Contemporary Practices of Strength & Conditioning Coaches in High-Level Male Ice Hockey: A Survey-Based Investigation

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Abstract:

The aim of this study was to provide an updated view of the common practices, ideologies, education level, and professional environment of strength and conditioning (S&C) coaches in elite male ice hockey. Nineteen S&C coaches from professional, semi-professional and top-tier collegiate hockey teams in North America completed an anonymous online survey. This was comprised of 10 sections: (a) background information; (b) technology use, (c) testing & periodization, (d) strength and power, (e) flexibility/mobility, (f) speed, (g) plyometrics, (h) aerobic and anaerobic conditioning, (i) rehabilitation, (j) challenges & areas of improvement. Fixed-response questions were analyzed via frequency analyses. Thematic analyses were used to identify common themes from open-response questions. S&C coaches had an average of eight (± 6.5) years of experience when they accepted their current role. The majority held a master's degree and S&C certification. Muscular power, linear speed, and body composition were the most frequently tested qualities. Neuromuscular fatigue was the most important consideration during the season and least important consideration during the off-season. Training frequencies for all physical capacities were lower during the season compared to the off-season. All S&Cs had access to technology, with wearables, with force plates identified as the most used devices. This information may be used by S&C coaches to compare working practices to those used by their peers and inform them of the likely requirements and skill sets needed for job applications. Educational institutions may use this information to align teaching to current practice and to inform future research.

KEYWORDS: S&C professionals, resistance training, plyometrics, aerobic conditioning, anaerobic conditioning

Introduction:

There have been a number of articles examining the practices of strength and conditioning (S&C) coaches in various sports (5, 9-11, 19, 31, 35); these articles have aimed to bridge the gap between scientific literature and practical implementation of strength and conditioning practices in baseball, football, basketball, soccer, rugby union, and swimming. Despite some recent manuscripts outlining proposed S&C methods in ice hockey, there is little published work examining whether these methods are actually used in practical settings (9, 24, 26).

The role of a strength and conditioning (S&C) coach in a team sport environment is multifaceted. The S&C coach expected to be capable of physically preparing athletes for the rigors of their sport, but they are also expected to have completed multiple years of formal education, hold recognized certifications, and demonstrate a working knowledge of sport science technology (32). For S&C coaches working in ice hockey, this may include creating and implementing on-ice and off-ice testing protocols, increasing strength and power through resistance training methods, developing aerobic and anaerobic qualities, effectively managing acute and chronic stress, as well as assisting in the rehabilitation process for injured athletes (24, 26).

The sport of ice hockey is similar to many team-based sports in that it requires short bursts of high-intensity actions such as accelerations, changes of direction, and contacts (24, 26). However, as a team sport, it is unique because it is played on ice. Thus, that the athlete experiences little to no friction with the playing surface when the skate blades are perpendicular to the ice, leading to the biomechanics of the hockey stride being significantly different than running on land (22, 24, 30). For example, greater external rotation and abduction at the hip, coupled with ground contact times that are longer than those seen during dryland running, mean that on-ice speed relies more heavily on biomechanical efficiency and impulse than the stretch shortening cycle (24). The average hockey player will play approximately 16 total minutes during a game with individual bouts (referred to as shifts) typically lasting anywhere from 30 – 85 seconds (4, 23, 33). Shifts are comprised of short duration intermittent bursts of near maximal activity where the player is working at or above 90% of their maximal heart rate (4, 23, 33). While the athlete

requires strong phosphocreatine and anaerobic glycolytic systems to power them during these intense bouts of activity, they also require robust aerobic systems to quickly recover during the 2 – 5 minutes they are allotted between shifts (4, 23, 29). The congested nature of the schedule places high emphasis on player recovery and regeneration as players demonstrate neuromuscular fatigue (determined via reductions in vertical jumping performance) as quickly as 3 weeks into a 6+ month season (14, 37). Moreover, this effect may be exacerbated after air travel, a factor that must be considered in high-level level ice hockey in North America (37).

