ON THE EDGE: LUMBAR SPINE HEALTH AND INJURY RISK IN HIGH-LEVEL COMPETITIVE FIGURE SKATERS

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Abstract:

The purpose of this study was to investigate the prevalence, risk factors, and rehabilitation strategies for low back pain among high-level competitive figure skaters across singles, pair, and ice dance disciplines. A total of 194 skaters completed a detailed questionnaire assessing training routines, on- and off-ice activities, and history of lumbar spine problems. Results indicated that 33.7% of singles skaters, 41.1% of pair skaters, and 25.9% of ice dancers reported low back pain interfering with training regime or competition. Statistical analysis showed that inclusion of trunk stability, balance, and strengthening exercises in off-ice training was associated with a significantly lower prevalence of low back pain ($p<.05$), with core stability exercises demonstrating the greatest effect: 94.6% of skaters without low back pain regularly performed these exercises compared with 24.6% of those with low back problems. Statistically significant associations ($p<.05$) were observed between low back pain and the execution of technically demanding lifts and complex spins, whereas no such association was found for less demanding skating elements. All participants reporting low back pain received individualized physiotherapy programs targeting core stability, strength, coordination, and proprioception, which were associated with effective recovery and return to sport-specific activities. These findings highlight the mechanical demands on the lumbar spine in high-level figure skaters and underscore the importance of structured on- and off-ice training programs, together with targeted physiotherapy, for the prevention and rehabilitation of low back pain.

Keywords: *figure skating, low back pain, injury prevention, off-ice training, physiotherapy*

Introduction

Figure skating is a complex, highly specialized Olympic winter sport in which athletes compete in four competitive disciplines: men's singles, women's singles, pairs, and ice dance. Its global popularity continues to grow, with athletes required to integrate technical precision, artistry, musical interpretation, speed, agility, flexibility, and strength—capacities developed only through long-term, intensive, and highly specialized training (Porter, Young, Niedfeldt, & Gottschlich, 2007).

Modern figure skating technique relies on the execution of advanced edgework, multi-rotation jumps, intricate steps and choreographic sequences, high-velocity spins, dance and overhead lifts, pair spins and throw jumps in pair skating. These elements impose substantial mechanical loads on the musculoskeletal system, especially on the lower extremities and lumbar spine, as a result of repeated impacts, forced hyperextension, high angular velocities, and asymmetrical loading patterns (Cabell & Bateman, 2018; Han, Geminiani, & Micheli, 2018; Slater, Vriner, Zapalo, Arbour, & Hart, 2016). The contemporary figure skating boot and blade design, although essential for jump stability, have been cited by clinicians as contributing factors to overuse injuries because of their rigidity and elevated heel structure (Dubravcic-Simunjak, et al., 2008; Pećina, Bojanić, & Dubravčić, 1990; Spiegl, Tarassova & Arndt, 2019).

Early specialization is common, with most skaters beginning structured training between five and eight years of age. Throughout adolescence, a period of life characterized by asynchronous growth of muscles and bones and temporarily reduced flexibility, skaters undergo high training

volumes both on and off the ice. Off-ice training typically includes strength and conditioning, flexibility training, agility work, aerobic and anaerobic conditioning, dance, and choreography (Mohney & Miller, 2016). These combined loads increase susceptibility to overuse injuries, which are widely documented as the most common injuries in figure skating (Dubravcic-Simunjak, Pecina, Kuipers, Moran, & Haspl, 2003; Dubravcic-Simunjak, et al., 2008; Fortin & Roberts, 2003).

The competitive season extends from late August to early April and includes an increasing number of national and international competitions. Athletes must maintain peak physical and psychological readiness throughout this period. Technical errors in jumps, spins, step and choreographic sequences, dance lifts, or pair elements (e.g. throw jumps, twists, lifts, synchronized elements) result in deductions under the ISU (International Skating Union) judging system, creating continuous performance pressure (ISU, 2025a, 2025b).

