population. Porac and Coren [11] found that 88% of the population prefers the right hand, 81% prefers the right leg and 84% currently prefers the right arm and right leg. Literature provides us with slightly differing information about the percentage of right-handed, left-handed and ambidextrous people, yet this information is extremely similar to the information provided in individual sources, despite some small differences.

The influence of lateral preference occurs in different ways in a large scale of various movements. The simplest example is that of unilateral movements (throwing, tennis, etc.) where the preferred limb performs the decisive action. Furthermore, there are movements actions where both limbs carry out a symmetrical movement with a great amount of force (eg. rowing, weightlifting, etc.) where laterality plays a minimal role. Furthermore, there are bilateral activities where the preferred and non-preferred limbs alternate in movement like walking or running. The influence of the lateral preference of the lower limbs is studied in symmetrical (e.g. [3,12,15]) or asymmetrical movements (e.g. walking: [5,14,16]; soccer kicking: [1,19]). A lot of scientific literature concerning fine motor skills are found in the field of psychology and motor control (e.g. journals Laterality, Behavioural Brain Research). It is surprising that in skiing, and especially in ski turning, the problem of laterality has not been in the focus of attention. The influence of the lateral preference of the lower limbs in ski turning was considered only from the point of view of knee injuries [17].

A ski turn is a very complicated action which leads to regular changes in the direction of the turn to the right and to the left. The frequency of the turns, their total duration, the radius of the turn, the speed of movement in relation to outer factors (for example the quality of the surface, inclination of the slope etc.) are all variables which considerably influence the outcome of the actual turn.

Firstly, in competitive skiing, where the track of the ski turn is defined by the course,, the effective realization right and left turns is the key to success in competition. The question of the lateral preference of the lower limbs is very relevant in connection with an effective ski turn. In the past where the traditional parallel ski turn was based on placing more weight on the outer leg during the turn [7,8,10] and a better turn was dependent on each leg laterality played very strong role. Skiers usually had a “stronger” or a “weaker” (better or worse) turn in relation to the lateral preference of the outer leg. Now that carving turns are more common in skiing weight is more evenly placed on both legs during a turn [7,8]. Scientific studies [2,8,9] have shown in a carving turn that after passing the contour line the weight placed on the outer leg is greater than the weight placed on the inner leg. In other words during the completion of the turn the outer leg plays a significant role in a carving turn too. The preferred leg will probably be more effective in controlling the final phase of the turn. In left turns the right leg is the outer leg



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Variable	1	2	3	4	5
t_{INI} (s)	0.63	0.31	0.38	0.31	0.50
t_{STE} (s)	0.87	0.94	0.93	0.69	0.81
t_{TOT} (s)	1.50	1.25	1.31	1.00	1.31
$t_{INI\%}$	42	25	29	31	38
$t_{STE\%}$	58	75	71	69	62
FM (N)	2690	2619	2976	2149	1893
FI (N·s)	638	979	1022	640	409
FA (N)	1655	1898	1912	1616	1262

FIG. 1. DYNAMOMETRICALLY MEASURED REACTION FORCE AND MEASURED VARIABLES BASED ON KINETIC ANALYSIS OF FZ(T) DURING SKI TURNS. A – FZ(T) FINAL GROUND REACTION FORCE, FZ = FZ1 + FZ2; B – GROUND REACTION FORCE ACTING ON THE SINGLE LEGS; C – EVALUATED VARIABLES.

