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original research

Lower Leg Anterior and Lateral Intracompartmental Pressure Changes Before and After Classic Versus Skate Nordic Rollerskiing

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Context: Chronic exertional compartment syndrome (CECS) is a debilitating condition resulting in loss of function and a decrease in athletic performance. Cases of CECS are increasing among Nordic skiers; therefore, analysis of intracompartmental pressures (ICPs) before and after Nordic skiing is warranted.

Objective: To determine if lower leg anterior and lateral ICPs and subjective lower leg pain levels increased after a 20-minute Nordic rollerskiing time trial and to examine if differences existed between postexercise ICPs for the 2 Nordic rollerskiing techniques, classic and skate.

Design: Crossover study.

Setting: Outdoor paved loop.

Patients or Other Participants: Seven healthy Division I Nordic skiers (3 men, 4 women; age = 22.71 ± 1.38 y, height = 175.36 ± 6.33 cm, mass = 70.71 ± 6.58 kg).

Intervention(s): Participants completed two 20-minute rollerskiing time trials using the classic and skate technique in random order. The time trials were completed 7 days apart. Anterior and lateral ICPs and lower leg pain scores were obtained at baseline and at minutes 1 and 5 after rollerskiing.

Main Outcome Measure(s): Anterior and lateral ICPs (mm Hg) were measured using a Stryker Quic STIC handheld monitor. Subjective measures of lower leg pain were recorded using the 11-point Numeric Rating Scale.

Results: Increases in both anterior ($P = .000$) and lateral compartment ($P = .002$) ICPs were observed, regardless of rollerskiing technique used. Subjective lower leg pain increased after the classic technique for the men from baseline to 1 minute postexercise and after the skate technique for the women. Significant 3-way interactions (technique × time × sex) were observed for the anterior ($P = .002$) and lateral ($P = .009$) compartment ICPs and lower leg pain ($P = .005$).

Conclusions: Postexercise anterior and lateral ICPs increased compared with preexercise ICPs after both classic and skate rollerskiing techniques. Lower leg pain is a primary symptom of CECS. The subjective lower leg pain 11-point Numeric Rating Scale results indicate that increases in lower leg ICPs sustained during Nordic rollerskiing may increase discomfort during activity. Our results therefore suggest that Nordic rollerskiing contributes to increases in ICPs, which may lead to the development of CECS.

Key Words: chronic exertional compartment syndrome, compartment syndrome, anterior compartment, lower leg pain Nordic skiing

Key Points

- The exact cause of chronic exertional compartment syndrome is currently unknown.
- The diagnosis of chronic exertional compartment syndrome is increasing within the competitive Nordic skiing population.
- Increases in anterior and lateral intracompartmental pressures were observed after a 20-minute time trial using either the classic or skating Nordic rollerskiing technique.

Chronic exertional compartment syndrome (CECS) is a debilitating condition resulting in loss of function and a decrease in athletic performance. In general, a compartment syndrome occurs when the circulation and function of tissues within a closed space are compromised by increased pressure within that space.[1] An increase in tissue pressure within an enclosed space can threaten perfusion and tissue viability. In the case of CECS, this increase in tissue pressure within the confined space is reversible and will decrease after exercise ceases.[2] Common symptoms of CECS in the lower leg include burning, aching, paresthesia, weakness, and an inability to dorsiflex the foot. These symptoms are detrimental to performance and, if left untreated, have the potential to end an athlete's career. Chronic exertional compartment syndrome has been reported among runners, cyclists, and military personnel.[3] Recently, increasing anecdotal evidence of CECS among competitive Nordic skiers has been shown; however, no researchers have examined the relationship between Nordic skiing and intracompartmental pressures (ICPs).

Rollerskiing is a typical dry-land method of Nordic ski training and may be performed using either the classic or the skate technique. Rollerskis are shortened Nordic skis with 1 wheel at each end designed to be used on smooth indoor or outdoor surfaces. Classic rollerskiing uses the same kick-and-glide motion as on snow. Classic rollerskis have wider wheels than skate rollerskis. A ratchet

mechanism on 1 wheel only rolls forward, providing unidirectional travel and limiting negative gain. Skate rollerskiing uses the same lateral leg push as on snow. Skate rollerskis have narrower wheels, similar to in-line skates, and both wheels roll freely in either direction. For both techniques, boots and bindings are the same as those used for Nordic skiing on the snow.