Previous studies report that overuse injuries of the lower extremities are common in figure skating due to increased technical complexity and high cumulative training loads (Dubravcic-Simunjak, et al, 2003, 2008; Madsen, Alfonso, & Vincent, 2024).

Recently, coaches, medical professionals, and skaters have raised concerns about a noticeable rise in low back pain, stiffness, and functional limitations. Contributing factors may include repetitive jump take-offs and landings, high rotational forces, extreme lumbar extension positions, and the asymmetrical nature of many skating elements (Han, et al., 2018; Purcell & Micheli, 2009). However, there is limited literature examining discipline-specific patterns, training load associations, and the influence of element difficulty on low back pain prevalence in competitive figure skaters.

The aim of this study was to investigate the prevalence of low back pain in high-level competitive figure skaters using a retrospective, self-reported, anonymous questionnaire. Specific objectives included assessing low back pain prevalence by sex, discipline, training modality, and performance of specific figure skating elements. Additionally, the study evaluated the self-reported effectiveness of physical therapy interventions following the onset of lumbar issue symptoms.

Methods

The research was conducted during the four consecutive editions of the ISU Figure Skating Challenger Series "Golden Spin of Zagreb", an international competition where senior-level skaters competed in four figure skating disciplines: men's singles, women's singles, pairs, and ice dance. This study adhered to the Declaration of Helsinki and was approved by the Ethics Committee of the Clinical Hospital "Sveti Duh."

Data were collected using an anonymous, self-reported questionnaire as part of a cross-sectional study design. The questionnaire, consisting of three sections and 26 items, was developed based on relevant literature, the clinical and research experience of the authors in physical medicine and rehabilitation, with expertise in sports-related musculoskeletal conditions. As the questionnaire assessed frequencies rather than psychometric constructs, it was not metrically validated, but was developed in line with similar instruments published in the scientific literature. The first section included demographic variables such as age, height, age at the start of figure skating training, age at the start of competition in a specific discipline, and information on on-ice and off-ice training regimes. The second section focused on the occurrence of low back problems across groups differing in training regimes and the execution of specific figure skating elements. The third section explored the use of physical therapy interventions and their perceived effectiveness. Completion of the questionnaire required approximately 15-20 minutes. All participants received a detailed explanation of the questionnaire content, provided written informed consent, and were allowed to consult their coach, physiotherapist, or physician if clarification was needed.

A total of 282 skaters participated in the study: 59 men's single skaters, 69 women's single skaters, 33 pairs (64 skaters), and 45 ice dancers (90 skaters). Of these, 194 participants returned fully completed questionnaires, forming the analytical sample. The final sample consisted of 35 men's single skaters, 45 women's single skaters, 28 pairs (56 skaters), and 29 ice dancers (58 skaters).

Statistical analysis included descriptive and inferential procedures. Descriptive statistics were used to organize data and calculate measures of central tendency and variability, as well as minimum and maximum values of the examined variables. Inferential statistics involved conducting ANOVA and chi-square tests to examine differences in frequencies across variables. A significance level of $p<.05$ was applied. Data analyses were performed using IBM SPSS Statistics 25.0.

Results

Results are presented for the final analytical sample of 194 competitive figure skaters across all the four skating disciplines. Participant characteristics stratified by discipline are shown in Table 1 and include age, height, body weight, body mass index (BMI), age at the start of training, age at the beginning of the competitive career, and weekly off-ice training volume. ANOVA revealed no statistically significant differences between groups for sex or body mass index ($p>.05$). In contrast, statistically significant differences were observed for age, height, age at the

Table 1. Participants' characteristics (demographic, anthropometric, and training variables)

