Dominant leg strength and proficiency in cross-country skiing

Ebru Cetin

School of Physical Education and Sport, Gazi University, Besevler, 06330 Ankara, Turkey

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Abstract The purpose of this study was to determine the effect of cross-country skiing training on dominant leg strength. The study included fifteen junior and twelve youth cross country skiers, and fourteen sedentary male volunteers. Test data were obtained from Cybex II Norm isokinetic strength measurement equipment. Statistical analysis was conducted using the Wilcoxon matched pairs test. Strength was determined at the 60°/sec (Isokinetic Speed 60°/sec Reps 5) and the 180°/sec (Isokinetic Speed 180°/sec Reps 20). Junior cross-country skiers did not have any significant difference for peak torque and ratio between legs (p<0.05). However, youth athletes and the control group had significant side differences in both quadriceps and hamstring muscle strength. Only the junior group did not have any significant ratio difference at 60°/sec, whereas only the control group had a significant ratio difference at 180°/sec between sides (p<0.05). According to the results of this study, there was no significant difference between right and left leg strength of the quadriceps (Q) and hamstrings (H), and Q/H ratios of junior cross country skiers (p<0.05).

Keywords: peak torque, isokinetic leg strength, cross-country skiing, dominant leg, Q/H ratio

Introduction

The dominant profile of a human usually develops at approximately 9 weeks in utero as the embryo develops the Moro reflex, a protective reflex for survival1). Dominant preferences in relation to the brain, eyes, ears, hands and feet evolve through environmental and programming influences experienced each day2). In evaluation of the training process, the determination of the dominant body side as well as its influence on the performance of basic techniques, have a major impact on sport performance3).

Most of the research on dominant side has covered strength and injury risks. Other research has looked at the dominant side in terms of biomechanics, speed and sport-specific technique evaluation3,5). Nevertheless, the literature includes contradictions, and some authors6,7) found no differences in peak torque outputs, regardless of dominance or sport activity level. A great majority of the studies on dominant leg have focused on soccer6,8,9). Although the concept of dominant leg may look to be advantageous in many types of sports, including soccer, it may also pose disadvantages, especially in terms of increased rates of injury6,10,11). Some researchers have suggested that dominant side training is effective for athletes especially at the professional level4,12).

Cross-country skiing is one of the most demanding endurance sports. Athletes have extraordinarily high aerobic power, both upper and lower body muscles are heavily involved up to various degrees in different skiing techniques. Competitive cross-country skiing has recently experienced rapid changes, with the addition of several new racing forms. In the past, researchers were sure that the most important parameter for competitive cross-country skiing performance was maximal oxygen consumption (VO2max)13,14). However, the increased diversity of competition, especially the widespread popularity of sprint races, has led researchers to review these factors. The increase in the speed factor in races puts forward the importance of strength among other motoric features of the neuro-muscular apparatus5). In addition to the effect of strength on performance, strength is also quite important in improving balance, technique and minimizing the risk of injury15,16). Cross-country ski athletes commonly use both sides of their body equally; although in some techniques they may use mainly one side according to race course or race distance and other conditions17,18,19). Hence, training for cross-country skiing includes very complex and diverse exercises.

The addition of demanding uniquely designed race courses and diversified race types requires using appropriate and effective techniques in the evolving sport of cross-country skiing. The foremost requirement for applying appropriate and effective techniques is strength13,20,21). Considering the characteristics of cross-country skiing, which is becoming increasingly competitive at the elite level, where minute differences play an important role in success, using the potential of both legs is important; thus both legs should be equally strengthened in competitive cross-country skiing beginning from a young age.

Therefore, the aim of this study was to evaluate cross-
country skiers in different age categories for dominant and non-dominant leg strength and the effect of cross-country skiing training on equally strengthened legs.