Anecdotally, some athletes complain that they experience more lower leg pain during classic rollerskiing than classic snow skiing, which could be attributed to the weight of the ski (approximately 2.5 kg per pair of classic rollerskis compared with approximately 1.18 kg per pair of classic snow skis). More recent anecdotal evidence has suggested that any increased pressure observed during the classic rollerskiing technique may be attributed to the quality of the rollerski wheels and the skier's effort needed to maintain forward tracking and control of the ski while in motion. This suggestion is similar to anecdotal reports of increased lower leg pain while skate skiing in icy conditions, when one must sustain muscular contractions in the lower leg and foot to maintain control of the ski.

It is unknown whether Nordic skiing causes chronic increases in anterior and lateral ICPs, which may contribute to the development of CECS. Combined with a thorough history and clinical examination, ICP testing is the gold standard used to diagnose CECS.[4] In this study, if anterior and lateral ICPs increased during Nordic rollerskiing, the findings could point to Nordic rollerskiing as a possible contributor in the development of CECS. Coaches, athletes, and health care personnel may then seek modified skiing techniques and equipment to avoid increased ICPs during Nordic rollerskiing.

The purpose of our study was to determine if ICPs of the anterior and lateral lower leg compartments increased among collegiate Nordic skiers after a 20-minute rollerskiing time trial. We also aimed to determine whether postexercise ICPs differed for the classic rollerskiing technique versus the skate rollerskiing technique. We hypothesized that the ICPs of both the anterior and lateral lower leg compartments would increase among collegiate Nordic skiers after the 20-minute time trial. We also hypothesized that postexercise anterior and lateral ICPs would be higher after the skate rollerskiing technique than the classic rollerskiing technique. Significant results will allow physicians, athletic trainers, coaches, and athletes to better understand CECS and the Nordic skiing population, which may lead to modified training methods or injury-prevention practices for both symptomatic and asymptomatic skiers.

METHODS

After the study was approved by the University of Utah Institutional Review Board, collegiate Nordic skiers were invited to attend an informal meeting about the study. Athletes were told that participation in the study was voluntary, and they could drop out for any reason throughout the study. Questions regarding protocol were answered, and each recruit signed a consent form agreeing to take part in the study. Each participant was required to complete a Preparticipation Health Questionnaire (PPHQ) and answer questions regarding his or her experience with Nordic skiing as well as any history of lower leg pain. Once the consent form and PPHQ were submitted, the participant was randomly assigned to a technique order group, which designated the technique (either classic or skate rollerskiing) for the first trial. Next, each participant scheduled 2 time trials 7 days apart.[5] Athletes were instructed to arrive at each trial well rested, having performed no exercise on the test day.

Table 1. Participant Demographics (N = 7)

Demographic	Mean ± SD
Age, y	22.71 ± 1.38
Height, cm	175.36 ± 6.33
Weight, kg	70.71 ± 6.58
Resting heart rate, bpm	51.83 ± 9.08
Maximum heart rate, bpm	192.07 ± 0.84
Skiing experience, y	10.57 ± 2.94

Participants

We recruited 8 volunteer Nordic skiers for this study. One skier dropped out before testing began, leaving 7 individuals (3 men and 4 women; age = 22.71 ± 1.38 y, height = 175.36 ± 6.33 cm, mass = 70.71 ± 6.58 kg) to complete the study. All volunteers were collegiate Nordic skiers averaging 500–600 training hours per year and registered with the International Ski Federation. All skiers had trained using the classic Nordic skiing technique and the skate Nordic skiing technique for at least the past 12 months, and they also had experience using rollerskiing as a dry-land method of training. Due to anecdotal evidence that a greater percentage of Nordic skiers from the United States are diagnosed with CECS, all participants met the inclusion criteria stating that they had trained in the United States for at least 85% of the time over the past 12 months. All participants were asymptomatic and healthy, with no history of knee, lower leg, or ankle surgery. Participant demographics are provided in Table 1.

