INJURY PATTERNS AND SPECIALIZATION AGE IN ELITE FEMALE ICE-HOCKEY ATHLETES

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BACKGROUND: Amongst youth athletes, a trend towards earlier specialization in a single sport has been observed and may be associated with increased injury rates and burnout. In elite women's ice-hockey, neither the implications of early sport specialization nor generalized injury patterns have been well described. This study investigates the association of early specialization in elite female ice-hockey players with injury prevalence and highest level of play attained and characterizes injury location in elite female ice-hockey players.
METHODS: An online survey was distributed to elite female ice-hockey players including current and retired high school, collegiate, professional, and Olympic/World Championship players. Athletes reported date of birth, height, weight, handedness, highest level of play and ice-hockey related injury data. Injury data included specific diagnoses, laterality, and if it required time out of sport.
RESULTS: 259 athletes completed the survey. Older age at specialization was associated with higher levels of play, with 12.9 (± 2.4) years for high school up to 15.0 (± 3.0) years for senior national team level. There was no association between the age at specialization and professional level play, total injuries, concussions, or fractures sustained during ice-hockey ($p > 0.05$). 49.0% of players reported ice-hockey related concussions, with mean number of concussions per player of 0.9 (± 1.1). Laterality of injury was associated with shooting side dominance. 71.8% of retired players reported ongoing physical and/or mental health issues.
CONCLUSION: No significant association was found between age at specialization in ice-hockey and professional level play or number of injuries, paralleling findings in elite men's ice-hockey players. Concussion was the most common injury reported, emphasizing the significant prevalence of head injuries on women's sports. A significant proportion of retired players reported ongoing issues secondary to ice-hockey injuries.

INTRODUCTION

Women's ice-hockey is one of the fastest growing youth sports in the United States, with a 34% increase in participation in the past 10 years.[1] A national trend towards early specialization, defined as committing at least 8-months of participation in a single sport at the exclusion of other sports before the age of 12, has been observed in various youth sports.[2] There are perceived advantages to single-sport specialization giving young athletes a competitive edge over their peers.[3] However, early specialization has been associated with higher rates of burnout and higher numbers of overuse injuries.[4,5]

In a study evaluating elite male ice-hockey players, age at specialization was not found to be associated with highest level of competition achieved or total number of injuries.[6] Previous research conducted among high school athletes suggests that female sport specialization patterns differ from males; female athletes have a greater tendency to specialize in a single sport, report increased overuse injuries and engage in higher training volumes compared to their male

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counterparts.[7-11] Researchers have theorized that elevated levels of noncontact and overuse injuries in ice-hockey players could be attributed to the interaction between the distinct biomechanics of the skating stride and early specialization.[12-14] Additionally, ice-hockey differs between sexes in terms of the no contact rule, with female ice-hockey prohibiting deliberate hits, which may lend itself to different injury patterns. This raises questions about the applicability of research conducted exclusively on male athletes to female athletes.

Previous research done on professional female ice-hockey players focusing on femoro-acetabular impingement (FAI), a well-documented cause of hip pain in ice-hockey players, found that the size of cam-lesions has been significantly correlated with later age of skeletal maturity (approximated by age at menarche), suggesting that exposure to this sport at a young age may contribute to the development of pathologic anatomy.[15] However, previous work has not found significant correlations between FAI incidence and age at specialization, player position, or handedness/ shooting-side.[15,16]

The effect of single sport specialization has not been well characterized in elite female ice-hockey players. Additionally, global injury patterns have not been well documented. The purpose of our study was to assess the effects of single-sport specialization on long-term success as well as injury prevalence. A secondary purpose was to characterize injury patterns in relation to other variables, including, but not limited to, age at menarche and ice hockey position in female ice-hockey players. We hypothesize that age at specialization in elite female-ice hockey players is not associated with injury risk.

METHODS

Recruitment Procedures

An online REDCap survey was distributed to elite female ice-hockey players. Inclusion criteria consisted of female ice-hockey players who had competed at the high school, collegiate, the professional, and/or the International Ice-Hockey Federation World Championship/Olympic level. Exclusion criteria consisted of players who only played before high school and those who did not complete the survey in its entirety.

The survey was disseminated via email to a select number of high school coaches at elite Canadian ice-hockey academies, all NCAA Division I coaches, a collection of NCAA Division III and Canadian US sports teams, and professional teams in the former Professional Women's Hockey Players Association (PWHPA) and Premier Hockey Federation (PHF) and some European professional teams. Additionally, the survey was distributed to members of five senior national programs (Canada, Hungary, Norway, Sweden, and the United States). Coaches were asked to distribute the survey to their teams. It is not possible to estimate how many potential players were contacted as coaches did not confirm whether they distributed the survey to their team.

Variables and Outcomes

Athletes selected the levels of competition at which they competed at least one or more seasons, as well as the number of years they participated at each level. Professional hockey was defined as playing in a professional league where players were financially compensated for their participation. Senior national team was defined as representing your country in international competition at the senior national level. Participants reported what age they began playing ice-hockey, competitive ice-hockey, and the age they specialized to only ice-hockey. Specialization was defined as at least 8-months of training dedicated to one sport at the exclusion of other sports. Date of birth, height, weight, and age at menarche as well as ice-hockey specific information, such as position and shooting side for players or catching side for goalies, was collected. Players also indicated whether they were active or retired. Athletes were categorized by their highest level of play. It was not possible to calculate the response rate given the method of distribution.

Athletes reported the number of injuries that had prevented them from participation in hockey for one or more sessions. Each injury was queried regarding anatomic location, diagnosis, laterality (if applicable), and how many seasons required time out of sport. Surgical and concussion histories were also collected. Retired players described the impact of their hockey-related injuries on their current lives.

Statistical Analysis

An a priori power analysis was conducted using G*Power Version 3.x (HHU - Gachenbach, Germany) to determine the sample size desired to test the null hypothesis that age at specialization in elite female-ice hockey players is not associated

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with injury risk. Previous literature on early sport specialization suggests associations with injury risk are generally small and heterogeneous.[6,17] Based on an expected effect size of r = 0.20, a = 0.05 (two-tailed), and power = 0.80, the desired sample size is 314 participants. Chi-square tests were performed for categorical variables, t-test or ANOVA for continuous variables. Pearson rank correlations were calculated to describe associations between continuous variables. A bivariate logistic regression model was developed to identify predictors of professional level play. Significance was set to a = 0.05. All statistical analyses were conducted using SPSS Version 29.0 (IBM – Armonk, New York, USA).