		N	$\bar{x}$	SD	Min	Max
Age (years)	Individuals (M+F)	80	19.14	3.291	14	29
	Pairs	56	21.63	4.960	15	30
	Ice dance	58	22.24	2.812	18	28
	Total	194	20.78	3.968	14	30
Height (cm)	Individuals (M+F)	80	166.45	8.157	148	183
	Pairs	56	168.80	12.544	147	189
	Ice dance	58	170.55	8.400	155	188
	Total	194	168.36	9.794	147	189
Weight (kg)	Individuals (M+F)	80	56.44	8.940	37	73
	Pairs	56	58.95	13.886	39	82
	Ice dance	58	59.09	10.011	43	77
	Total	194	57.95	10.903	37	82
BMI (kg/m^2)	Individuals (M+F)	80	20.2150	1.48598	16.20	23.10
	Pairs	56	20.3250	1.95069	16.00	23.40
	Ice dance	58	20.1328	1.56546	17.90	22.50
	Total	194	20.2222	1.64848	16.00	23.40
Start of training (age in years)	Individuals (M+F)	80	4.80	1.287	2	8
	Pairs	56	5.00	1.758	2	9
	Ice dance	58	6.66	1.292	4	9
	Total	194	5.41	1.649	2	9
Start of competitive career (age in years)	Individuals (M+F)	80	8.04	1.152	6	10
	Pairs	56	9.11	1.498	6	13
	Ice dance	58	10.47	1.417	8	13
	Total	194	9.07	1.674	6	13
Off-ice training hours per week	Individuals (M+F)	80	5.79	1.556	3	10
	Pairs	56	5.71	1.371	3	8
	Ice dance	58	5.88	1.807	3	9
	Total	194	5.79	1.580	3	10

beginning of training, and age at the competitive debut ($p<.05$), with the highest values recorded in ice dancers.

Participants competing in the singles discipline (men's and women's singles combined) most commonly trained six days per week (67.3%). A similar training frequency was observed in the other disciplines, with 78.6% of pair skaters and 89.7% of ice dancers reporting six training days per week. In the singles discipline, 58.8% of participants reported that on-ice training sessions most frequently lasted three hours per day, a pattern also observed in 43.1% of ice dancers. In pair skating, on-ice training sessions most commonly lasted two hours per day. The distribution of training regimes across skating disciplines is presented in Table 2.

The occurrence of low back pain among participants is summarized in Tables 3 and 4. Low back pain was reported by 27 (33.8%) of 80 participants in the singles discipline, 23 (41.1%) of 56 participants in pair skating, and 15 (25.9%) of 58 participants in ice dance. Table 3 presents the incidence of low back pain in relation to the training regimen and activities of daily living across disciplines. Table 4 shows the incidence of low back pain during different periods of the competitive season.

All participants reported participation in off-ice training in addition to regular on-ice training, with a weekly volume ranging from three to 10 hours (mean: 5.79 ± 1.58 hours). To further characterize off-ice training, the primary focus of training activities was analyzed and compared between the disciplines (Table 5).

Statistical analysis showed that the inclusion of core stability, balance, and strengthening exercises in off-ice training was associated with a significantly lower prevalence of low back pain ($p<.05$), whereas the inclusion of stretching exercises showed no significant association. The largest between-group difference was observed for core stability exercises: 94.6% of participants without low back pain reported regular performance of

Table 2. Distribution of on-ice training regimes across figure skating disciplines

		Skating disciplines							
		Singles (M+F)		Pairs		Ice dance		Total	
		N	%	N	%	N	%	N	%
Training frequency (times/week)	Every day	17	21.3%	12	21.4%	6	10.3%	35	18 %
	6 days a week	61	76.3%	44	78.6%	52	89.7%	157	80.9%
	5 days a week	2	2.5%	0	0 %	0	0 %	2	1 %
Training duration (hours)	2	33	41.3%	20	35.7%	21	36.2%	74	38.1%
	3	47	58.8%	15	26.8%	25	43.1%	87	44.8%
	4	0	0 %	21	37.5%	12	20.7%	33	17 %

Note. Values are presented as the number of participants (N) and percentages (%).