Materials and Methods

Subjects. The study included 41 male volunteers who were all right dominant (Table 1). Although dominancy is a wide subject, and measurement of dominance requires a series of tests, superior strength in one leg is referred to as “dominant side” in this study. Subjects were examined in 3 different groups: 15 junior (18.5 ± 2.1 years) cross-country skiers, 12 youth (14.5 ± 1.5 years) cross-country skiers, and 14 controls. Members of the control group were selected from high school students who were not active in any sports branch. Both the junior and youth cross-country skiers were competing at the national and international levels. The junior skiers had been training for at least six years; likewise, the youth skiers had at least three years of regular training in the same ski club. The training volume of the previous season for both groups is given in Table 2. The volume of training was increased on a yearly basis. All the subjects signed an informed consent form prior to testing, detailing the contents of the study. They were free to withdraw from the study at any time without giving any reason. The study was approved by the local ethical committee of Gazi University.

Test procedures. The peak torque (Newton-meters, Nm) and Q/H ratios of the quadriceps and hamstring muscles during concentric contraction in both legs were measured. Test data were obtained from Cybex Norm (Henley Corp, Sugarland, TX, USA) type isokinetic strength testing equipment. At first, all the subjects completed a familiarization session prior to testing at least 3 days earlier than actual testing session. On the first visit for measurement, subjects were tested for strength at 60°/sec for 5 repetitions for both legs, resting 5 minutes between changing sides. Measurement at 180°/sec for 20 repetitions took place at least two days apart from the first visit and, again, a 5 minute resting period was given for changing sides. The isokinetic strength measurements were taken in April, just after the competition season. Subjects performed the tests in a climate-controlled room, two hours after breakfast. They were instructed to refrain from any strenuous exercise for two days before the tests. When subjects arrived for testing they performed warm-up exercises on a Monark Bicycle Ergometer (Monark-Crescent AB, Varberg, Sweden) for 15 minutes (60 rpm, 105 W).

Measurements were taken in the sitting position. A lumbar cushion was placed to support the lumbar region. During knee extension/flexion measurements, the degree of rotation of the dynamometer bench was set at 40°, its back angle at 85°, the tilt of the dynamometer was adjusted for full extension of the knee joint, and its rotation to 40°. Angular velocities were chosen as 60°/sec for 5 repetitions and 180°/sec for 20 repetitions.

Concerning isokinetic measurements, an angular velocity of 180°/sec for 20 repetitions for general endurance strength, and an angular velocity of 60°/sec for 5 repetitions for maximal strength are commonly used standards11). Several studies have used these same generally accepted angular speeds and repetitions22-24).

Statistical analysis. Descriptive statistics (age, height, weight, strength) were expressed as mean ± SD. The corresponding differences in quadriceps and hamstring strength and ratios were evaluated by Wilcoxon matched pairs test, since the collected data was not normally distributed. P<0.05 was considered statistically significant. GraphPad Prism (GraphPad Software, San Diego, USA) was used for statistical analysis of the data. Average values were automatically calculated using every single repetition for both 5 and 20 repetition measurements by

Table 1. Physical characteristic of the subjects (Mean ± SD).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Junior (n=15)</th>
<th>Youth (n=12)</th>
<th>Control (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>167.5±11.4</td>
<td>161.5±9.2</td>
<td>165.6±6.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.7±12.4</td>
<td>56.2±4.7</td>
<td>60.9±7.5</td>
</tr>
<tr>
<td>Age (years)</td>
<td>18.5±2.1</td>
<td>14.5±1.5</td>
<td>18.7±2.4</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.6±1.7</td>
<td>21.3±1.8</td>
<td>22.2±1.1</td>
</tr>
</tbody>
</table>

Table 2. Training volume of youth and junior cross-country skiers in the previous season.

<table>
<thead>
<tr>
<th>Category</th>
<th>Distance (km)</th>
<th>Aerobic</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (h)</td>
<td>Distance/Sprint</td>
<td>Time (h)</td>
</tr>
<tr>
<td></td>
<td>Skiing</td>
<td>Roller</td>
<td>Running and</td>
</tr>
<tr>
<td>Youth</td>
<td>2700</td>
<td>300</td>
<td>75/25</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>570</td>
<td>1480</td>
</tr>
<tr>
<td>Junior</td>
<td>5900</td>
<td>450</td>
<td>70/30</td>
</tr>
<tr>
<td></td>
<td>1950</td>
<td>1480</td>
<td>2470</td>
</tr>
</tbody>
</table>
the isokinetic system software. The strength ratio of quadriceps to hamstrings was calculated as a percentage (Q/H ratio % = (leg flexion strength / leg extension strength) x100).