To the author's knowledge, there has only been a single article examining common practices of S&Cs in elite level ice hockey (9). This article only observed S&C coaches in the National Hockey League (NHL) and stated that the vast majority of S&C coaches in the NHL did not utilize on-ice testing methods with their athletes (9). Since then, it has been shown that off-ice testing protocols significantly underestimate on-ice $\dot{V}o_2$ maximum and lactate threshold, with Nightingale, Miller and Turner (25) suggesting that testing protocols for hockey athletes should include a combination of on-ice and off-ice methods. Additionally, both the pace of play of the sport itself and the technology available to the S&C coach has changed substantially since 2004 (32, 38). For these reasons, it is important to provide an updated view of S&C practices within the sport. Thus, the aim of this study is to provide an updated view of the common practices, ideologies, education level and professional environment of S&C coaches currently employed by high-level ice hockey clubs within North America.

Methods:

Experimental Approach to the Problem:

This cross-sectional study was designed to investigate the common practices and ideologies held by S&C coaches currently employed by North American ice hockey teams using an anonymous online survey (Supplementary Digital Content 1). Eligible S&Cs were targeted through a biography search of online resources such as LinkedIn, team websites, and the Strength & Conditioning Association of Professional Hockey (SCAPH).

The survey comprised 10 sections: (a) background information; (b) technology use, (c) physical testing & periodization, (d) strength and power development, (e) flexibility/mobility, (f) speed development, (g) plyometrics, (h) aerobic and anaerobic conditioning, (i) rehabilitation, (j) challenges & areas of improvement. A link to complete the survey was emailed to all S&Cs who currently work for professional, semi-professional, or top-tier university male ice hockey clubs within North America. The results of the survey were then analyzed to identify similarities and differences in strength and conditioning practices and available resources based on level of competition as well as uncover overarching themes that were present among all S&Cs surveyed.

Subjects:

To be included in this study, S&C coaches were required to be currently employed with a professional (NHL, AHL), semi-professional (ECHL, SPHL, FPHL), or top-tier university (Usports, NCAA D1) male ice hockey team within North America, and to be over the age of 18. There were 7 ice hockey leagues and 190 S&C coaches that met the inclusion criteria for this study. Contact information was sought through a biography search of online resources such as LinkedIn, team websites and the Strength & Conditioning Association of Professional Hockey (SCAPH). Contact information was found for 110 S&Cs, all of whom were emailed a link to participate in the survey. All subjects were asked to complete an informed consent form prior to participating in the survey. Ethical approval was obtained from the Research and Ethics Committee of ***deleted for peer review***.

Procedures:

The survey (Supplementary Digital Content 1) was adapted from previous research that has examined the practices implemented by S&C coaches across various sports (9-11, 31, 35, 36). The survey included 52 fixed response questions and 12 open-ended questions. Most fixed response questions allowed for S&C coaches to include additional comments if desired. Some fixed response questions allowed for more than one option

to be selected. The survey was pilot tested by 3 S&C coaches to ensure that the questions were appropriate and easily understood. Each coach that was identified for inclusion received an initial email outlining the purpose of the study, inclusion criteria, expected time commitment, confirmation of anonymity, and a link to complete the survey via an online application (Qualtrics, Provo, UT. 2022). All eligible coaches were then sent reminder emails at 7 and 14 days after initial contact. Once the coach had completed the entire survey, they were directed to a page thanking them for their time and commitment to the research project.

Statistical Analysis:

The only survey responses included for analysis were those over 95% completed. Seventeen survey responses were omitted from analysis due to being incomplete. Frequency analysis was utilized to identify themes among the fixed response questions. All frequency analysis was completed through Qualtrics (Qualtrics, Provo, UT. 2022). Open-ended question responses were analyzed through the 6 step thematic analysis approach outlined by Braun and Clarke (3). This approach allowed for thematic recognition through a 6 stage process including: (a) data familiarization, (b) generating initial codes, (c) searching for themes, (d) reviewing themes, (e) naming and defining themes, (f) producing the report. The frequency and thematic analyses were completed on two levels. The initial analysis occurred across the entirety of survey results regardless of the league the coach worked within. Subsequently, both types of analysis were completed separately for professional (including one respondent from the ECHL) and collegiate level coaches. This breakdown allowed for the identification of overarching themes across the entirety of high-level North American ice hockey as well as the ability to examine differences and similarities seen between professional and collegiate levels of play.