Legend: t_{INI} – time of INI phase, t_{STE} – time of STE phase, t_{TOT} – total time of the turn, $t_{INI\%}$ – time of INI phase expressed at a percentage of the turn duration, $t_{STE\%}$ – time of STE phase expressed as a percentage of the turn duration, FM – maximal reaction force, FI – force impulse, FA – average value of FZ(t) computed from FI and the time of STE phase [$FA = FI/t_{STE} + Fg \cdot \cos(\alpha)$, where $Fg \cdot \cos(\alpha)$ is the component of the gravitational force perpendicular to the ground]

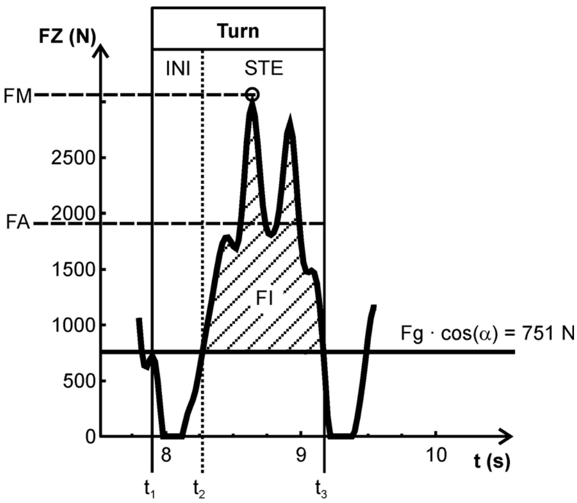

FIG. 2. KINETIC ANALYSIS OF THE GROUND REACTION FORCE FZ(T).
Legend: t_1, t_2, t_3 – key time information for determination of turn phases

and in right turns the left leg is the outer leg. In competition skiing where an expert skiing is expected, the quality of turning to both sides is supposed to be similar. In other words after a long time of skiing training it can be assumed that the laterality of the lower limb will not play a significant role.

The above mentioned consideration leads to the logical question whether or not the lateral preference of the lower limb does or does not have influence on the ski turn. The aim of the study is to discover whether a lateral preference of the lower limbs influences the execution of successive symmetrical carving turns or not. We can presume from a theoretical point of view that a turn where the outer leg is preferred will be different in comparison with a turn from the opposite side. In contrast to the given hypothesis an alternative hypothesis (H0) can be formulated. The long-term development of left and right turning causes the disappearance of the differences between both turns and the lateral preference does not influence their execution.

MATERIALS AND METHODS

The research was carried out with a group of six mature skiers comprised of very skilled skiing instructors and former alpine skiing national team members (men, age 26.5 ± 1.61 years old, body height 1.80±0.04 m, body weight 78.83±5.46 kg). The task was to ski at a competitive speed through a symmetrical slalom course constructed along the fall line where the vertical offset between the gates was 14 meters and the horizontal offset was 4 meters. Five turns were examined for each skier (three to the left and two to the right), making for a total of thirty turns. The lateral preference of the lower limbs was established on the basis of the following questions: which leg do you kick a ball with, which leg do you take off of the high jump and which is your preferred side when making a ski turn? All of the skiers had a right-sided lateral preference in the lower limb. All skiers preferred to turn to the left, with the exception of one skier (he had no lateral preference). The dynamometric method of measuring reaction force during ski turns was used to the research. The method used for taking experimental data was the kinetic analysis of the reaction force FZ(t), which acts perpendicularly to the surface of the ski. The final FZ(t) is the sum of reaction forces acting on the left and right skis. The graphical form of reaction forces acting on each ski, the final reaction force and measured variables are displayed in Figs. 1 and 2. Based on the FZ(t) curve the time of the duration of the turn and its initiation and steering phases, the magnitude of the force impulse and the maximum and average of the reaction force in individual turns were evaluated. Based on measured variables the symmetrical indices (SI = left/ right turn) were calculated.

The method of the kinetic analysis of the reaction force FZ(t), the criteria for the definition of the initiation and steering phases of ski turns, and a description of the dynamometrical system of measurement is described in detail in Vaverka and Vodickova (in review). On the basis of the STATISTICA version 8 statistical programme, the following statistical procedures were applied: basic statistical characteristics, Kolmogorov-Smirnov test of normality distribution and Mann-Whitney U test.