RESULTS

Patient Cohort

The survey was completed by 261 athletes. Two responses were excluded due to incomplete surveys. Players stratified into groups based on their highest level of competition played. Forty-six athletes (17%) played at the senior national team level. Thirty-seven athletes (14%) played at the professional level but not the senior national team level. One hundred fifty-six athletes (57%) played at the collegiate level. Twenty athletes (7%) played at the high school level. Mean age at the time of survey completion was 23.6 years (range 16-38 years). Participants reported that they began to play ice-hockey at a mean age of 5.6 years (± 2.3) and specialized to only ice-hockey at a mean of 14.7 years (± 2.9). The mean number of injuries across the players' careers to date was 2.3 (± 1.8). Seventy-three athletes (28%) had at least one surgery, with the mean number of surgeries per player in this cohort being 1.7 (± 1.1) and an average incidence of 0.5 (± 1.0) across all athletes queried. One hundred twenty-eight players (49%) had at least one concussion, with the mean number of concussions per player in this cohort being 1.8 (± 1.0), and an average incidence of 0.9 (± 1.0) across all athletes queried. (Table 1). Seventy-one (27.4%) athletes were retired.

Injury Characterization

Two hundred twenty-nine players reported hockey-related injuries (88.4%). The most common injury location at all levels of play was the head (n=129, 49.4%), followed by the knee (n=63, 24.1%). Figure 1 displays the number of players reporting injuries per anatomical location, highlighting the ten most injured anatomical locations, with Table 4 illustrating all specific injuries per anatomical location.

Surgery Characterization

Seventy-two players (27.8%) underwent surgery for a hockey-related injury (Table 2). The most common surgery type was tendon or labral repair, with 11.4% of the total cohort requiring this type of surgery (n=31), followed by debridement (n=24, 8.8%), and ligament reconstruction (n=17, 6.2%). The knee (n=24, 8.8%) and shoulder (n=18, 6.6%) required the most surgeries.

Specific surgeries were also reported by players. The procedures with the most players reporting were shoulder instability and labral repairs (n = 18), knee arthroscopy (n = 13), hip arthroscopy and FAI procedures (n = 11), ACL reconstruction (n = 10), and open reduction and internal fixation (ORIF) (n = 8). Of note, half of the ORIF procedures were in the wrist. Number of procedures and number of players reporting those surgeries are shown in Figure 2. Several patients had multiple surgeries, both unilateral and bilateral, with the mean number of surgeries per patient shown in Table 3. Hip arthroscopy had the highest mean number of surgeries per patient with 1.61 surgeries (± 0.98). There was no significant difference between mean number of surgeries per patient for the five most reported surgeries.

The mean ages at survey completion were 19.4 ± 2.7, 22.9 ± 3.6, 25.7 ± 3.4, and 26.5 ± 3.9 years for high school, collegiate, professional, and senior national team players, respectively. These differences were significant based on ANOVA ($p < 0.001$). The mean ages for specialization in ice-hockey were 12.9 (± 2.4), 14.8 (± 2.9), 14.9 (± 2.7), and 15.0 (± 3.0) for high school, collegiate, professional, and senior national team players, respectively, and these differences were significant based on ANOVA (p = 0.038). Tukey's multiple comparisons tests revealed a significantly lower mean age at specialization for high school as compared to collegiate level players (p = 0.031) and for high school compared to senior national team players (p = 0.040).

There was a significant positive correlation between age at specialization and total number of years played (r = 0.132, p = 0.034). There was also a significant positive correlation between total number of years played and number of injuries (r = 0.203, p = 0.001), number of concussions (r = 0.169, p = 0.007), and number of surgeries from hockey

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injuries (r = 0.145, p = 0.019). There was no significant correlation between age at specialization and number of injuries (r = -0.027, p = 0.661), number of concussions (r = -0.034, p = 0.583), or number of surgeries (r = -0.034, p = 0.590). While the p-values are statistically significant, the small r-values suggest that the clinical relevance of these correlations is minimal.

Table 1. Demographic and injury data for total cohort

Variable (unit)	***Mean (Standard Deviation)***
Age at time of survey (years)	23.6 (± 4.1)
BMI	24.2 (± 3.1)
Age at menarche (years)	13.1 (± 1.4)
Age at starting hockey (years)	5.6 (± 2.3)
Age starting competitive hockey (years)	9.0 (± 2.6)
Age starting professional hockey (years)	21.5 (±3.7)
Age starting senior national team (years)	19.5 (± 2.2)
Age of specialization in ice hockey (years)	14.7 (± 2.9)
Number of years played high school hockey	3.9 (± 0.9)
Number of university seasons played	3.3 (± 1.3)
Number of years as professional	3.7 (± 3.0)
Number of years at senior national team level	5.5 (±3.9)
*Number of injuries**	2.3 (± 1.8)
Number of surgeries for hockey injuries	0.5 (± 1.0)
Number of concussions sustained during ice hockey	0.9 (± 1.1)
*Number of fractures**	0.5 (± 0.7)

*Sustained during ice hockey, preventing participation in ice hockey for 1 or more sessions