Instrumentation

The course for the 20-minute time trial was a paved loop with lanes specifically created for joggers and cyclists, separate from motorized vehicle traffic. The paved loop was approximately 2.21 km and had a total elevation gain of 26 m and a total elevation change of 51 m. Trials were performed 7 days apart to avoid residual effects.[5] Each participant arrived at the course 15 minutes before his or her scheduled time slot for setup, baseline testing, and completion of the 7-Day Physical Activity Record Interview. The 7-Day Physical Activity Record was used to determine if the athletes' activities were similar during the weeks before the first and second tests. In addition, each woman was required to take a pregnancy test (First Response Early Pregnancy Test; Church & Dwight Co, Inc, Ewing, NJ) to determine if she should be excluded from the study to prevent any potential harm to a growing fetus. Finally, each participant put on the same heart-rate monitor (model FT 80; Polar Electro Inc, Lake Success, NY), a safety vest, and either classic or skate boots. To eliminate any differences between skis during testing, 1 pair of classic rollerskis and bindings and 1 pair of skate rollerskis and bindings were used for all testing sessions. For financial reasons and to maintain a comfortable and familiar testing

Table 2. Statistical Analysis of Anterior and Lateral Intracompartmental Pressures and Lower Leg Pain Scores

	Intracompartmental Pressure					
	Anterior		Lateral		Lower Leg Pain	
Variable(s)	F Value	*P* Value	F Value	*P* Value	F Value	*P* Value
Technique	14.17	.002	0.51	.506	0.004	.955
Technique × sex	22.46	.005	1.94	.222	9.884	.026
Time	22.01	.000	13.35	.002	4.629	.038
Time × sex	1.51	.267	0.44	.658	0.433	.654
Technique × time	9.62	.005	1.07	.379	0.068	.935
Technique × time × sex	13.23	.002	7.74	.009	9.453	.005

environment, the participants wore their own classic and skate boots and used their own classic and skate poles.

Procedures

For ICP testing, participants lay on a treatment table in the supine position with their boots on. Because it is common for CECS to occur bilaterally, we took anterior and lateral ICP measurements from the participant's dominant leg. *Leg dominance* was determined by asking the participant which foot he or she would naturally use to kick a ball. The participant was positioned with the leg in 90° of flexion hanging off the table and instructed not to pull away from the needle to avoid any movements that might alter the readings. After injecting lidocaine for numbing purposes, 2 Board-certified orthopaedic surgeons obtained all ICPs using a handheld monitor (model Quic STIC 295; Stryker Surgical, Kalamazoo, MI). Anterior ICPs were obtained from the muscle belly of the tibialis anterior over the midshaft of the tibia. Lateral ICPs were obtained from the peroneal muscle bellies between the lateral malleolus and fibular head. We circled the injection site with a permanent marker to make sure testing occurred in the same location during the postexercise measures and the subsequent time trial. All injection sites were wiped with sterile gauze and covered with a Band-Aid (Johnson & Johnson Consumer Companies, Inc, New Brunswick, NJ) and Powerflex (Andover Healthcare, Inc, Salisbury, MA) to be worn loosely during the 20-minute time trial. While baseline ICPs were being obtained, the primary investigator (K.M.W.) used a Microlet lancet (Bayer AG, Leverkusen, Germany) to prick the participant's finger and a Lactate Plus Blood Analyzer (Sports Resource Group, Inc, Hawthorn, NY) to measure blood lactate level. The participant was also instructed to use the 11-point Numeric Rating Scale (NRS) to rate any current leg pain that was not related to the actual ICP testing, such as a needle stick.

Just before exercise, each participant was read a script describing the time-trial protocol. The script instructed the participant to rollerski for 20 minutes while keeping his or her heart rate between 85% and 90% of the maximum heart rate using the formula: maximum heart rate = 208 − (0.7 × age).[6] This heart-rate range was given to each participant to note on the heart-rate monitor during activity. Each participant was also shown the Borg Rating of Perceived Exertion Scale and instructed to exercise at a level of 15 to 17, which is between *hard* and *very hard*, or *very strenuous*.[7] When using the classic rollerski technique, the participant was instructed to double pole as little as possible to maintain continuous lower leg movement. When using the skate rollerskiing technique, the participant was instructed to use the V2 method of poling to maintain even poling on both sides. The importance of skiing for only 20 minutes was expressed to the participant. In the unforeseen event of a complication or injury during the test, the participant was instructed to immediately stop activity and wait on the side of the course for assistance.

Data Collection

Postexercise methods for obtaining measurements were identical to the preexercise methods. Anterior and lateral ICPs, blood lactate levels, and lower leg pain were each obtained at 1 minute postexercise and at 5 minutes postexercise. All data were recorded at baseline, 1 minute postexercise, and 5 minutes postexercise.

