

The effect of pre-season dance training on physical indices and back pain in elite cross-country skiers: a prospective controlled intervention study

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Objective: To evaluate the effect of pre-season dance training on back pain, joint mobility, and muscle flexibility, and on speed and agility in elite cross-country skiers.

Methods: 26 skiers participated (mean (SD) age, 19 (3.9) years). An intervention group (n = 16) had 12 weeks of dance training; a control group (n = 10) did not dance; otherwise both groups followed a similar pre-season physical training programme. Joint mobility and muscle flexibility of the spine, hip, and ankle were measured. Two sports related functional tests (slalom and hurdle) were also done. All measurements/ tests were carried out before and after the dancing period.

Results: Four (of six) subjects from the intervention group who initially complained of ski related back pain did not report back pain after the dance training; the three subjects with back pain from the control group were unchanged. At study onset the intervention group had a slightly impaired range of motion in the spine compared with the control group. After dance training, there was a better relation between kyphosis of the thoracic spine and lordosis of the lumbar spine, and a 7.1° increase in hip flexion with the knee extended (p = 0.02). In the control group hip extension decreased by 0.08 m on average (p = 0.01). No positive effects of dance training on sports related functional tests were observed.

Conclusions: Preseason dance training improved the range of hip motion and joint mobility and the flexibility of the spine. These improvements might explain the reduction in ski related back pain in the intervention group.

In Sweden cross-country skiing is one of the most popular sports. It places high demands on both the cardiovascular and the musculoskeletal systems, activating all the major muscle groups.¹ Cross-country skiers either use the classical style or the skating technique, and diagonal or double poling.

Considerable compressive and shearing forces acting on the lumbar disks can occur during this sport.² Earlier investigators have described back problems in cross-country skiers.^{3–5} Eriksson *et al* reported that the prevalence of back problems was 64% in young Swedish elite cross-country skiers.³ Mahlamäki *et al* found a higher percentage of back problems among young Finnish cross-country skiers than in age matched controls.⁴ Furthermore, the same investigators found that elite cross-country skiers with back problems often showed muscle tightness of their hip flexors and tension in the erector spinae musculature.⁵

Cross-country skiing is a monotonous sport often leading to muscle tightness,³ which can result in injuries or impaired sport performance. Svensson⁶ reported that a good range of motion is an important factor in acquiring a good technique in cross-country skiing. Good flexibility of the hip is also of special importance in cross-country skiing, particularly when employing the skate technique.⁶ Thus good joint mobility and muscle flexibility are of particular importance in this sport, while the frequency and the angular movements of the hip, knee, and ankle joints are important for speed development.⁷

Alricsson *et al* found that an eight month period of dance training improved speed, agility, hip flexion, and the range of motion of the spine in young cross-country skiers.⁸ During the ski season Swedish elite cross-country skiers at top level have a heavy ski training programme, practising for several hours almost daily. Furthermore, these elite skiers often are away for ski competitions. For these reasons a long term dance training period combined with ski training is not

possible. Our aim in the present investigation was therefore to evaluate the effect of additional pre-season dance training on joint mobility and muscle flexibility of the spine, hip, and ankle and on speed and agility in top level cross country skiers. Another aim was to determine whether pre-season dance training could reduce the number of skiers with ski related back pain.

METHODS

Study design

The study was a three month, prospective, controlled intervention study.

Subjects

Twenty six elite cross-country skiers (mean (SD) age, 19 (3.9) years) from the cross-country ski high school in Järpen and cross-country university in Östersund, Sweden, participated voluntarily in the study. All skiers were well trained young individuals at top international and national level of their age groups. Only skiers who were fully physically active were allowed to participate in the study. As Järpen and Östersund are boarding schools, the skiers came from different parts of Sweden. Competition to enter these schools is very high, with previous results in international and national races as merits.

The subjects were divided into an intervention group (six male, 10 female) and a control group (six male, four female). There were no significant differences between the groups with regard to age, height, or body weight (table 1). Assignment to group was, in effect, geographically based. Thus all skiers who were able to pursue the dance training programme on a weekly basis were included in the intervention group, while skiers who were unable to participate regularly in dance training, because of trips home to their families or other factors, formed the control group.