Results

Background Information

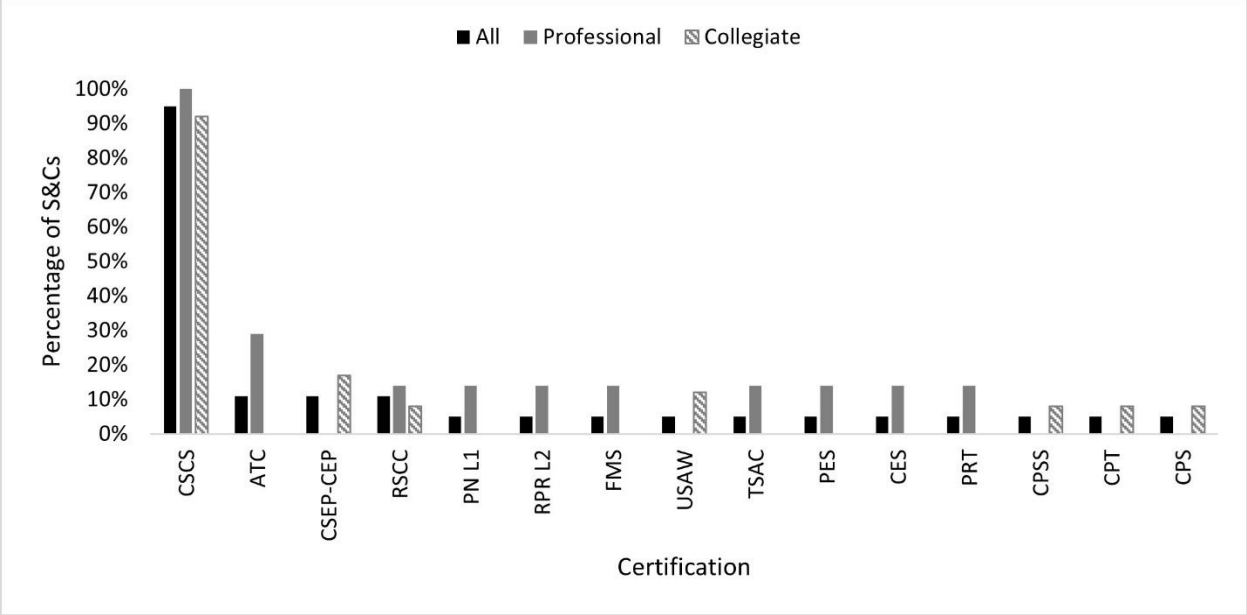
Nineteen S&C coaches across 5 leagues completed the survey in its entirety: 7 from professional leagues (NHL = 5, AHL = 1, ECHL = 1) and 12 from collegiate leagues (NCAA D1 = 6, USports = 6). The S&Cs had an average of 14.3 ± 9.6 years of total experience at the time of the survey and had 8.0 ± 6.5 years of experience when they accepted their current position (Supplementary Digital Content 2; Table 1). In terms of full-time, paid S&C coaches, rehabilitation, or sport science professionals, 74% (86% professional, 67% collegiate) employed ≤ 2 staff members, 21% (14% professional, 25% collegiate) employed 3-5, and 5% (0% professional, 8% collegiate) employed 6-10. Tenure was found to be limited as 63% (58% professional, 67% collegiate) had been with their current club less than 5 years, 16% (14% professional, 17% collegiate) had between 6-10 years of tenure, and 21% (29% professional, 17% collegiate) had greater than 10 years.

Professional certifications were held by 100% of S&C coaches. Forty-seven percent held more than one professional certification with the Certified Strength & Conditioning Specialist (CSCS) from the National Strength & Conditioning Association (95%) being the most popular overall, Certified Athletic Therapist (ATC) from National Athletic Trainers Association (29%) and Clinical Exercise Physiologist (CSEP-CEP) from the Canadian Society for Exercise Physiology (17%) were second most popular at the professional and collegiate levels respectively (Figure 1). The highest level of education completed by the majority of S&C coaches was a master's degree (79% overall, 71% professional, 83% collegiate), followed by an undergraduate degree (16% overall, 14% professional, 17% collegiate), and a doctorate (5% overall, 14% professional, 0% collegiate).

Figure 1 – Professional certifications held by S&C coaches in elite ice hockey.