RESULTS

We used appropriate data-screening techniques to identify missing values or outliers. The normality of anterior and lateral ICPs and lower leg pain ratings was confirmed. The Mauchley test for sphericity was calculated to examine the variance of the differences between all possible pairs of groups, and the assumption was met. To make sure there were no confounding variables that would affect the results, we measured blood lactate level and physical intensity and examined the 7-Day Physical Activity Record interviews for each participant.

The data were analyzed using a 2 × 2 × 3 mixed-factorial repeated-measures design. The independent variables were the Nordic ski techniques (classic or skate), sex (male or female), and time (preexercise, 1 minute postexercise, or 5 minutes postexercise). The primary dependent variables were anterior and lateral compartment ICPs (mm Hg) and subjective lower leg pain scores from the 11-point NRS.

Participant intensity, measured by recording average heart rate (bpm) and blood lactate level (mmol/L), was the same regardless of the technique used and therefore ruled out as a confounding variable. No technique interaction occurred for average heart rate ($P = .896$). We expected and observed an increase in blood lactate levels across time ($P \leq .000$). However, the 3-way interaction for blood lactate levels was not significant ($P = .257$).

Anterior Compartment

A 3-way interaction for the anterior compartment was present ($F_{2,10} = 13.23$, $P = .002$; Table 2). We conducted an additional data analysis using a Helmert contrast, which revealed a technique × time × sex interaction between the preexercise measure and both postexercise measures ($F_{1,5} = 16.633$, $P = .010$). A moderator approach to the significant

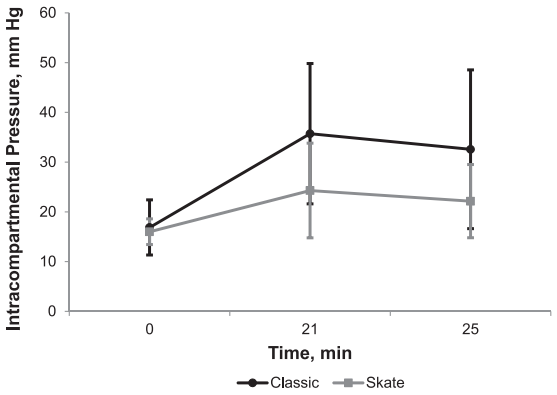

Figure 1. Anterior intracompartmental pressures for skate versus classic Nordic rollerskiing technique.

interaction effect using a single-degree-of-freedom contrast[8] demonstrated that men had an increase in postexercise anterior ICP after the classic rollerskiing technique compared with the skate rollerskiing technique at 1 minute ($t = 8.434$, $P < .05$) but no decrease at 5 minutes for either technique. Women showed a similar increase in postexercise anterior ICPs after the classic or skate rollerskiing technique at 1 minute postexercise but a similar nonsignificant decrease in ICPs at 5 minutes for both techniques (Table 2 and Figure 1). Anterior ICP increased over time ($P < .001$), regardless of technique or sex. The individual anterior ICP data are contained in Table 3.

Lateral Compartment

A 3-way interaction was noted for the lateral ICPs ($F_{2,10} = 7.74$, $P = .009$; Table 2 and Figure 2). An additional data analysis using a Helmert contrast revealed that the baseline values were lower than the average of both postexercise pressure values ($F_{1,5} = 38.045$, $P = .002$). A single-degree-of-freedom contrast[8] for the men indicated that lateral pressure increased more with the classic technique than the skate technique from baseline to 1 minute postexercise ($t = 3.076$, $P < .05$) and decreased more with the skate technique than the classic technique from 1 minute postexercise to 5 minutes postexercise. For women, ICP increased similarly with both techniques from baseline to 1 minute postexercise; however, the women showed a greater reduction in lateral pressure for the classic technique from 1 minute postexercise to 5 minutes postexercise compared with the skate technique. Lateral ICP increased over time ($P = .002$), regardless of technique or sex. The individual lateral pressure values are presented in Table 3.