Table 1 Descriptive information about the study groups

Characteristic	Intervention group (n = 16)			Control group (n = 10)			p Value*
	Mean	SD	Range	Mean	SD	Range	
Age (years)	19.6	3.0	16 to 25	18.7	5.1	16 to 32	0.56
Height (m)	1.75	0.9	1.60 to 1.88	1.76	0.6	1.66 to 1.85	0.74
Weight (kg)	66.9	9.2	54.0 to 84.0	65.8	10.3	51.0 to 85.0	0.79

*Differences between intervention and control groups.

The two groups were of equivalent elite level. Because of the method of selection, the two groups did not include the same numbers of subjects.

Dance training

In the pre-season period, when the skiers underwent physical training such as roller skiing and running, the intervention group also received dance training, on average for six hours a week on two different occasions over 12 weeks. None of the skiers had any previous experience of dance training. The training, which generally did not involve a partner, was taught by an independent professional instructor and was carried out to music. The dance exercises included different types of dancing such as ballet, modern dance, jazz dance, and character dance, the aim being to improve balance, coordination, muscle flexibility, and agility. The school ski trainers were not involved in choosing the different dance exercises included in the programme. The skiers in both the intervention group and the control group followed the standard training programme of roller skiing and running. All types of physical exercise undertaken by the skiers in the two groups were carefully checked by their trainers and recorded in notebooks. The only difference in exercise training between the groups was that the intervention group added dance training to their standard physical training protocol.

Questionnaire on back pain

At the start of the study and three months later all subjects answered a questionnaire about back pain. This was a somewhat modified version of an earlier one published by Eriksson *et al* in 1996.³ It was tailored for cross-country skiers and therefore included questions about back pain related to cross-country skiing. We carried out a test-retest protocol on the questionnaire and found very good reliability ($r = 1.0$, Spearman rank correlation test; and $p = 1.0$, Wilcoxon signed rank test; submitted for publication). On recruitment to the present study, nine subjects—six from the intervention group and three from the control group—reported ski related back pain, although they all participated fully in the physical training programme. The degree of back pain did not differ between the skiers in the intervention group and those in the control group.

Range of motion and functional tests

The different joint motion and muscle flexibility measurements and the sports related functional tests were carried out by the same test leaders on all test occasions. All measurements and tests were done at the same time of the day on both test occasions. The test leaders had no knowledge of the subjects' group, which was not revealed until after the final measurement/test had been carried out at the three month testing.

Range of motion of the spine

Before the start of the study and three months later, measurements were made of the range of motion of the spine in each subject.

Flexion and extension of the thoracic and lumbar spine

Maximum active flexion and extension of the thoracic and lumbar spine were measured using Debrunner's kyphometer (Protek AG, Bern, Switzerland). This was done once in each direction (flexion, extension) with the subjects in the standing position, keeping their arms at their sides and looking straight forward.⁹⁻¹¹ The subject carried out a maximal active flexion and extension of the thoracic spine, which was measured between the second/third thoracic vertebrae and the 11th/12th thoracic vertebrae, and maximal active flexion and extension of the lumbar spine, which was measured between the 11th/12th thoracic vertebrae and the first/second sacral vertebrae. The results are given in degrees.

Rotation of the thoracic spine

A goniometer was used for measuring maximum active rotation of the thoracic spine, one trial in each direction, with the results given in degrees.¹²⁻¹³ Subjects sat on a stool with their feet "locked" around the stool legs in order to stabilise the pelvis. The goniometer was applied perpendicular to the sternum.

Lateral flexion of the lumbar spine

Maximum active lateral flexion of the lumbar spine was measured once in each direction. This measurement was done with the subject in a standing position, back against a wall, keeping the back and leg straight and the arms by the sides. The third finger was kept along the lateral side of the leg and marked with a pen on the thigh bilaterally before and after the measurements. A ruler was used to measure the distance in centimetres between the two marks.¹⁴

Thoracic kyphosis and lumbar lordosis

Debrunner's kyphometer (Protek AG, Bern, Switzerland) was used for measuring the difference between the thoracic kyphosis and lumbar lordosis of the spine. Subjects stood with their arms at their sides looking straight forward.⁹⁻¹¹ When measuring the thoracic spine the kyphometer was placed from a point between the second and third thoracic vertebrae to a point between the 11th and 12th thoracic vertebrae. When measuring the lumbar spine, the kyphometer was placed from between the 11th and 12th thoracic vertebrae to between the first and second sacral vertebrae.¹⁰⁻¹¹ One trial was allowed per variable. The result of the different measurement variables is given in degrees.