**Results**

**Differences in strengths between the dominant and non-dominant leg.** For both 60° and 180° angular velocities there was no significant difference in the peak torques of the junior skiers, while significant differences for quadriceps and hamstrings were found in the youth skiers and the control group between the dominant and non-dominant legs (Fig. 1 and Fig. 2).

At the angular velocity of 60°/sec for 5 repetitions, the peak torque values of junior skiers for quadriceps were 180.0 ± 17.7 Nm and 172.9 ± 19.7 Nm for dominant and non-dominant legs, respectively; and peak hamstring torque values were 105.9 ± 14.0 Nm and 100.6 ± 15.5 Nm. Dominant side quadriceps were 3.9% and hamstrings 4.2% stronger than non-dominant. The peak torques of the youth skiers were Q (quadriceps): 125.7 ± 34.6 Nm, 107.6 ± 35.8 Nm; H (hamstrings): 67.3 ± 11.6 Nm, 57.8 ± 11.7 Nm for dominant and non-dominant legs, respectively; and quadriceps muscle strength was 14.3% and hamstring 14.1% weaker in the non-dominant leg. The results of the control group were Q: 163.8 ± 14.6 Nm, 133.5 ± 14.8 Nm; H: 92.3 ± 11.0 Nm, 77.3 ± 6.4 Nm for dominant and non-dominant legs. The dominant leg quadriceps were 18.5% and hamstrings 16.3% stronger than the non-dominant.

At 180°/sec for 20 repetitions, the peak torques of the quadriceps of junior skiers were 126.3 ± 18.7 Nm and 121.6 ± 22.5 Nm, and the peak torques of hamstrings were 82.1 ± 10.4 Nm and 76.1 ± 6.6 Nm for dominant and non-dominant legs, respectively. Dominant side quad-

![Fig. 1](image1.png)  
**Fig. 1** Comparison of the leg strength between dominant and non-dominant side in 60 degree/sec (Mean ± SD). *: p<0.05 and **: p<0.01.

![Fig. 2](image2.png)  
**Fig. 2** Comparison of the leg strength between dominant and non-dominant side in 180 degree/sec (Mean ± SD). *: p<0.05 and **: p<0.01.
riceps were 3.7% and hamstrings 7.3% stronger than the non-dominant side. In the youth skiers, the values were Q: 80.7 ± 10.5 Nm, 70.2 ± 7.8 Nm and H: 54.0 ± 10.0 Nm, 44.8 ± 10.7 Nm for dominant and non-dominant legs, respectively. The dominant side quadriceps were 13.0% and hamstrings 16.9% stronger than the non-dominant side. In the control group, the values were Q: 116.6 ± 18.2 Nm, 81.3 ± 11.1 Nm; H: 78.5 ± 8.7 Nm, 64.1 ± 11.3 Nm for dominant and non-dominant legs, respectively. The dominant leg quadriceps were 29.0% and hamstrings 18.3% stronger than the non-dominant leg.

**Differences in ratios between the dominant and non-dominant leg.** When the values at angular velocities of 60°/sec and 180°/sec were examined, the Q/H ratios of the junior skiers at 60°/sec were 58.8 ± 5.9% and 60.1 ± 7.6% Nm, at 180°/sec were 64.9 ± 10.8% and 65.3 ± 11.2% Nm for dominant and non-dominant legs, respectively. In the youth skiers, the Q/H ratios were 54.3 ± 12.2 / 56.8 ± 12.2% Nm at 60°/sec, and 59.1 ± 14.2 / 61.3 ± 11.3% Nm at 180°/sec. And in the control group, the Q/H ratios were 56.9 ± 6.9 / 68.8 ± 5.1% Nm at 60°/sec, and 67.5 ± 9.7 / 79.3 ± 17.2% Nm at 180°/sec for dominant and non-dominant legs, respectively. The Q/H ratio in the control group was significantly different between dominant and non-dominant side at both angular speeds, while the ratio in the junior skiers was not significantly different between the dominant and the non-dominant side. In the youth skiers, the Q/H ratio was statistically significant at the speed of 60°/sec; however, no significant difference for the Q/H ratio was observed at the speed of 180°/sec (Fig. 3).