RESULTS

The basic statistical characteristics of the measured variables computed from all analyzed ski turns (n=30) are presented in Table 1. The results give the fundamental view about the duration of the time of turns and the magnitude of the force variables regardless of the direction of turning. The statistics indicate that the variability of measured variables is relatively great (coefficient of variation=16-44). Lower level of variability was found in the time of the turn phases (coefficient of variation = 10-23) whereas there was a greater amount of variability of the force variables (coefficient of variation=20-44). The greatest amount of variability was shown by the force impulse FI (coefficient of variation = 44). The normal distribution of all

TABLE 1. BASIC STATISTICAL CHARACTERISTICS OF MEASURED VARIABLES OF ALL MEASURED SKI TURNS

Variable	n	Mean	S.D.	CV	Min	Max	K-S test
t_{INI} (s)	30	0.492	0.115	23	0.300	0.740	*
t_{STE} (s)	30	0.852	0.163	19	0.540	1.180	*
t_{TOT} (s)	30	1.344	0.210	16	0.980	1.680	*
t_{INI}%	30	36.67	6.49	18	20	50	*
t_{STE}%	30	63.33	6.49	10	50	80	*
FM (N)	30	2241	511.7	23	1114	3612	*
FI (N•s)	30	647	282.4	44	125	1099	*
FA (N)	30	1548	305.7	20	961	1999	*

Legend: CV – coefficient of variation, K-S test – Kolmogorov-Smirnov test
* data conform to a normal distribution
t_{INI} – time of INI phase, t_{STE} – time of STE phase, t_{TOT} – total time of the turn, $t_{INI\%}$ – time of INI phase expressed at a percentage of the turn duration, $t_{STE\%}$ – time of STE phase expressed as a percentage of the turn duration, FM – maximal reaction force, FI – force impulse, FA – average value of FZ(t) computed from FI and the time of STE phase

TABLE 2. DIFFERENCES BETWEEN MEASURED VARIABLES OF THE LEFT AND RIGHT TURNS AND SYMMETRY INDICES

Variable	Left turn (n=18)		Right turn (n=12)		DIF	M-W U test	
	Mean	S.D.	Mean	S.D.		p	SI
t_{INI} (s)	0.504	0.126	0.473	0.097	0.031		
t_{STE} (s)	0.880	0.159	0.810	0.166	0.07	0.19	1.09
t_{TOT} (s)	1.384	0.216	1.283	0.194	0.101	0.23	1.08
t_{INI}%	36.4	6.67	37.08	6.47	0.68	0.75	0.98
t_{STE}%	63.6	6.67	62.92	6.47	0.68	0.75	1.01
FM (N)	2368	579.3	2051	325.6	317	0.06	1.15
FI (N•s)	695	316.1	576	215.5	119	0.17	1.21
FA (N)	1572	332.3	1514	271.3	58	0.60	1.04

Legend: SI – symmetry indices (SI = left/right turn), t_{INI} – time of INI phase, t_{STE} – time of STE phase, t_{TOT} – total time of the turn, $t_{INI\%}$ – time of INI phase expressed at a percentage of the turn duration, $t_{STE\%}$ – time of STE phase expressed as a percentage of the turn duration, FM – maximal reaction force, FI – force impulse, FA – average value of FZ(t) computed from FI and the time of STE phase

measured variables was proved in all cases (using a test for normality). The results of statistical analyses related to a lateral preference of the lower limbs and ski turns are shown in Table 2. Differential testing between left and right turns showed that there were no significant differences in any measured figures. The time of the steering phase (tSTE), maximal reaction force (FM) and force impulse (FI) are the variables which are the closest to the necessary level of significance. In spite of the fact that the analyses of differences have not been statistically significant, the magnitude of the measured variables suggested certain tendencies related to the principle of ski turns and laterality of the lower limbs. More information about these relations is included in the values of symmetry coefficients (Table 2). Turns to the left side (where the outer right leg is the dominant limb) have a longer time for the entire turn and also have a longer time during both phases of the turn. When comparing the duration of the two phases of the turn we can ascertain that the time of the preparation phase of left turns is shorter than the one of right turns. As for the duration of the steering phase it is vice versa. The biggest differences between left and right turns can be seen in the area of measured reaction force. The magnitude of the force applied by the skiers is greater during left turns.