At the start of the study there were minor group differences in some of the ranges of movement in the spine. The intervention group had a slightly smaller range of movement in flexion-extension and rotation of the thoracic spine than the control group. The intervention group also had a slightly greater difference than the control group between the kyphosis of the thoracic spine and the lordosis of the lumbar spine (table 2).

Range of motion of the hip

Before the start of the study and three months later, different range of motion measurements of the hip were done in each

Table 2 Results for slalom test, hurdle test, and range of motion of the spine, hip, and ankle at the start of the study for both groups

Test	Intervention group (n = 16)			Control group (n = 10)			p Value*
	Mean	SD	Range	Mean	SD	Range	
Slalom test (s)†	11.8	0.9	10.6 to 13.7	11.4	0.8	10.4 to 13.0	NS
Hurdle test (s)†	10.8	1.1	8.9 to 13.5	10.9	1.2	9.4 to 12.7	NS
Thoracic flexion–extension (°)	28.8	8.3	17 to 45	38.9	15.3	17 to 73	0.04
Thoracic rotation (°)	117.6	17.5	90 to 158	144.0	27.8	109 to 195	0.006
Lumbar flexion–extension (°)	76.9	13.3	52 to 97	78.1	12.3	60 to 97	NS
Lateral flexion (m)	0.46	6.6	0.32 to 0.57	0.50	7.5	0.40 to 0.62	NS
Kyphosis–lordosis (°)	16.6	8.7	1 to 29	9.0	10.9	–6 to 28	0.03
Knee flexion, hip extension (m)	0.05	5.3	0.0 to 0.19	0.07	7.5	0.0 to 0.26	NS
Hip extension, knee extension (m)	0.20	6.9	0.08 to 0.36	0.23	5.1	0.16 to 0.27	NS
Hip flexion, knee extension (°)	100.2	12.4	65.0 to 117.5	97.7	19.3	75 to 140	NS
Hip abduction + external rotation (°)	139.7	8.4	129.0 to 156.5	136.9	8.7	127.0 to 151.5	NS
Ankle dorsiflexion (°)	34.1	4.2	26 to 40	36.9	7.1	30 to 54	NS

*Difference between groups.

†For the slalom and hurdle tests, n = 15 for intervention group.

Flexion–extension of the thoracic and lumbar spine, respectively, is reported as the total range of motion (flexion + extension). Rotation of the thoracic spine and lateral flexion of the spine, respectively, is reported as the total value of right and left sides.

Each range of motion variable of the hip and ankle joints is reported as the total value of right and left sides divided by 2.

subject. In an earlier study,¹⁵ the four flexibility tests for hip motion described below were assessed for reliability using the intraclass correlation coefficient according to Shrout and Fleiss.¹⁶ A dynamometer (Salter 235 PIAB, Täby, Sweden) was used to measure the force (in Newtons) applied by the examiner during the different range of motion measurements of the hip. On the first test occasion (at the start of the study), a force for the different hip measurements was established for each subject. This force was used on the second test occasion three months later. One trial of all the four hip motion measurements was used in each leg. At the start of the study there were no significant group differences in any of the hip movements studied (table 2).

Knee flexion with the hip extended

A knee flexion test with the hip extended was carried out according to Alricsson and Werner.¹⁵ The measurement was made with the subject in the prone position lying on a bench with the knee of the contralateral leg slightly flexed and the foot supported on the floor. The dynamometer was placed on the test leg perpendicular to the longitudinal axis of the tibia at the level of the mallei. The pelvis was manually stabilised in contact with the bench. The subject's knee was passively flexed to a maximally flexed position, where the force registered by the dynamometer was recorded. The distance between calcaneus and the buttock was measured using a centimetre ruler.