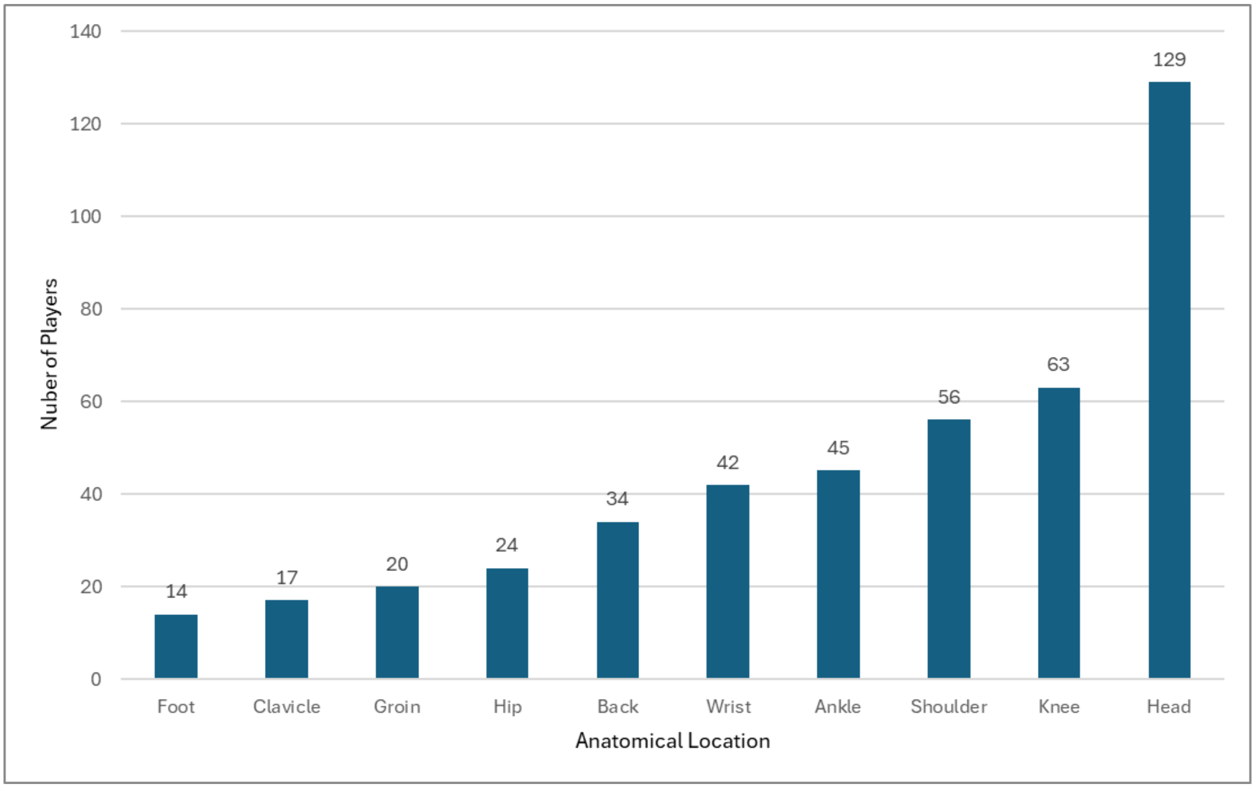

Figure 1. Number of players reporting injuries per anatomical location

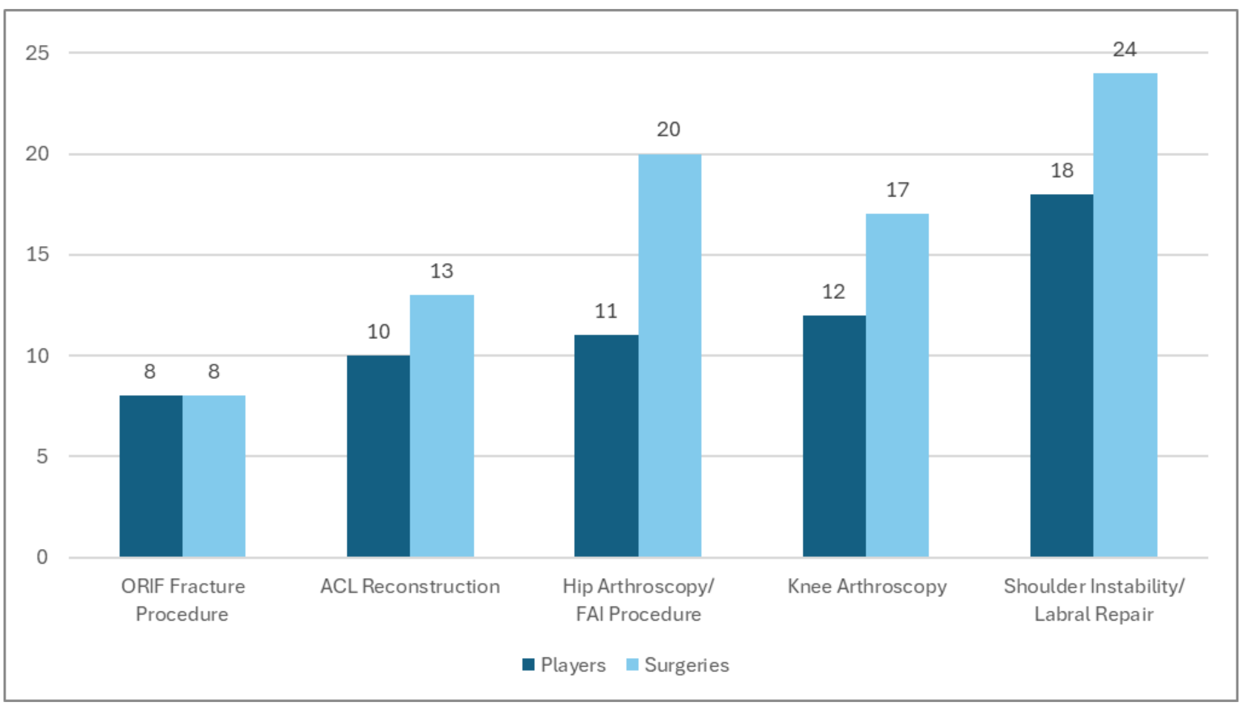

Figure 2. Top 5 procedures by number of players and surgeries

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Table 2. Reported surgery types and anatomical locations undergoing surgery

	Number of players (n=259)
Surgery type	
Ligament reconstruction	17 (6.2%)
Fracture fixation/repair	12 (4.4%)
Tendon or labral repair	31 (11.4%)
Debridement (meniscus surgery, bursitis, plica)	24 (8.8%)
Spine surgery (microdiscectomy)	4 (1.5%)
Other	2 (0.7%)
Unspecified	5 (1.8%)
Surgery anatomical location	
Knee	24 (8.8%)
Leg/ankle/foot	9 (3.3%)
Arm/Wrist	14 (5.4%)
Shoulder	18 (6.6%)
Back	4 (1.5%)
Hip	13 (4.8%)
Unspecified	7 (2.6%)

Table 3. Mean number of surgeries per player receiving surgery

Procedure Type	***Mean Surgeries Per Affected Player (Standard Deviation)***
Open Reduction and Internal Fixation (ORIF)	1.00 (± 0.00)
ACL Reconstruction	1.30 (± 0.48)
Hip Arthroscopy/FAI Procedure	1.82 (± 0.98)
Knee Arthroscopy	1.42 (± 0.67)
Shoulder Instability/Labral Repair	1.33 (± 0.77)

Highest Level of Competition – Associated Factors

No differences were observed between competition level groups in age at menarche, total injuries sustained, including subgroup analysis of number of fractures sustained, number of concussions, surgeries while playing ice-hockey ($p > 0.05$) (Table 3). There was statistically significant difference between competition level groups for age of specialization.