Table 3. Incidence of low back pain in relation to training regimen and activities of daily living

		Figure skating disciplines							
		Individuals (M+F)		Pairs		Ice dance		Total	
		N	%	N	%	N	%	N	%
Low back pain (training regimen)	None	53	66.3%	33	58.9%	43	74.1%	129	66.5%
	During on-ice training	8	10 %	5	8.9%	7	12.1%	20	10.3%
	During off-ice training	7	8.8%	6	10.7%	1	1.7%	14	7.2%
	During on-ice and off-ice training	11	13.8%	6	10.7%	7	12.1%	24	12.4%
	During training and daily activities	1	1.3%	6	10.7%	0	0 %	7	3.6%
	Total	80	100 %	56	100 %	58	100 %	194	100 %

Note. Values are presented as the number of participants (N) and percentages (%).

Table 4. Incidence of low back pain across the competitive season by figure skating discipline

		Figure skating disciplines							
		Individuals (M+F)		Pairs		Ice dance		Total	
		N	%	N	%	N	%	N	%
Low back pain (competitive season)	None	53	66.3%	33	58.9%	43	74.1%	129	66.5%
	Preseason	8	10 %	10	17.9%	6	10.3%	24	12.4%
	In-season	7	8.8%	3	5.4%	3	5.2%	13	6.7%
	Off-season	4	5 %	0	0 %	0	0 %	4	2.1%
	Preseason and in-season	6	7.5%	7	12.5%	6	10.3%	19	9.8%
	Preseason, in-season, and off-season	2	2.5%	3	5.4%	0	0 %	5	2.6%
	Total	80	100 %	56	100 %	58	100 %	194	100 %

Note. Values are presented as the number of participants (N) and percentages (%).

these exercises, compared with 24.6% of those with low back pain.

In addition to off-ice training, participants reported experiencing low back pain during the execution of specific on-ice skating elements. Table 6 presents the skating elements identified by each discipline as the main focus of on-ice training. Data are presented as absolute numbers and percentages.

Analysis of absolute and relative frequencies indicated that some participants across all the disciplines experienced low back pain while performing multiple sport-specific elements. In the singles discipline, 16 participants (20%) reported low back pain while executing Biellmann and combination spins, 14 (17.5%) during jump landings, and 7 (8.8%) while performing steps or choreographic elements. In pair

Table 5. Distribution of off-ice training focus across figure skating disciplines

Off-ice training		Figure skating discipline							
		Individuals (M+F)		Pairs		Ice dance		Total	
		N	%	N	%	N	%	N	%
Stretching exercises	Yes	76	95 %	56	100 %	58	100 %	190	97.9%
	No	4	5 %	0	0 %	0	0 %	4	2.1%
	Total	80	100 %	56	100 %	58	100 %	194	100 %
Balance exercises	Yes	54	67.5%	40	71.4%	50	86.2%	144	74.2%
	No	26	32.5%	16	28.6%	8	13.8%	50	25.8%
	Total	80	100 %	56	100 %	58	100 %	194	100 %
Strengthening exercises	Yes	46	57.5%	56	100 %	28	48.3%	130	67.0%
	No	34	42.5%	0	0 %	30	51.7%	64	33 %
	Total	80	100 %	56	100 %	58	100 %	194	100 %
Core stability exercises	Yes	53	66.3%	39	69.6%	46	79.3%	138	71.1%
	No	27	33.8%	17	30.4%	12	20.7%	56	28.9%
	Total	80	100 %	56	100 %	58	100 %	194	100 %

Note. Values are presented as the number of participants (N) and percentages (%).