Hip extension with the knee extended

A hip extension test¹⁵ was similar to the previous test except that the knee was kept extended.¹⁵ The dynamometer was placed on the test leg perpendicular to the leg at the level of basis patellae. The test leg was raised passively as high as possible (maximum hip extension), where the force of the dynamometer was recorded. The distance between basis patellae and the bench was measured in centimetres.

Hip flexion with the knee extended

For the hip flexion test,¹⁵ the subject was measured in the supine position with a goniometer applied at the basis patellae. The pelvis and the contralateral leg were manually stabilised in contact with the bench. The dynamometer was placed perpendicular to femur. The test leg was raised passively with the knee in extension until maximum hip flexion was reached. At this position the force registered by the dynamometer was recorded and maximum hip flexion was measured in degrees.

Abduction and external hip rotation

This test involved a combination of abduction and external rotation of the hip.¹⁵ The subject was measured in the supine position lying on the floor with the knee extended. The pelvis was manually stabilised against the floor and the contralateral leg was secured against a firm support at the level of the ankle. A two legged goniometer^{12, 17} was applied bilaterally at the anterior superior iliac spine. The dynamometer was placed perpendicular to the test leg at the level of the mallei. The test leg was abducted passively as far as possible, keeping the hip in external rotation. In this position the force registered by the dynamometer was recorded and the range of motion was measured in degrees.

Ankle dorsiflexion

Ankle dorsiflexion was measured in degrees using a goniometer. The subject stood with one leg in front of the other. The goniometer was applied at the apex of the patella on the posterior leg, which was the test leg. The subject was asked to lean forward and dorsiflex the ankle maximally while keeping the knee straight and the heel against the floor.¹² At the start of the study there was no significant group difference in ankle dorsiflexion (table 2).

Sports related functional tests

Before the start of the study and three months later all the subjects undertook two sports related functional tests, the slalom test and the hurdle test. Both these tests, which emphasise speed and agility, have high reliability.¹⁸ The tests were done indoors after a standardised warm up programme. At the start of the study there were no significant group differences in either the slalom test or the hurdle test (table 2).

Slalom test and hurdle test

Six hurdles 60 cm high and 80 cm wide were placed over a total distance of 12 metres at two metre intervals. For the slalom test (a speed test) the subjects ran at maximum speed in a slalom pattern between the hurdles forward and back to the starting point. For the hurdle test (an agility test) the subjects jumped over the first hurdle, crawled under the second, jumped over the third, and so on until they had cleared the sixth and final hurdle, at which point they ran directly back to the starting point taking the shortest path. For both these tests the time was measured manually in seconds using a sports chronometer. The test leader started the chronometer at the moment when the subjects crossed

the starting line with their "first" foot, and stopped it when their "last" foot crossed the same line.¹⁸

Statistical analysis

Descriptive statistics (mean, SD, range) were used. Student's *t* test for independent variables was employed when comparing the subjects of the intervention and control groups for age, height, and body weight. Possible group differences in the range of motion measurements of the spine, hip, and ankle, and the two sports related functional tests were analysed at the second test occasion using the *t* test for independent variables. Possible differences in the same indices within the intervention group before and after dance training were analysed using the *t* test for dependent variables. The level of significance was set at 5%.

Ethical considerations

The study design was approved by the ethics committee at the Karolinska Institute. All subjects gave their informed consent to participate in the investigation.

RESULTS

On average 79% of the skiers from the intervention group participated in all the dance training sessions, while 21% did not attend every session because of illness or travel problems.

Back pain

Four of the six subjects from the intervention group who had reported ski related back pain at the start of the study no longer complained of back pain after the 12 week period of dance training. The other six subjects, three from each group, did not report any changes in their back pain.

Range of motion of the spine

After dance training the intervention group showed improvement in the different indices of thoracic and lumbar spine flexibility (table 3). In comparison with the control group some of these variables showed slight impairment before dance training. In the control group there were no differences in any of the range of spinal motion measurements at the three month testing.