Injury Outcomes and Player Position

The type of injuries observed by position played is displayed in Table 4. A significant difference in the proportion of players with hip injuries by position was found ($p < 0.001$). More goalies had hip injuries (29.4%) than forwards (5.4%) or defense (7.7%). There was no significant difference in the proportion of players with overall shoulder or knee injuries by position ($p > 0.05$). The proportion of players with rotator cuff injuries differed by position ($p=0.017$), with both defense (5.1%) and goalies (5.9%) having higher rates than forwards (0%).

Injury Laterality and Side Dominance

Right-dominant (shoot-right) players were significantly less likely than left-dominant (shoot-left) players to sustain left-sided injuries (36.1% vs. 49.0%, p = 0.043). Although left-dominant players also showed fewer right-sided injuries than right-dominant players (50.3% vs. 62.0%), this difference was not statistically significant (p = 0.076; Table 5).

Concussions

Concussions sustained during hockey were reported by 49.0% of players (Table 4). However, mean number of total concussions reported by responding athletes was 0.9 (± 1.1). There was no significant difference in the proportion of players who sustained a concussion by highest level of play (p = 0.848), by play at the professional level specifically (p = 0.684), or by player position (p = 0.415).

Factors Associated with Professional Level Play

A bivariate logistic regression model was developed to identify predictors of professional level play. Age at menarche was a significant independent predictor of playing at the professional level (p < 0.001), with 1.25-fold increase in the odds of playing professionally for each additional year of age at menarche (Figure 2). Age at specialization and BMI were not significant independent predictors of playing at the professional level (p > 0.05).

Ongoing Issues After Retirement

Fifty-one out of 71 retired players (71.8%) reported ongoing physical and mental health issues. The most commonly affected anatomical locations were knee (31.4%), shoulder (17.6%), and back (15.7%). About two-thirds of ongoing musculoskeletal issues were pain-related, while the remainder of issues were described as instability, stiffness, weakness, catching/locking, and numbness. Six players reported ongoing non-musculoskeletal issues after concussions, such as headaches, memory problems, eyesight problems, "brain fog", and light sensitivity. Three players reported ongoing anxiety related to hockey.

Table 4. Injury data by highest level of competition

Variable (unit)	*Level of Competition*	*Mean (Standard Deviation)*	*P-value*
Age at menarche	Senior national team	13.5 (± 1.7)	0.129
	Professional	13.2 (± 1.3)	
	Collegiate	13.0 (± 1.3)	
	High school	12.8 (± 1.3)	
Age of specialization in ice hockey	Senior national team	15.0 (± 3.0)	0.038
	Professional	14.9 (± 2.7)	
	Collegiate	14.8 (± 2.9)	
	High school	12.9 (± 2.3)	
Number of injuries	Senior national team	2.9 (± 2.1)	0.068
	Professional	2.4 (± 1.6)	
	Collegiate	2.1 (± 1.8)	
	High school	1.9 (± 1.6)	
Number of fractures sustained during ice hockey	Senior national team	0.7 (± 0.8)	0.204
	Professional	0.4 (± 0.6)	

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	Collegiate	0.4 (± 0.7)	
	High school	0.5 (± 0.8)	
Number of surgeries for hockey injuries	Senior national team	0.6 (± 1.2)	0.163
	Professional	0.7 (± 1.0)	
	Collegiate	0.5 (± 0.9)	
	High school	0.1 (± 0.3)	
Number of concussions sustained during ice hockey	Senior national team	1.1 (± 1.4)	0.703
	Professional	0.9 (± 1.2)	
	Collegiate	0.9 (± 1.1)	
	High school	0.8 (± 1.1)	

Table 5. Anatomic location of injuries observed by position played

	Overall (n=259)	***Forward (n=147)***	***Defense (n=78)***	***Goalie (n=34)***	***P-value***
Knee	63 (24.3%)	36 (24.5%)	18 (23.1%)	9 (26.5%)	0.926
ACL	16 (6.2%)	10 (6.8%)	5 (6.4%)	1 (2.9%)	0.697
Meniscus	21 (8.1%)	10 (6.8%)	6 (7.7%)	5 (14.7%)	0.310
Patellofemoral	12 (4.6%)	8 (5.4%)	3 (3.8%)	1 (8.3%)	0.761
Hip	24 (9.3%)	8 (5.4%)	6 (7.7%)	10 (29.4%)	<0.001
Labral tear	17 (6.6%)	4 (2.7%)	6 (7.7%)	7 (20.6%)	<0.001
FAI	15 (5.8%)	3 (2.0%)	4 (5.1%)	8 (23.5%)	<0.001
Shoulder	56 (21.6%)	32 (21.8%)	18 (23.1%)	6 (17.6%)	0.812
Acromioclavicular	27 (10.4%)	16 (10.9%)	9 (11.5%)	2 (5.9%)	0.641
Labral tear	18 (6.9%)	7 (4.8%)	8 (10.3%)	3 (8.8%)	0.274
Rotator cuff	6 (2.3%)	0 (0%)	4 (5.1%)	2 (5.9%)	0.017

Sternoclavicular	1 (0.4%)	0 (0%)	1 (1.3%)	0 (0%)	0.312
Glenohumeral	15 (5.8%)	10 (6.8%)	3 (3.8%)	2 (5.9%)	0.665
Upper body					
Clavicle	17 (6.6%)	7 (4.8%)	9 (11.5%)	1 (2.9%)	0.098
Chest	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Abdomen	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Back	34 (13.1%)	20 (13.6%)	8 (10.3%)	6 (17.6%)	0.548
Lower body					
Buttocks	2 (0.8%)	1 (0.7%)	0 (0%)	1 (2.9%)	0.258
Pelvis	4 (1.5%)	2 (1.4%)	2 (2.6%)	0 (0%)	0.577
Groin	20 (7.7%)	13 (8.8%)	4 (5.1%)	3 (8.8%)	0.590
Leg/foot					
Upper leg	5 (1.9%)	4 (2.7%)	0 (0%)	1 (2.9%)	0.332
Lower leg	11 (4.2%)	7 (4.8%)	3 (3.8%)	1 (2.9%)	0.874
Ankle	45 (17.4%)	31 (21.1%)	8 (10.3%)	6 (17.6%)	0.124
Foot	14 (5.4%)	6 (4.1%)	6 (7.7%)	2 (5.9%)	0.518
Arm					
Biceps/triceps	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A
Elbow	6 (2.3%)	4 (2.7%)	2 (2.6%)	0 (0%)	0.627
Forearm	4 (1.5%)	4 (2.7%)	0 (0%)	0 (0%)	0.213
Wrist	42 (16.2%)	25 (17.0%)	15 (19.2%)	2 (5.9%)	0.196
Hand	9 (3.5%)	4 (2.7%)	5 (6.4%)	0 (0%)	0.176
Finger(s)	12 (4.6%)	7 (4.8%)	3 (3.8%)	2 (5.9%)	0.889
Head/neck					
Concussion	127 (49.0%)	77 (52.4%)	36 (46.2%)	14 (41.2%)	0.415
Jaw	2 (0.8%)	2 (1.4%)	0 (0%)	0 (0%)	0.464
Throat	0 (0%)	0 (0%)	0 (0%)	0 (0%)	N/A