**Discussion**

The results revealed no significant difference in the junior skiers’ quadriceps and hamstring peak torques between dominant and non-dominant sides. Q/H ratios were not statistically different between the two sides for both angular speeds. The decrease in torques at 180°/sec was greater than 60°/sec. In the youth skiers and in the control group, the results were the opposite of those of the junior skiers. Peak torques for the quadriceps and hamstrings were significantly different at both 60°/sec and 180°/sec angular velocities. Q/H ratios for these two groups were significantly different except for the youth skiers at 180°/sec.

In the daily life of an individual, having a dominant left or right side of the body - and the difference in strength between the two sides - is not considered important. Neither is it classified as good or bad, true or wrong. However, when these factors are considered in terms of sporting performance, the situation may be different. Some studies suggest that having a dominant side is a favorable and effective factor in strength development and learning some basic techniques. The dominant side should even be developed by some specific methods in order to increase performance in sports such as football or basketball, and this development is very important in terms of sporting performance\(^4,12\). On the other hand, some studies on different types of sports support the idea of also developing non-dominant areas, and suggest that the ability of an athlete to use both sides equally well represents a potential performance advantage\(^6,7\). While many studies exist on upper body strength\(^25-27\), and using it as an indication of overall strength in cross-country skiing, the number of studies examining lower body strength is limited\(^28,29\), and studies on dominant side could not be found.

When the results of the current study are reviewed under the light of the above situation, it is thought that endurance training methods done on a regular basis for a long time can reduce dominant leg disparities in cross-country skiers. The effects of dominant and non-dominant sides on strength and basic technical skills among cross-country skiers may be different than other types of sports.
The basic reasons for these differences most likely are the diverse competition courses, distances and techniques used. The training regime undertaken by the study groups mainly consisted of distance training, 70% for junior and 75% for youth cross country skiers, respectively. The total amount of training increased by age. The possibility of an increase in strength encourages junior cross-country skiers to utilize all possible cross-country skiing techniques more affectively.

When both classical and freestyle techniques are considered, it can be seen that cross-country skiers use the dominant side excessively in kick double pole, V1 skate and alternate skate out of 9 different techniques. Recently, sprint races have been added to cross-country skiing disciplines, thereby requiring assessment of some different parameters for success. When long distance races of 15-90 km are considered, strength and endurance are important for the best performance and effective use of all four of a cross-country skiers’ extremities; however, in sprint races additional parameters are required and using appropriate techniques might be essential. Using the strongest part of the body might be considered an advantage, especially on uphill race courses, to increase velocity.

When the peak torques and Q/H ratios of the quadriceps and hamstrings of the current study were examined, no significant difference was found between dominant and non-dominant leg strength and ratio parameter among junior cross-country skiers. On the other hand, significant differences were found in dominant and non-dominant leg peak torque and ratio in the control group and youth skiers, except for the Q/H ratio of 180°/sec angular speed. This situation is thought to be related to training level and age of cross-country skiers in the youth category. When the characteristics of the training in cross-country skiing is considered, the intensity and volume of training increases by age, this along with the learning effect improves the use of both legs equally, in turn strengthening the non-dominant side to the same level as the dominant side.

The results of this study show that the dominant leg effect is diminishing as training age increases in cross-country skiing. Designing a training program, which puts more emphasis on equally strong legs, as early as possible, would help to increase potential performance and success of cross-country skiers. Cross-country skiing training results in equally strong legs. Because of its characteristics, cross-country skiing is probably the most demanding, stamina-requiring sport. Being able to use all body parts effectively in a harmonious way might be a determining factor for success, especially in long distance cross-country skiing. Thus, trainers should emphasize, in their training programs, reducing the strength imbalance between legs in young cross-country skiers.

Future studies may also include and compare cross-country skiers’ race times from the previous seasons, this would be helpful to identify the relationship between strength, performance and changes in dominant leg effect. Sprint races were introduced into cross-country skiing in the last decade. Cross-country skiers have just recently been specializing especially for sprint races; thus, different evaluation methods are essential for sprint races and conventional long distance cross-country skiing races.

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