Range of motion of the hip

After dance training the intervention group showed an increase in hip flexion by, on average, 7.1° ($p = 0.02$). The control group showed a decrease in hip extension at the three month test occasion (0.08 m reduction, $p = 0.01$) (table 3).

Ankle dorsiflexion

After dance training the intervention group showed an increase in ankle dorsiflexion by, on average, 3.5° ($p = 0.0007$) (table 3).

Sports related functional tests

After the study period there were no significant differences in either the slalom test or the hurdle test between the intervention group and the control group, and no significant improvements were found in either of the groups (table 4).

DISCUSSION

Our study showed that additional pre-season dance training had a positive effect on joint mobility and muscle flexibility of the spine in top level cross-country skiers. At the start of the study these athletes had a slight impairment of their range of spinal motion compared with a control group.

The subjects from the intervention group increased their range of motion in flexion-extension and rotation of the spine. We believe that this was the result of the type of exercises used within the dance training programme, which was aimed at improving posture, flexibility, and coordination. Furthermore, there was an increase in lateral flexion of the spine after dance training. The same increase in flexion-extension and lateral flexion of the spine was also shown after a dance training programme lasting eight months during the ski season in a group of somewhat younger elite cross-country skiers.⁸ Although, the increase in lateral flexion of the spine was small in the present study it could be expected to improve the skiers' technique in diagonal poling by easing the propulsion of the pelvis and hip and of the contralateral upper extremity, which characterises diagonal poling in this sport.

The relation in degrees between the kyphosis of the thoracic spine and the lordosis of the lumbar spine decreased after three months of dance training. Several cross-country skiers at the top level have developed a larger kyphosis relative to their lumbar lordosis. A possible reason for this could be the long training required for this type of skiing, which involves keeping the spine in a static flexed position—above all when skiing using the classic technique. Wojtys *et al* reported that a high exposure to intensive athletic training might increase the risk of developing adolescent hyperkyphosis in certain sports.¹⁹

At the start of our study the subjects from the intervention group showed a more pronounced difference between kyphosis and lordosis of the thoracic and lumbar spine than the control group. Wojtys *et al* reported that there is a known association between hyperkyphosis and adult onset back pain.¹⁹ This might at least partly explain why there were more subjects from the intervention group who complained of back pain at the start of the investigation. Four of the six subjects who reported ski related back pain from the intervention group did not complain of this after the period of dance training. Owing to the small number of subjects we cannot prove that this reduction in back pain depended on the dance training programme. However, we can speculate that, as the

Table 3 Differences in range of motion of the spine, hip and ankle between the first (start of study) and second (after three months) test occasion for both groups

Movement	Intervention group (n = 16)			Control group (n = 10)			I versus R, p value
	Mean	SD	p Value*	Mean	SD	p Value*	
Thoracic flexion-extension (°)	11.9	11.1	0.0006	-0.9	10.6	NS	0.02
Thoracic rotation (°)	13.6	12.2	0.0005	-9.4	19.4	NS	0.009
Lumbar flexion-extension (°)	4.8	6.8	0.01	-0.5	9.0	NS	NS
Lateral flexion (m)	0.03	5.4	0.02	-0.01	5.0	NS	NS
Kyphosis-lordosis (°)	-6.2	5.2	0.0002	0.4	8.4	NS	NS
Knee flexion, hip extension (m)	-0.004	2.8	NS	-0.006	7.9	NS	NS
Hip extension, knee extension (m)	-0.03	8.4	NS	-0.08	8.2	0.01	NS
Hip flexion, knee extension (°)	7.12	11.0	0.02	-6.1	11.4	NS	0.02
Hip abduction + external rotation (°)	0.28	5.9	NS	2.9	7.8	NS	NS
Ankle dorsiflexion (°)	3.5	2.6	0.00007	-0.55	2.2	NS	0.001

*Differences within groups.