Table 6. Proportion of left-dominant and right-dominant players with any right-sided, left-sided, and bilateral

	Left-dominant (n=151)	*Right-dominant (n=108)*	*P-value*
Right-sided injury	76 (50.3%)	67 (62.0%)	.076
Left-sided injury	74 (49.0%)	39 (36.1%)	.043
Bilateral injury	24 (15.9%)	16 (14.8%)	.863
Non-sided injury	58 (38.4%)	49 (45.4%)	.306

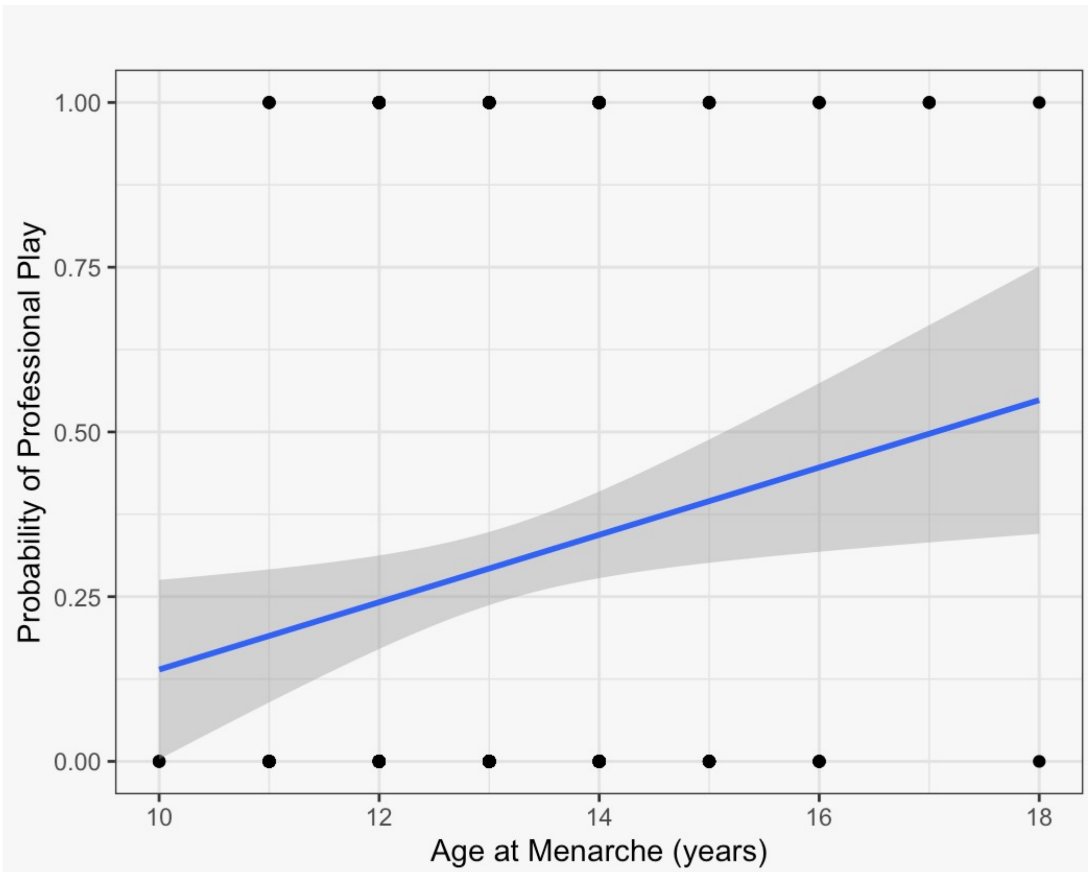

Figure 3. Probability of playing professionally based on age at menarche

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DISCUSSION

The most important findings of this study are that mean age at specialization was not associated with increased number of injuries, and the age of specialization was only associated with maximum level of competition in regard to our high school cohort. Notably, players are specializing at earlier ages than previously described (14 as opposed to 16) and later age at menarche was positively correlated with playing at the professional level.[18] Almost 90% of players experienced hockey-related injuries preventing participation in ice hockey for 1 or more sessions. Concussions were the most common injury and nearly one-third of goalkeepers sustained hip injuries. There is a trend toward a positive correlation shooting and ipsilateral injury. Additionally, over seventy percent of retired players reported ongoing health issues from career-related injuries.

This study presents interesting data on injury profiles in female ice-hockey athletes and specialization timeline. Previous research has explored the epidemiology of injuries in elite male hockey players and the impact of age specialization.

Specialization

Growing concern surrounds early sport specialization and its potential contribution to overuse injuries.[3,19-21] In our study, athletes began ice-hockey at mean 5.6 years of age, and specialized to ice-hockey at mean age 14, which differs from the previously published specialization age for elite female hockey players of 16 by Bloom et al.[18]

Ross et al found mean age at specialization in male hockey players to be 13, with no difference in highest level of play between early and late specialization.[6] Further, their study found no correlation between number of concussions, number of injuries, or age at specialization. Compared to the work of these authors, our survey comprised a larger cohort and identified a younger age at specialization for elite females, which was similar to males. Notably, the high school cohort, the youngest group in our sample, reported the earliest mean age at specialization (12.9 years), further supporting a shift toward earlier specialization among contemporary youth players. The significant positive correlation found between age at specialization and total number of years played, suggesting that later specialization is associated with longer careers, may not be truly reflective based on the recent shift in earlier specialization in youth players. [19] Additionally, our finding that age of specialization was not associated with professional level play is congruent with the results from Bloom et al.[18]

Injury Characterization

Most athletes surveyed (88.4%) reported at least one time-loss injury occurring at any point during their playing career, up to the time of survey completion or retirement. The most common injury was concussion followed by knee injury, which is not dissimilar from previously published data in ice-hockey.[22-26]

In a survey-based study on elite male hockey players, Ross et al found an average of 8 time-loss injuries in a player's career following specialization.[6] This is significantly more than our finding of 2-3 time-loss injuries, with more injuries reported with older age of survey respondent. Mean number of surgeries was also lower in the female compared to male cohort (0.5 vs 1, respectively). Total number of concussions were similar between sexes (1 vs 0.9 in men vs women data, respectively). The difference in number of time-loss injuries with over twice as many reported in male players compared to females is likely multifactorial. Contributing factors may include higher total number of games per season in male professional leagues, bodychecking prohibition in women's hockey, and potential underreporting from female players. This study also demonstrated a correlation between injury laterality and side dominance in play, which has not yet been established in the ice-hockey literature.