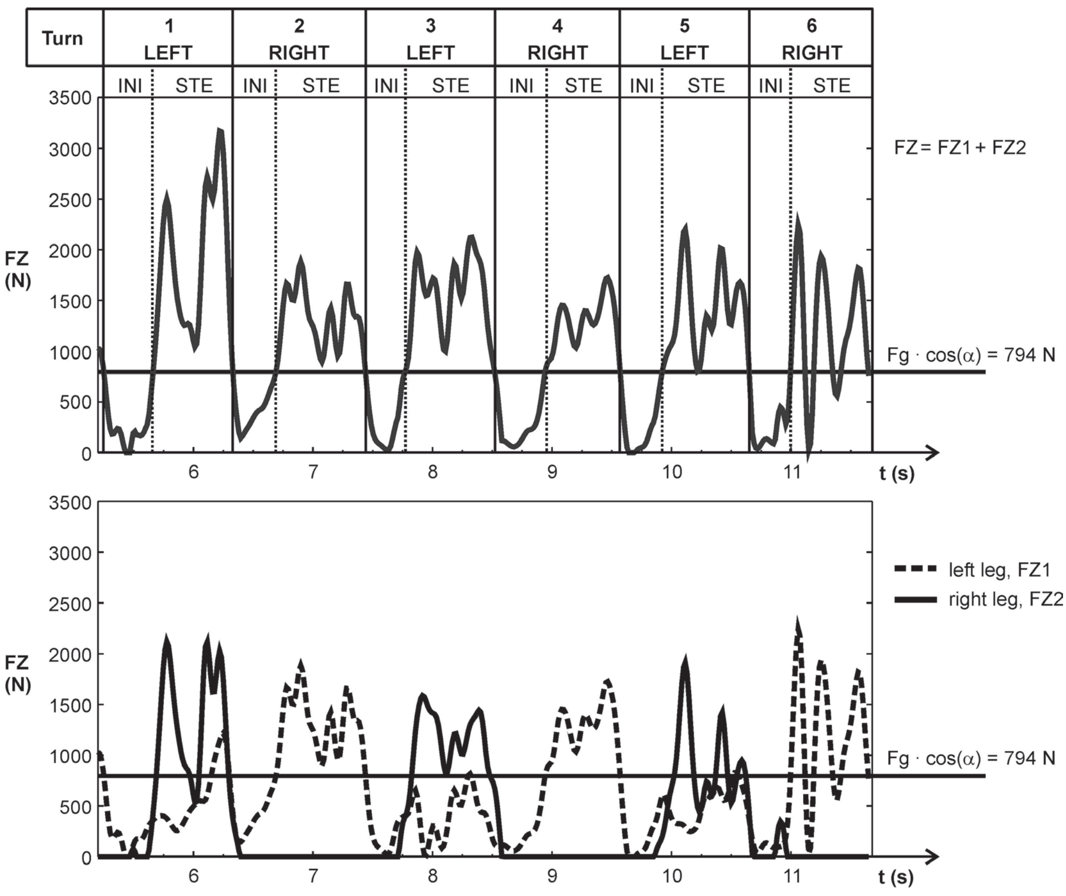

FIG. 3. GROUND REACTION FORCES FZ(T) DURING SKI TURNS (SKIER NO.5)

DISCUSSION

The methodology of the kinetic analysis of the reaction force during ski turns enables us to quantify the time proportionality of the two key phases of the turn and the amount of force exerted by the skier. The measured magnitude of the maximal reaction force during a turn was around 2.5-3.5 G and this corresponds with literature data [4,7,8]. The great variability of force impulses is primarily influenced by the different weights of the participants in the experiment.