Lower Leg Pain

We observed a 3-way interaction for perception of lower leg pain ($F_{2,10} = 9.453$, $P = .005$; Table 2 and Figure 3). An

Table 3. Anterior and Lateral Intracompartmental Pressures (ICPs) and Lower Leg Pain Scores by 11-Point Numerical Rating Scale and Sex for Classic Versus Skate Nordic Rollerskiing Technique

			Participant (Sex) Technique						
Technique, Trial 1	Measurement	Time	1 (M) Classic	2 (M) Classic	3 (F) Skate	4 (F) Skate	5 (F) Skate	6 (F) Classic	7 (M) Classic
Classic									
	Anterior ICP[a]								
		Preexercise	18[c]	14	15[c]	20	8	17[c]	26[c]
		1 min Postexercise	58[c]	42[c]	20	32[c]	31[c]	29	47[c]
		5 min Postexercise	58[c]	39[c]	18	28[c]	26[c]	13	46[c]
	Lateral ICP								
		Preexercise	12	17[c]	13	16[c]	8	11	16[c]
		1 min Postexercise	22	40[c]	13	24	24	14	28
		5 min Postexercise	21[c]	32[c]	10	16	18	9	27[c]
	Lower leg pain score[b]								
		Preexercise	0	1	0	1	0	0	0
		1 min Postexercise	7	5	0	7	4	5	2
		5 min Postexercise	6	5	0	7	2	3	1
Skate									
	Anterior ICP								
		Preexercise	18[c]	18[c]	14	19[c]	13	17[c]	13
		1 min Postexercise	19	24	22	44[c]	27	19	15
		5 min Postexercise	16	24[c]	18	34[c]	30[c]	17	16
	Lateral ICP								
		Preexercise	23[c]	18[c]	13	11	6	11	14
		1 min Postexercise	29	30[c]	20	23	20	15	20
		5 min Postexercise	10	28[c]	17	19	19	14	15
	Lower leg pain score								
		Preexercise	0	0	0	3	0	1	0
		1 min Postexercise	0	0	0	0	2	7	0
		5 min Postexercise	0	0	0	0	0	5	0

Abbreviations: F, female; M, male.

[a] All ICPs measured as mm Hg.

[b] Range, 1–11.

[c] Pressure meets diagnostic criterion of Pedowitz et al[4] for chronic exertional compartment syndrome.

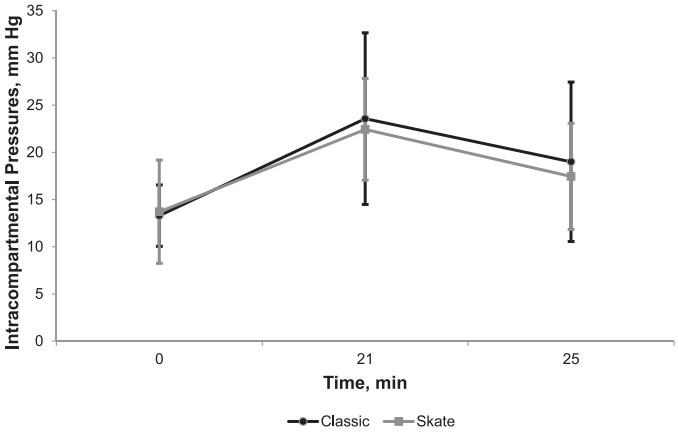

Figure 2. Lateral intracompartmental pressures for skate versus classic Nordic rollerskiing technique.

additional analysis using a Helmert contrast again indicated that the baseline pain values were lower than the postexercise values observed at minutes 1 and 4 after exercise. The single-degree-of-freedom[8] post hoc comparison for men showed that perceptions of pain increased greatly from baseline to 1 minute postexercise for the classic technique but not for the skate technique. Pain perception did not change across the 2 techniques from 1 minute postexercise to 5 minutes postexercise. The single-degree-of-freedom[8] contrast for women revealed an increase in subjective pain perception for the skate technique compared with the classic technique. Although pain perception decreased slightly for both techniques between the first and fifth minute after exercise, the change was not significant. The individual pain ratings are shown in Table 3.

DISCUSSION

The purpose of our study was to determine if ICPs in the anterior and lateral lower leg compartments as well as perceptions of pain increased among collegiate Nordic skiers after a 20-minute rollerskiing time trial. The results confirmed our hypothesis that Nordic rollerskiing would increase ICPs of the anterior and lateral compartments among collegiate or professional Nordic skiers after a 20-minute time-trial activity. Pain perception also increased from a baseline assessment to 1 minute and 5 minutes postexercise. These results support the findings of Baltopoulos et al,[5] who compared anterior ICPs between male and female recreational athletes and long-distance runners. These authors confirmed a relationship between long-distance runners and an increased risk of CECS, demonstrated by postexercise pressure increases within the anterior compartment after an acute bout of treadmill exercise. Regardless of the pressure increase, none of the participants complained of lower leg pain or discomfort during activity.