Table 6. Focus of on-ice training elements by figure skating discipline

On-ice training		Figure skating disciplines							
		Individuals (M+F)		Pairs		Ice dance		Total	
		N	%	N	%	N	%	N	%
Jumps	Yes	73	91.3%	13	23.2%	Do not perform jumps or side by side spins		86	44.3%
	No	7	8.8%	43	76.8%			108	55.7%
	Total	80	100 %	56	100 %			194	100 %
Spins	Yes	72	90 %	13	23.2%			85	43.8%
	No	8	10 %	43	76.8%			109	56.2%
	Total	80	100 %	56	100 %			194	100 %
Choreo / steps / death spirals	Yes	41	51.2%	22	39.3%	20	34.5%	83	42.8%
	No	39	48.8%	34	60.7%	38	65.5%	111	57.2%
	Total	80	100 %	56	100 %	58	100 %	194	100 %
Lifts	Yes	Do not perform lifts		56	100 %	30	51.7%	86	44.3%
	No			0	0 %	28	48.3%	108	55.7%
	Total			56	100 %	58	100 %	194	100 %
Throws	Yes	Do not perform throws		27	48.2%	Do not perform throws		27	13.9%
	No			29	51.8%			167	86.1%
	Total			56	100 %			194	100 %
Dance elements	Yes	Do not perform elements specific to ice dancers				58	100 %	58	29.9%
	No					0	0 %	136	70.1%
	Total					58	100 %	194	100 %

Note. Values are presented as the number of participants (N) and percentages (%).

skating, low back pain occurred in 22 participants (39.3%) while performing overhead lifts, 7 (12.5%) during throw jumps, and 4 (7.1%) in the execution of pair spins, death spirals, or choreographic elements. In ice dance, 8 participants (13.8%) reported pain during dance lifts and dance spins, while 3 (5.2%) reported pain throughout various dance elements.

A substantial proportion of singles skaters (men and women) performed multiple triple jumps and jump combinations in their free skating programs. Nearly half of them executed six or seven triple jumps, while a subgroup of male single skaters performed one or more quadruple jumps.

Despite these distributions, chi-square analysis did not demonstrate a statistically significant association between low back pain prevalence and the performance of the majority of analyzed sport-specific elements ($p>.05$). To further explore the role of technical complexity, skating elements were additionally analyzed according to their difficulty level.

Element difficulty in figure skating is graded by the Technical Panel using a five-level scale (Basic Level and Levels 1-4) for specific element groups (e.g., spins, step sequences, choreographic sequences, and lifts), with higher levels reflecting greater technical demands and increased mechanical loading on the lumbar spine. Chi-square analysis demonstrated a statistically significant association ($p<.05$) between low back pain and the execution of technically demanding pair lifts and complex solo spins. However, no statistically significant association was found for the other analyzed elements.

Among the 65 participants reporting low back pain, 58 (89.2%) reported having been diagnosed with low back pain syndrome by a physician.

All participants who reported low back pain interfering with regular training underwent some form of physiotherapy intervention. Table 7 presents the distribution of physiotherapy interventions across disciplines.

Table 7. Distribution of physiotherapy interventions used in the treatment of low back pain across figure skating disciplines