Shoulder Pathology

In our cohort, the most common surgical procedure was for instability/ labral repair (n = 24), consistent with high rates of instability reported in ice-hockey athletes.[27] Additionally, we observed a significant positional difference in rotator cuff pathology, despite no positional differences in overall shoulder injury rates or in any other specific shoulder subcategory. Prior MRI studies in elite male ice-hockey players show that rotator cuff abnormalities are relatively uncommon (approximately 6% of shoulders), suggesting that our finding may reflect variability in how respondents understood or applied specific shoulder-injury terminology.[28] Consequently, these results should be interpreted cautiously, and further work is needed to clarify true positional patterns in rotator cuff injury in elite female ice-hockey players.

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Hip Pathology

Given the proposed relationship between ice-hockey participation and cam deformity development due to repetitive rotational motion during growth, then it would reason that goalkeepers would experience higher rates of hip injuries and conditions due to the extreme ranges of motion required in this position.[15,16] Our survey found that almost one third of goalkeepers reported hip injuries, which was 4 times more than defense and 6 times more than forwards. These findings highlight the substantial hip-specific demands placed on elite ice-hockey players and help contextualize the broader patterns of FAI and groin injuries described in elite hockey players.

FAI and groin injuries have been well described in ice-hockey athletes, particularly those at high risk.[29,30] A radiograph-based study on elite female hockey athletes found a high rate of cam deformity in asymptomatic athletes, with 92% of athletes imaged having alpha angle > 55 degrees. Further, the study identified a positive correlation between age at menarche and alpha angle, with later menarche correlating with larger cam lesions.[15] Nguyen et al reported moderate to high sport specialization in ice-hockey athletes was associated with higher odds of developing a cam deformity, however age at specialization was not associated. These findings suggest that level of sport specialization in youth athletes may be associated with presence of cam deformity.[16] Our study did not find an association between age at menarche and hip injury.

Concussion

Interestingly, despite the "no contact" rules in women's hockey, we found concussion rates to be the same as male players. Average number of concussions was 0.9, however, only half of players had concussions, revealing a concerning finding that those who sustain a concussion are likely to have multiple. This fits with known data: Eliason et al assessed risk factors for concussion in Canadian youth ice-hockey athletes and found female players (despite policy prohibiting bodychecking), athletes at lower levels of play, and individuals with history of concussion had higher rates of concussion.[31] As research continues to highlight the long-term sequelae of multiple concussions are clarified, our findings underline the previously published alarming rate in female ice-hockey.

Further, our findings likely underestimate the total number of concussions as studies have shown that 30-80% of players may not report concussion symptoms.[32-34] Specifically, Wallace et al. found 55% of high school athletes didn't report suspected concussions, while Delaney et al. found 78% of university athletes did not report suspected concussions.[32,34] Kristensen et al recently studied perceived social pressure's influence on return to play for injured athletes; they found that players who perceived pressure to play, sought approval from others, and experienced game-specific temptations were more likely to return to play when injured, emphasizing players drive to continue to play regardless of symptoms or diagnoses.[35]

Sequelae of hockey-related injuries

Of retired players, 72% reported ongoing physical and mental health issues. Most were musculoskeletal, however, 12.5% of this subset reported ongoing mental or psychological conditions following concussion. This high incidence of ongoing physical and mental conditions after retiring, reported by almost three in four retired athletes, is concerning and underlines the need for injury prevention and optimal management in women's ice hockey.

Age at Menarche and Professional Play

Later age at menarche significantly predicted playing at the professional level. Elite female athletes tend to experience menarche later than the general population.[36] No consensus has been reached regarding an underlying mechanism linking later menarche with athletic success; however, several hypotheses have been proposed. Likely, the cause is multifactorial and consists of genetic, physiologic, and psychologic components. More research is needed to understand how age of specialization may moderate the relationship between age at menarche and prevalence of injuries

Stager and Hatler found athletes experience menarche significantly later than their non-athlete sisters, suggesting that training delays menarche.[37] Delayed menarche is more common in athletes compared to the general population.[36,38] Additionally, studies on physique and onset of menarche found that certain physical characteristics, such as lower weight-for-height percentage and lower body fat, are associated with later maturation and onset of menarche.[36] Interestingly, individuals with later maturation

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physique characteristics performed better on physical activities, particularly those that involved propelling the body forward.[36,39,40] These studies suggest a genetic connection between athleticism and menarche modified by behavior. However, hockey's diversity allows individuals of varying body types to succeed; at the 2022 Beijing Olympic Games, player BMIs ranged from 18.7 to 28.4.[41]

Another proposed hypothesis is the psychosocial implications of menarche on the developing athlete, as it pertains to her socialization in society. Although early maturing athletes have a physical advantage in sport initially, given their size and strength advantages, the social implications of entering puberty may socialize these individuals away from sport, resulting in the population of elite female athletes having delayed menarche compared to non-athlete peers.[36,42] It has been hypothesized that late-maturing girls may have increased motivation to succeed athletically. While evidence on women being socialized away from sport is incomplete, girls disengage from sport at a higher rate than boys, often due to social stigmatization.[43] As society promotes women's equality and celebrate women's athleticism, we hope to see a shift away from young women leaving sport.

The explanation of age at menarche as a significant independent predictor of playing at the professional level is likely multifactorial, consisting of genetic, physiologic, and psychologic components. Further longitudinal studies on menarche in athletes and sports socialization are needed to identify key factors.