Based on statistically non-significant differences between left and right turns the alternative hypothesis supporting the idea about the unimportant role of laterality in ski turns can be accepted. However, these strictly statistical starting points do not have to be the only grounds for the solution of our problem. We have to take into account the small number of analyzed ski turns and the quality of the tested skiers (former members of national ski team and very experienced ski instructors) as well. Even small differences in the execution of the movements can play a significant role when performed by such expert skiers. It is necessary to remember that all participants of the experiment have a preference for the right leg and their desire for turning to the left (except one participant) is more consistent. Let us look at two variants of the turns and interpret what the measured variables actually mean. We can see differences between measured variables in left and right turns which support the alternative hypothesis. A ski turn to the left (where the outer leg is the right leg – the preferred limb) differs from a right turn in regards to a longer time of duration, a proportionally longer time of duration of the steering phase in comparison with the initiation phase, and considerably greater values of the force variables. In regards to skiing it shows that left turns are crucial for the regulation of speed which is important for an optimal run on a symmetrically constructed track. Due to the position of the gates (the same distance, direction of the fall line) the turns should theoretically last the same amount of time and possess the same amount of force. It seems that also expert skiers prefer the left turns (where coordination is higher with the outer leg) for regulating the ride. A lateral preference is still evident with expert skiers because of the greater values of time and force in left turns.

An analysis of the reaction force FZ(t) gives complex information about the final forces acting on the skier. The magnitude and the variation of the reaction force in dependence on time is a mathematical sum of forces acting on the left and right skis. The variation of the partial component of reaction forces acting on each ski offers very important information about the influence of each leg on the final force of the turn. In Fig. 1B we can see great differences in the proportion of reaction forces measured on the left and right legs. The reaction forces acting on the left and right leg are relatively similar in left turns and the pattern of placing weight on skis is similar to that of a carving turn [7,8,13]. On the contrary, we found great differences between reaction forces acting on each leg during right turns. The model of proportionality of reaction forces in right turns is very close to a traditional parallel turn where more weight is placed on the outer leg [7,8,13]. We have also found very similar instances of reaction forces acting on each leg with the other participants of the experiment. Fig. 3 shows an example of a skier who produces greater differences in weight loading during a left and right turn in comparison with the skier in Fig. 1. Similar to the previous example, in left turns the distribution of weight on different legs is similar to a carving turn and right turns are typical of traditional parallel turns with more weight placed on the outer leg. The explanation of this given phenomenon is very interesting and informative. The subjects of the experiment were taught the traditional technique of turning at a young age with more weight placed on the outer ski and was followed by a transition to carving skiing after they had mastered traditional turning. Turning on the side where the outer leg is preferred allowed for better control of the turn according to the requirements of the carving technique. A turn to the opposite side, where the outer leg is not a preferred leg, was characterized by a return to the more safe form of the traditional parallel turn. The results indicated the most effective movement in ski turning in the situation where the outer leg in a turn is the preferred leg. The comparison of the quantitative evaluation of the final reaction force acting on a skier in combination with the assessment of the distribution of weight on each leg during a ski turn indicates the very important role of the laterality of the lower limbs in ski turning.

CONCLUSIONS

The influence of lateral preference of the lower limbs on the execution of a ski turn by expert skiers from a statistical point of view has not been confirmed. Factual analyses of measured variables in relation to the technique of turning showed that left turns where the outer leg is the preferred limb, take a longer time and produce greater force then right turns. The results have shown, that as for the control of the ride, the skiers preferably use the turns where the outer leg is their preferred limb. The role of the lateral preference of lower limbs on ski turn execution by expert skiers was also proven. Based on the results of this experiment it can be assumed that the stated method of the kinetic analyses of reaction force in combination with an evaluation of the weight placed on each leg during a ski turn could be a very useful way for assessing the effectiveness of one's technique during ski turns and as a guide for their improvements. It indicates the necessity to devote more attention to the question of laterality in alpine skiing in practice.

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