Table 4 Slalom test, hurdle test, and range of motion of the spine, hip, and ankle at the end of the study

Test	Intervention group (n = 16)			Control group (n = 10)			p Value*
	Mean	SD	Range	Mean	SD	Range	
Slalom test (s)†	12.2	1.0	10.2 to 13.4	11.9	1.3	10.3 to 13.6	NS
Hurdle test (s)†	10.5	0.8	8.6 to 11.7	10.9	1.2	9.6 to 12.9	NS
Thoracic flexion-extension (°)	40.7	11.7	12 to 52	38.0	13.1	17 to 60	NS
Thoracic rotation (°)	131.2	18.6	96 to 160	134.6	22.3	100 to 180	NS
Lumbar flexion-extension (°)	81.6	12.1	57 to 102	77.6	10.2	60 to 94	NS
Lateral flexion (m)	0.49	4.9	0.43 to 0.60	0.48	6.2	0.36 to 0.56	NS
Kyphosis-lordosis (°)	10.3	9.9	-11 to 25	8.2	8.4	-5 to 23	NS
Knee flexion, hip extension (m)	0.04	3.9	0 to 13	0.07	3.2	1 to 11	NS
Hip extension, knee extension (m)	0.16	4.1	0.06 to 0.23	0.15	6.2	0.07 to 0.25	NS
Hip flexion, knee extension (°)	107.3	10.8	90 to 129	91.6	23.7	65 to 140	0.03
Hip abduction + external rotation (°)	140	6.3	129.5 to 151	139.8	7.9	129.5 to 147.5	NS
Ankle dorsiflexion (°)	37.6	4.2	27 to 43	36.4	7.3	28 to 51	NS

*Differences between groups.

†For slalom and hurdle tests, n = 12 in intervention group and n = 7 in control group.

three subjects from the control group who reported back pain continued to complain of back problems, the dance exercises may have played a role in reducing back pain. Furthermore, there often seems to be a correlation between tightness of the hamstring muscles and back problems. In the present investigation the skiers from the intervention group increased their hip flexion with the knee extended, which is a test of hamstring flexibility. This may also be a factor explaining the reduction in back pain in the intervention group.

Svensson⁶ pointed out the importance of a good range of motion of the hip, both from an injury prevention point of view and from a technical point of view in cross-country skiers. After three months of dance training the subjects from the intervention group improved their hip flexion, while the controls showed a reduction in hip extension. The decreased mobility in hip extension in the control group could be explained by the fact that major muscles such as the hip flexors are very active in cross-country skiing,^{1, 5} and hard working muscles are likely to become shortened.¹⁷ The dance training included flexibility training with stretching exercises, which may explain the increase in hip flexion in the intervention group.

Ankle dorsiflexion increased after dance training. However, this was a small increase (3.5°), which probably has no clinical relevance. Furthermore, Khan *et al* reported that dorsiflexion did not change over time because it is limited by bony apposition rather than by soft tissue.²⁰

The dance training did not lead to any changes in sports performance as assessed by sports related functional tests (the slalom test and the hurdle test). Both these tests, which include sprint distances, put large demands on fast acceleration and running ability. However, these indoor "running"

tests may not reflect important aspects of cross-country skiing. To our knowledge there are no sports related functional tests that imitate the demands of cross-country skiing. As skiing is done outdoors, it is likely that weather and snow conditions differ from time to time, which will affect the reliability of this type of functional test. This might be the reason for the lack of such tests. The dance training done in the present study was aimed at improving balance, coordination, muscle flexibility, and rhythm, which could extent explain why there were no improvements in the slalom and hurdle tests.

The results of our study suggest that it may be important to carry out a pre-season examination of cross-country skiers to identify those in whom dance training could improve the flexibility of the spine. As tension in the erector spinae musculature has been reported earlier in cross-country skiers with back problems,⁵ this improvement of flexibility might lead to a reduced risk of back pain.

In the light of our findings, we recommend additional pre-season dance training in cross-country skiers with an impaired range of motion of the spine, and also as a complement to the monotonous ski training that cross-country skiers have to undertake.

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Take home message

- Additional preseason dance training:
 - had a positive effect on joint mobility and muscle flexibility, including the relation between kyphosis of the thoracic spine and lordosis of the lumbar spine, in elite cross-country skiers with a slightly impaired range of motion of the spine.
 - had a positive effect on mobility in hip flexion with the knee extended in elite cross-country skiers.
 - showed a tendency to reduce ski related back pain in elite cross-country skiers with back problems.

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