Physiotherapy intervention		Figure skating disciplines							
		Individuals (M+F)		Pairs		Ice dance		Total	
		N	%	N	%	N	%	N	%
Core stability exercises	Yes	24	88.9%	19	82.6%	11	73.3%	54	83%
	No	3	11.1%	4	17.4%	4	26.7%	11	17%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
Mobilization techniques	Yes	17	63%	17	73.1%	11	73.3%	45	69.2%
	No	10	37%	6	26.9%	4	26.7%	20	30.8%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
Dynamic neuromuscular stabilization	Yes	10	37%	11	47.8%	8	53.3%	29	44.6%
	No	17	63%	12	52.2%	7	46.7%	36	55.4%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
Coordination and proprioception exercises	Yes	21	77.8%	15	65.2%	11	73.3%	47	72.3%
	No	6	22.2%	8	34.8%	4	26.7%	18	27.7%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
Stretching exercises	Yes	23	85.1%	19	82.6%	11	73.3%	53	81.5%
	No	4	14.9%	4	17.4%	4	26.7%	12	18.5%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
TENS therapy	Yes	13	48.1%	8	34.8%	7	46.7%	28	43.1%
	No	14	51,9%	15	65.2%	8	53.3%	37	56.9%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
TECAR therapy	Yes	14	51.9%	12	52.2%	6	40%	32	49.2%
	No	66	48.1%	11	47.8%	9	60%	33	50.8%
	Total	27	100 %	23	100 %	15	100 %	65	100%
Magnetotherapy	Yes	6	22.2%	6	26.1%	4	26.7%	16	24.6%
	No	21	77.8%	17	73.9%	11	73,3%	49	75.4%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
Laser therapy	Yes	5	18.5%	3	13%	3	20%	11	17%
	No	22	81,5%	20	87%	12	80%	54	83%
	Total	27	100 %	23	100 %	15	100 %	65	100 %
Ultrasound therapy	Yes	8	29.6%	5	2.7%	4	26.7%	17	26.2%
	No	19	70.4%	18	78.3%	11	73.3%	48	73.8%
	Total	27	100 %	23	100 %	15	100 %	65	100 %

Note. Values are presented as the number of participants (N) and percentages (%).

Discussion and conclusions

To the authors' knowledge, this is the first systematic study to quantify low back pain prevalence in relation to discipline-specific demands and off-ice training characteristics in high-level competitive figure skaters. The findings provide novel insights into the biomechanical and epidemiological factors associated with lumbar spine problems in this population. It should be noted that, despite reported low back pain during the performance of various skating elements, no statistically significant association was found for the majority of the analyzed elements, suggesting that low back pain appears to be more frequently associated with technically demanding jumps, spins, and lifts. Given the sport's progressive technical demands and the cumulative mechanical loads associated with multirotational jumps, deep edges, rapid transitions, spins, and complex lift mechanics, the lumbopelvic region may be subjected to substantial mechanical stress and loading (Abbott & Hecht, 2013; Cabell, et al., 2018; Han, et al., 2018; Simunjak, Dubravcic-Simunjak, Abbott, & Busac, 2020; Slater, et al., 2016).

Biomechanically, the lumbar region is exposed to repetitive high-intensity loads and sustained asymmetrical loading postures. Such movements may contribute to increased stress along the lower-extremity and lumbopelvic kinetic chain, where limitations or weaknesses in the ankle, knee, hip, or pelvis may further increase lumbar loading. These loads include compressive, shear, and torsional forces that place significant demands on both the passive (ligaments, discs, facet joints) and active (muscular) stabilizing structures of the lumbopelvic region (Cabell, et al., 2018; Karandikar & Vargas, 2011).

In line with these biomechanical considerations, the present study indicated that 33.7% of single skaters, 41.1% of pair skaters, and 25.9% of ice dancers reported low back pain interfering at least once with regular training or competition. Importantly, statistical analysis indicated a significant association ($p<.05$) between low back pain prevalence and the absence of core stability, strength, and proprioception exercises in off-ice training programs, suggesting a potential protective association of these targeted interventions.

The prevalence of low back pain also varied across the competitive season. Specifically, 12.4% of athletes experienced pain during the preseason summer preparation, a period of particularly intense on- and off-ice training, and 9.8% of skaters during both the summer preparation and the competitive season, which includes an increasing number of national and international ISU competitions where skaters should earn at least a minimum of technical element scores qualifying them for participation in the European and World Championships (Dubravčić-Šimunjak, et al., 2003; Madsen, et al., 2024; Slater, et al., 2016).

These findings are consistent with current literature, indicating that the lumbar spine and lower extremities are commonly affected regions in competitive figure skaters, with overuse injuries predominating, particularly in disciplines with higher technical demands (Madsen, et al., 2024). However, Schmidt et al. (2025) highlight that high-quality research on injury risk and mechanisms in figure skating remains limited, with inconsistent reporting and the lack of standardized methodologies, which complicates accurate interpretation of injury burden. In this context, the present results support the growing consensus that sport-specific biomechanical demands continue to challenge spinal health.