Limitations

As a survey-based study, this study is subject to recall bias by the participants, however, retired players may be at greater susceptibility given prolonged time periods since injuries, medical diagnoses, and the age at specialization occurred. Our cross-sectional cohort (responders aged 16-38) allows us to compare between levels of competition; however, it also presents limitations: specifically, adolescent athletes reported fewer injuries due to fewer years of play, and they may serve as a proxy for annual trends in sports specialization. We do not have specific physical data, such as fat percentage at the time of specialization, or menarche. As a survey study with non-medical professionals, we also opted to utilize checkbox questions relating to specifics of injuries in an effort to get detailed information but also lead to some overlap of conditions. While we asked players to confirm if their diagnoses were confirmed with imaging, we do not have confirmation from healthcare professionals based on the nature of our survey and included all injuries reaching our definition of time out of hockey for at least 1 session. Additionally, as a retrospective study, the data does not permit an analysis of changes in injury patterns or professional success over time, nor does it evaluate long-term impacts of sport specialization. With the recent growth of professional women's ice-hockey, including the development of the PWHL across the U.S. and Canada, we are limited in how we can capture the current trends of specialization and injuries, but this remains a motivation for continued research. Finally, our power calculation assuming a small-to-moderate effect size of (r = 0.20), 80% power would require approximated 314 participants. Our study included 259 athletes, which is slightly under this threshold. Thus, the study may have been underpowered to detect small associations.

CONCLUSION

The salient findings of this study are: (1) almost 90% of players experienced time-loss injuries over their career; (2) no association was found between age at specialization and professional play; (3) a high incidence of concussion in women's ice-hockey was observed; (4) injury laterality frequently correlated with player shooting side; (5) goalkeepers were found to have high rates of hip pathology compared to other positions; (6) menarche age showed no association with injury type or volume; (7) retired players experienced high rates of ongoing musculoskeletal and/or psychological issues post-retirement, potentially secondary to concussions sustained during players' careers.

These findings add to an existing body of knowledge on injury patterns and risk factors and will help guide future treatment and prevention guidelines. Future work should focus on etiology of high concussion rates in elite women's ice-hockey given the "no contact" rules. It is also worth further examining the relationship of hip injuries/ FAI to skeletal development and sport, based on mixed data thus far in the literature in hockey athletes.

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Conflict of Interest Statement
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REFERENCES

1. Hockey USA. Girls & Women. (https://www.usahockey.com/girlshockey).
2. Jayanthi NA, LaBella CR, Fischer D, Pasulka J, Dugas LR. Sports-specialized intensive training and the risk of injury in young athletes: a clinical case-control study. Am J Sports Med 2015;43(4):794-801. DOI: 10.1177/0363546514567298.
3. Feeley BT, Agel J, LaPrade RF. When Is It Too Early for Single Sport Specialization? Am J Sports Med 2016;44(1):234-41. DOI: 10.1177/0363546515576899.
4. Brooks MA, Post EG, Trigsted SM, et al. Knowledge, Attitudes, and Beliefs of Youth Club Athletes Toward Sport Specialization and Sport Participation. Orthop J Sports Med 2018;6(5):2325967118769836. DOI: 10.1177/2325967118769836.
5. DiFiori JP, Benjamin HJ, Brenner JS, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. Br J Sports Med 2014;48(4):287-8. DOI: 10.1136/bjsports-2013-093299.
6. Ross KA, Fried JW, Bloom DA, Gonzalez-Lomas G. The effect of specialization and level of competition on injury in elite male ice hockey players. Phys Sportsmed 2022;50(4):295-300. DOI: 10.1080/00913847.2021.1916786.
7. Bell DR, Post EG, Trigsted SM, Hetzel S, McGuine TA, Brooks MA. Prevalence of Sport Specialization in High School Athletics: A 1-Year Observational Study. Am J Sports Med 2016;44(6):1469-74. DOI: 10.1177/0363546516629943.
8. Post EG, Bell DR, Trigsted SM, et al. Association of Competition Volume, Club Sports, and Sport Specialization With Sex and Lower Extremity Injury History in High School Athletes. Sports Health 2017;9(6):518-523. DOI: 10.1177/1941738117714160.
9. Post EG, Biese KM, Schaefer DA, et al. Sport-Specific Associations of Specialization and Sex With Overuse Injury in Youth Athletes. Sports Health 2020;12(1):36-42. DOI: 10.1177/1941738119886855.
10. Post EG, Trigsted SM, Riekena JW, et al. The Association of Sport Specialization and Training Volume With Injury History in Youth Athletes. Am J Sports Med 2017;45(6):1405-1412. DOI: 10.1177/0363546517690848.
11. Roos KG, Marshall SW, Kerr ZY, et al. Epidemiology of Overuse Injuries in Collegiate and High School Athletics in the United States. Am J Sports Med 2015;43(7):1790-7. DOI: 10.1177/0363546515580790.
12. Dalton SL, Zupon AB, Gardner EC, Djoko A, Dompier TP, Kerr ZY. The Epidemiology of Hip/Groin Injuries in National Collegiate Athletic Association Men's and Women's Ice Hockey: 2009-2010 Through 2014-2015 Academic Years. Orthop J Sports Med 2016;4(3):2325967116632692. DOI: 10.1177/2325967116632692.
13. Sheppard M, Nicknair J, Goetschius J. Early Sport Specialization and Subjective Hip and Groin Dysfunction in Collegiate Ice Hockey Athletes. J Athl Train 2020;55(3):232-237. DOI: 10.4085/1062-6050-0375-19.
14. Stull JD, Philippon MJ, LaPrade RF. "At-risk" positioning and hip biomechanics of the Peewee ice hockey sprint start. Am J Sports Med 2011;39 Suppl:29S-35S. DOI: 10.1177/0363546511414012.
15. Carter CW, Campbell A, Whitney D, et al. Characterizing cam-type hip impingement in professional women's ice hockey players. Phys Sportsmed 2021;49(2):203-206. DOI: 10.1080/00913847.2020.1808434.
16. Nguyen M, Bixby S, Yen YM, Miller P, Stracciolini A. Moderate and High Sport Specialization Level in Ice Hockey Athletes Is Associated With Symptomatic Cam Deformity. Sports Health 2023;15(5):753-759. DOI: 10.1177/19417381221123528.
17. Adlou B, Wilson A, Wilburn C, Weimar W. Early sport specialization impact on rates of injury in collegiate and professional sport participation: A systematic review and meta-analysis. Int J Sports Sci Coa 2024;19(4):1833-1843. (In English). DOI: 10.1177/17479541241248565.
18. Bloom DA, Wolfert A, Whitney D, Gonzalez-Lomas G, Carter C. Characterizing Sport Specialization Patterns in Professional Women's Ice Hockey Players. Bull Hosp Jt Dis (2013) 2021;79(2):93-97. (https://www.ncbi.nlm.nih.gov/pubmed/34081885).
19. Myer GD, Jayanthi N, Difiori JP, et al. Sport Specialization, Part I: Does Early Sports Specialization Increase Negative Outcomes and Reduce the