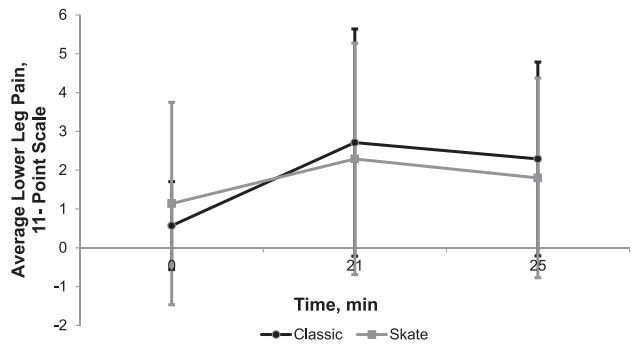

Figure 3. Lower leg pain for skate versus classic Nordic rollerskiing technique.

We also wanted to compare postexercise ICPs with the classic rollerskiing technique versus the skate rollerskiing technique. We hypothesized that the skate rollerskiing technique would result in higher ICPs of the anterior and lateral lower leg compartments after the 20-minute rollerskiing time trial. Previous research by Pedowitz et al[4] has suggested that at 5 minutes postexercise, ICPs should begin to return toward baseline values compared with 1 minute postexercise. When comparing the classic versus skate technique, we discovered a difference between postexercise ICPs for both the anterior and lateral compartments. However, we expected that ICPs would be higher after the skate rollerskiing time trial than the classic rollerskiing time trial, which was the opposite of what occurred.

Our results may have been complicated somewhat by a 3-way interaction among technique, sex, and time. The men showed greater anterior and lateral ICPs and subjective pain perception with the classic technique compared with the skate technique at 1 minute postexercise, whereas the women showed higher anterior and lateral ICPs with the skate technique, although they were not statistically greater at 1 minute postexercise compared with the classic technique. The women's subjective perception of pain with the skate technique was, however, greater than with the classic technique. To our knowledge, this is the only study comparing changes in anterior and lateral ICP pressures for classic versus skate Nordic rollerskiing. Similar studies in the future may enable clinicians to prevent CECS within this population.

Although no additional investigators have compared the anterior and lateral ICPs of male and female Nordic skiers after exercise, Baltopoulos et al[5] detected a difference between male and female recreational athletes (control group) and male and female endurance runners (athlete group) at 1 minute before exercise and at 1 minute after starting exercise. They did not take measures at 1 minute postexercise and found no statistical significance at 5 minutes postexercise. Our results demonstrated that the classic rollerskiing technique increased both anterior and lateral postexercise ICPs more than the skate rollerskiing technique did in the men, but both the classic and the skate rollerskiing techniques produced similar increases in anterior and lateral 1-minute postexercise ICPs among the women (Table 3). Using the Helmert contrasts, differences in the anterior and lateral ICPs were noted between the preexercise measures and the combined 1-minute and 5-minute postexercise pressures. Our study supports the possibility that sex may be a factor in lower leg ICP differences. However, current research demonstrating postexercise differences in ICPs related to sex with which to compare our results is lacking.

Although we did not state a hypothesis concerning ICP from 1 minute postexercise to 5 minutes postexercise, a previous investigation[4] suggested that pressures should

begin to decrease. Intracompartmental pressures that do not decrease have been used clinically as a diagnostic indicator of CECS. Our results revealed that men demonstrated very little recovery in anterior ICP when using either technique, whereas women showed additional recovery, regardless of the technique or which compartment was measured. The men did show the beginning of additional recovery in the lateral compartment, regardless of technique.

We did not consider lower leg pain a primary dependent variable because all participants stated they were asymptomatic before the start of the study. However, because increased ICPs and lower leg pain seem to be related, we wanted to examine the relationship between them. Classic rollerskiing technique increased lower leg pain more than the skate rollerskiing technique did in the men from preexercise to both 1 minute and 5 minutes postexercise (Table 3), whereas the women responded with a higher perception of pain after the skate technique. Although the differences were statistically significant, it is important to remember that lower leg pain measurements were obtained using the 11-point NRS, which is based on subjective participant responses. The results suggest a sex difference with regard to pain perception during Nordic rollerskiing, but further investigation is needed in this area.