The observed prevalence exceeds earlier reports by Dubravčić-Šimunjak et al. (2003, 2008) and Fortin and Roberts (2003), suggesting that increased spinal stress may be associated with intensified training demands, evolving technical requirements, and changes in scoring systems over recent decades (Abbott, et al., 2013; Lockwood & Gervais, 1997; Porter, et al., 2007; Porter, 2013; Purcell & Micheli, 2009). Analysis of specific skating elements indi-

Figure 1. An elite figure skater performing the Biellmann spin. Reproduced with permission from Fizikalni čimbenici u fizioterapiji by Dubravčić-Šimunjak et al. (2023).

cates that high-level spins, including Biellmann spins, combination spins, and high-level pair and dance lifts, involve repetitive spinal flexion, extension, and rotation combined with axial loading, which may be associated with cumulative microtrauma to paravertebral muscles, ligaments, and facet joints (Cabell, et al., 2018; Hirosawa, Watanabe, & Aoki, 2022; Purcell & Micheli, 2009; Schäfer, et al., 2023).

Recent analyses of elite pair skating and ice dance indicate increasing technical difficulty and total scores at major competitions, which may be associated with increased mechanical demands and injury risk (Rauer, et al., 2022). Similarly, jumps with triple and quadruple rotations generate substantial landing forces, with reported impacts exceeding 3.5 times body weight in laboratory settings, indicating high mechanical loading on the lumbar spine (Saunders, Hanson, Koutakis, Chaudhari, & Devor, 2014). Restriction of ankle motion and shock absorption imposed by skating boots may redistribute forces proximally to the knee, hip, and lumbar region (Spiegel, et al., 2019). Neuromuscular imbalances, including tight hip flexors and adductors combined with weak gluteal activation, may be associated with asymmetric forces during rotational jumps and lifts, potentially contributing to greater susceptibility to low back pain, stress reactions, facet joint strain, disc protrusions, spondylolysis, and spondylolisthesis (Goldman & Moyer, 2007; Karandikar & Vargas, 2011; Simunjak, et al., 2019; Schäfer, et al., 2023).

Physical preparation appears to play an important role in musculoskeletal health in figure skaters. Strength, endurance, flexibility, core stability, balance, and proprioception are all important for the execution of technically demanding elements. However, prolonged and intensive training may be associated with muscle fatigue and increased risk of overuse symptoms if not appropriately dosed. Correct exercise execution and training design are considered important factors in athlete load management, while maladaptive training responses may occur in conditions of excessive or poorly controlled load (Cabell, et al, 2018; De Blaiser, et al., 2019; Dubravčić-Šimunjak, et al., 2023; Kirillov, Smith, & Driban, 2023; Madsen, et al., 2024).

Kirillov et al. (2023) highlight the importance of correct exercise execution and training level, while also emphasizing the risk of developing complex and unpredictable overtraining syndromes, whose causes remain incompletely understood. From the youngest beginners to senior competitors, skaters repetitively practice demanding jumps, spins, spirals and lifts. Learning each element is mentally and physically challenging; mistakes and falls are frequent, which may lead to fatigue, frustration, and increased incidence of musculoskeletal injuries, painful syndromes, and overuse conditions.

Given the high injury risk in figure skating, every training session must be carefully planned. Properly structured on-ice training should include light warm-up exercises, pre-skating dynamic stretching, on-ice warm-up, targeted skill training that balances technical progression with avoidance of overfatigue, and a concluding cool-down phase incorporating muscle relaxation and stretching. Off-ice training, introduced from an early age, should be tailored to the skater's age and developmental stage (Dubravčić-Šimunjak, et al., 2023).