Opportunity for Success in Young Athletes? Sports Health 2015;7(5):437-42. DOI: 10.1177/1941738115598747.
20. Pasulka J, Jayanthi N, McCann A, Dugas LR, LaBella C. Specialization patterns across various youth sports and relationship to injury risk. Phys Sportsmed 2017;45(3):344-352. (In eng). DOI: 10.1080/00913847.2017.1313077.
21. Post EG, Struminger AH, Hibberd EE. Sport specialization is associated with upper-extremity overuse injury in high school baseball players. J Shoulder Elbow Surg 2020;29(9):1775-1782. DOI: 10.1016/j.jse.2020.01.092.
22. Abbott K. Injuries in women's ice hockey: special considerations. Curr Sports Med Rep 2014;13(6):377-82. DOI: 10.1249/JSR.0000000000000102.
23. Anderson GR, Melugin HP, Stuart MJ. Epidemiology of Injuries in Ice Hockey. Sports Health 2019;11(6):514-519. DOI: 10.1177/1941738119849105.
24. Decloe MD, Meeuwisse WH, Hagel BE, Emery CA. Injury rates, types, mechanisms and risk factors in female youth ice hockey. Br J Sports Med 2014;48(1):51-6. DOI: 10.1136/bjsports-2012-091653.
25. Tuominen M, Stuart MJ, Aubry M, Kannus P, Parkkari J. Injuries in world junior ice hockey championships between 2006 and 2015. Br J Sports Med 2017;51(1):36-43. DOI: 10.1136/bjsports-2016-095992.
26. Tuominen M, Stuart MJ, Aubry M, Kannus P, Tokola K, Parkkari J. Injuries in women's international ice hockey: an 8-year study of the World Championship tournaments and Olympic Winter Games. Br J Sports Med 2016;50(22):1406-1412. DOI: 10.1136/bjsports-2015-094647.
27. Swindell HW, McCormick KL, Tedesco LJ, et al. Shoulder instability, performance, and return to play in National Hockey League players. JSES Int 2020;4(4):786-791. DOI: 10.1016/j.jseint.2020.08.008.
28. Hacken B, Onks C, Flemming D, et al. Prevalence of MRI Shoulder Abnormalities in Asymptomatic Professional and Collegiate Ice Hockey Athletes. Orthop J Sports Med 2019;7(10):2325967119876865. DOI: 10.1177/2325967119876865.
29. Silvestri MA, Cleather DJ, Patterson S, Legg HS. Femoroacetabular Impingement in Ice Hockey Athletes. J Strength Cond Res 2023;37(10):2106-2117. DOI: 10.1519/JSC.0000000000004531.
30. Suits WH, O'Neil MM, Fogarty KJ. Acute Effects of Ice Hockey on Hip Range of Motion, Strength, and Pelvic Tilt in Competitive Male Players. Sports Health 2023:19417381231190649. DOI: 10.1177/19417381231190649.
31. Eliason P, Galarneau JM, Shill I, et al. Factors Associated With Concussion Rates in Youth Ice Hockey Players: Data From the Largest Longitudinal Cohort Study in Canadian Youth Ice Hockey. Clin J Sport Med 2023;33(5):497-504. DOI: 10.1097/JSM.0000000000001177.
32. Delaney JS, Lamfookon C, Bloom GA, Al-Kashmiri A, Correa JA. Why university athletes choose not to reveal their concussion symptoms during a practice or game. Clin J Sport Med 2015;25(2):113-25. DOI: 10.1097/JSM.0000000000000112.
33. Mrazik M, Perra A, Brooks BL, Naidu D. Exploring minor hockey players' knowledge and attitudes toward concussion: implications for prevention. J Head Trauma Rehabil 2015;30(3):219-27. DOI: 10.1097/HTR.0000000000000018.
34. Wallace J, Covassin T, Nogle S, Gould D, Kovan J. Knowledge of Concussion and Reporting Behaviors in High School Athletes With or Without Access to an Athletic Trainer. J Athl Train 2017;52(3):228-235. DOI: 10.4085/1062-6050-52.1.07.
35. Kristensen JA, Haugen T, Ommundsen Y. Perceived social pressure and intention to play through injuries in junior ice hockey: The sporting environment matters. J Sports Sci 2023;41(14):1363-1371. DOI: 10.1080/02640414.2023.2273084.
36. Malina RM. Menarche in athletes: a synthesis and hypothesis. Ann Hum Biol 1983;10(1):1-24. DOI: 10.1080/03014468300006141.
37. Stager JM, Halter LK. Menarche in athletes: the influence of genetics and prepubertal training. Medicine & Science in Sports & Exercise 1988;20(4):369-373. (https://journals.lww.com/acsm-msse/fulltext/1988/08000/menarche_in_athletes__the_influence_of_genetics.7.aspx).
38. Tsukahara Y, Namba A, Kamada H, et al. Factors that affect menarche in Japanese national-level track-and-field athletes. Am J Hum Biol 2022;34(2):e23622. DOI: 10.1002/ajhb.23622.
39. Beunen G, de Beul G, Ostyn M, Renson R, Simons J, van Gerven D. Age of Menarche and Motor Performance in Girls Aged 11 Through 18. In: Hebbelinck M, Borms J, eds. Pediatric Work Physiology: S.Karger AG; 1978:0.
40. Espenschade A. Motor Performance in Adolescence Including the Study of Relationships with Measures of Physical Growth and Maturity. Monographs of the Society for Research in Child Development 1940;5(1):i-126. DOI: 10.2307/1165475.
41. Beijing 2022 Women's Ice Hockey Teams. IIHF. (https://www.iihf.com/en/events/2022/olympic-w/teams).
42. Jones HE. Motor performance and growth: a developmental study of static dynamometric strength. University of California Press 1949.
43. Reframing Sport for Teenage Girls: Tackling Teenage Disengagement. Women In Sport. (https://womeninsport.org/wp-content/uploads/2022/03/2022-Reframing-Sport-for-Teenage-Girls-Tackling-Teenage-Disengagement.pdf).