Intracompartmental pressure measurements for asymptomatic compartments should stay below 15 mm Hg at rest.[4] Objective criteria for the diagnosis of CECS have been established by Pedowitz et al[4] and are widely used in both clinical and research settings. The criteria state that, when combined with a thorough history and clinical examination, the diagnosis is confirmed if the patient meets 1 or more of the following 3 requirements: (a) a resting ICP of 15 mm Hg or more, (b) a 1-minute postexercise ICP greater than or equal to 30 mm Hg, or (c) a 5-minute postexercise ICP greater than or equal to 20 mm Hg. According to these diagnostic criteria, with a positive history and clinical examination, all 7 participants in this study would have been diagnosed with CECS of the anterior compartment, and 4 of the 7 participants in this study would have been diagnosed with CECS of the lateral compartment (Table 3).

Before testing, we assumed that, due to the repetitive nature of Nordic skiing as an endurance sport, some participants might exhibit preexercise ICPs greater than 15 mm Hg. For the anterior compartment, 6 participants presented with ICPs greater than 15 mm Hg at rest for 1 or both trials. For the lateral compartment, 4 participants presented with ICPs greater than 15 mm Hg at rest for 1 or both trials. In addition, the mean baseline anterior ICP for the male athletes in the Baltopoulos et al[5] study was 6.78 mm Hg lower than for the male Nordic skiers in our study. Similarly, the mean baseline anterior ICP for the female athletes in the Baltopoulos et al[5] study was 6.81 mm Hg lower than for the female Nordic skiers in our study. Therefore, it is possible that either the diagnostic criteria[4] are inadequate for use in Nordic skiers or that Nordic skiing plays a role in the development of high ICPs. We should note that these measurements were taken after a 20-minute time trial. Most Nordic skiers exercise for at least 60 minutes during a single workout. Equally important is the fact that this study was performed on asymptomatic, collegiate Nordic skiers between the ages of 18 and 30 years. For a diagnosis of CECS to be made, the patient must also have a positive clinical presentation.

Although we were still able to detect differences between preexercise and postexercise ICPs, the first and biggest limitation of our study was the small sample size. Due to costs, health concerns, and lack of availability of eligible recruits, we were unable to establish a larger sample. A retrospective analysis with $n = 7$ for technique versus time showed power of 0.357 for the anterior compartment and 0.057 for the lateral compartment. These values are much lower than the commonly accepted power level of 0.80; however, our results continued to demonstrate statistical significance. Second, the majority of the data for the study were collected in an uncontrolled, outdoor environment. The temperature for the first trial was approximately 10°C (50°F), and the paved surface was dry. The temperature for the second trial was approximately 4°C (40°F) with intermittent periods of wind, hail, and light rain. The paved surface was dry for some participants and slightly wet for others. This change in environmental conditions may have had an adverse effect on the participants' ability to ski, the temperature of their muscles, and their perceptions and attitudes. No difference in participant intensity between trials was demonstrated, so the possibility of an order effect being influenced by the weather was at least partially eliminated. Third, more than 1 Board-certified orthopaedic physician was responsible for obtaining the ICP measurements, which may have affected intertester reliability. Finally, although the order of testing was determined by random assignment, all of the men ($n = 3$) performed the classic technique first. This potential confounding of order and sex may have biased the sex outcomes. Therefore, the small sample size and potential confounding of order and sex should temper conclusions drawn from this research.

As this is the first study of its kind to examine Nordic skiing and CECS, many opportunities are available for future research on this topic. It would be interesting to study the preexercise and postexercise ICPs among skiers previously treated by surgical fasciotomy, rather than solely asymptomatic skiers with no history of CECS. Our investigation was confined to dry-land rollerskiing activity. It would be beneficial to see how anterior and lateral ICPs are affected by Nordic skiing on snow. Additional evaluation involving fine-wire electromyography to understand the contract-relax phase of certain muscles during classic and skate skiing is also warranted. This new knowledge would help to better explain why Nordic athletes commonly experience increased pain in the anterior and lateral compartments during ski activity, particularly during classic rollerskiing and skate skiing over icy snow.

CONCLUSIONS

Compared with preexercise, postexercise anterior and lateral ICPs increased after both the classic and skate rollerskiing techniques. Sex may also be a factor with regard to technique and increased ICPs: only the men showed higher postexercise anterior and lateral ICPs after classic rollerskiing versus skate rollerskiing. Our results suggest that Nordic skiing contributes to increases in anterior and lateral ICPs, which may lead to the development of CECS. Additional research on this topic

is warranted to better understand its incidence and long-term effects within this specific population.

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