Educated kinesiologists and coaches contribute to off-ice training programs aimed to enhance sport-specific performance while preventing overuse injuries and spinal pain syndromes. Off-ice training should include not only sport-specific elements (jumps, lifts, dance moves) but also exercises targeting at improving core stability, proprioception, strength, endurance, and flexibility. Core muscles (including back, abdominal, and gluteal muscle groups) are essential for balance control during jumps, spins, steps, and spirals (De Blaiser, et al., 2019; Mohney, et al., 2016; Slater, et al., 2016). Most skating elements are performed on one well-sharpened narrow skate blade, demanding well-developed lower limb and core proprioception with the integration of visual, vestibular, and somatosensory input. Strength and agility influence height of jumps, execution of spins and skating speed, while endurance is crucial for completing demanding programs lasting 2-4 minutes depending on skater's age and category. The majority of skating elements require advanced dynamic flexibility across multiple muscle groups (Madsen, et al., 2024; Schmidt, et al., 2025).

The findings of the present study suggest that a balanced and appropriately dosed training approach may be associated with lower prevalence of spinal issue symptoms, injuries, and musculoskeletal overuse syndromes. Statistical analysis indicated a significant difference ($p<.05$) in low back pain prevalence between the skaters who included *versus* those who did not include core stability, strength, and proprioception exercises in off-ice training.

Therapeutic exercises are an essential component of rehabilitation programs for individuals with musculoskeletal pain or injury (Dubravčić-Šimunjak, et al., 2023). In the present study, movement-based therapeutic exercises combined with mobilization techniques formed the core of physiotherapy interventions for skaters reporting lumbar pain. Participation in individualized, physiotherapist-supervised rehabilitation programs was associated with improved pain alleviation and functional recovery outcomes. Pain relief was rated as excellent or very good by the majority of participants, suggesting that structured and well-designed rehabilitation programs may support a safe return to sport-specific activities, including both training and competition.

Despite these effective therapeutic outcomes, the frequency of physiotherapy utilization indicates a broader concern regarding lumbar spine symptoms in figure skaters. The high proportion of athletes presenting with lumbar symptoms is consistent with concerns among coaches and medical staff regarding the increasing prevalence of lumbar spine problems in this population. These findings may be associated with intensive, asymmetrical, and repetitive spinal loading during training, further influenced by the progressive escalation of technical demands required to achieve higher levels and technical scores in complex skating elements.

Interpretation of the study findings must be approached with caution, as retrospective cross-sectional investigations of sports injuries inherently carry limitations, including reliance on self-reported questionnaire data, which may be subject to recall bias and reporting inaccuracies, as well as the absence of detailed medical documentation. Furthermore, the cross-sectional design precludes causal inference. In addition, recent high-quality studies focusing on specific technical elements in figure skating remain scarce, highlighting the need for standardized research methodologies to accurately quantify injury prevalence and associated risk factors (Schmidt, et al., 2025).

Nevertheless, the present results are valuable, representing the first systematic assessment in the past two decades to quantify the prevalence of lumbar spine problems among high-level competitive figure skaters. Beyond contributing to the scientific understanding of musculoskeletal injury patterns in this sport, these findings provide important insights for coaches, physiotherapists, and sports medicine professionals, offering an evidence-based foundation for the development of targeted injury prevention strategies, optimized training programs, and rehabilitation protocols. In this way, the study not only advances academic knowledge but also provides practical guidance for safeguarding spinal health in one of the most physically demanding Olympic winter sports.

The findings support the implementation of evidence-based preventive and rehabilitation programs, with particular emphasis on incorporating proprioceptive, core stability, strength, and flexibility exercises into off-ice training. While some sports have adapted technical requirements in response to scientific and medical recommendations, in figure skating, the continued increase in element difficulty highlights the need for careful consideration of injury prevention and athlete safety. By integrating scientific insights into training and competition planning, coaches, physiotherapists, medical doctors, and ISU governing bodies can optimize performance while minimizing injury risk, ultimately contributing to the long-term health and athletic longevity of figure skaters.

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