Key: CSCS = Certified Strength & Conditioning Specialist, ATC = Certified Athletic Trainer, CSEP-CEP = Canadian Society of Exercise Physiology – Certified Exercise Physiologist, RSCC = Registered Strength & Conditioning Coach, PNL1 = Precision Nutrition Level 1, RPRL2 = Reflexive Performance Reset Level 2, FMS = Functional Movement

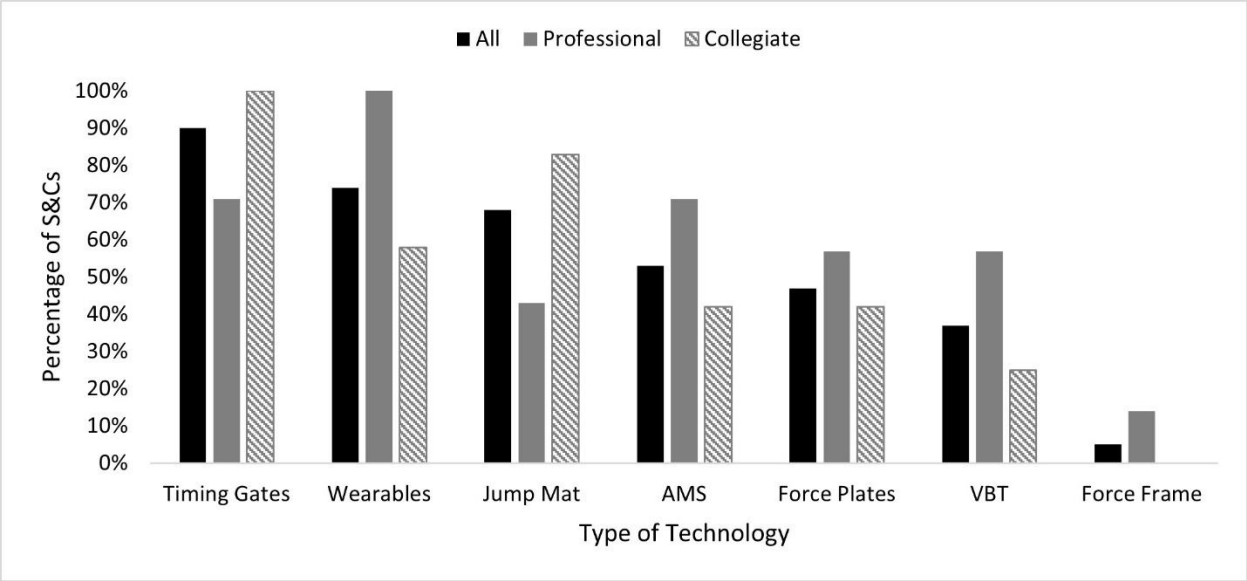
Systems, USAW = USA Weightlifting, TSAC = Tactical Strength & Conditioning Facilitator, PES = Performance Enhancement Specialist, CES = Corrective Exercise Specialist, PRT = Postural Restoration Trained, CPSS = Certified Performance & Sport Scientist, CPT = Certified Personal Trainer, CPS = Certified Posture Specialist



Technology Use

The three pieces of technology that were most widely available across all leagues were timing gates (90%), wearable technology (74%), and jump mats (68%) (Figure 2). Wearable technology (100%), athlete management systems (71%), and timing gates (71%) were most available in professional leagues, while timing gates (100%), jump mats (83%), and wearable technology (58%) were most available in collegiate leagues. Heart rate monitors (74%) and player positioning systems (32%) were most available by those that had wearable technology. Wearable technology (32% overall, 14% professional, 42% collegiate) and force plates (32% overall, 57% professional, 17% collegiate) were identified as the most useful pieces of technology (Supplementary Digital Content 2; Table 2).

Figure 2 – Technology available to S&C coaches in elite ice hockey.



When attempting to implement new technologies into their practice, S&Cs identified that convincing stakeholders of its value (53%), getting “buy-in” from the athletes (21%), and learning how to use the technology (16%) were the most common roadblocks. Other responses included “learning what to do with the data” and “time for data management”. Sixty-eight percent of all S&C coaches did not feel that the value they provide to their athletes would be substantially different if they did not have access to technology (Table 1). Fifty-eight percent of all coaches did not feel that the value they currently provide would be substantially improved if they had access to more technology than they currently have. Explanations included “it would be nice, but not essential”, “staffing must supersede technology”, and “I don’t know that I could handle taking in more data on my own”, however there were not sufficient written explanations to create higher order themes.

Table 1: S&C responses to why they feel removing technology from their practices would not substantially change the value they provide.

Rank	Theme	Exemplar Responses	Overall (n=19)	Professional (n=7)	Collegiate (n=12)
1	Only One Tool	"Technology only enhances what I already do" and "It is only a tool in development"	21%	0%	33%
2	Validates & Informs	"Technology provides granularity to the process and informs but does not direct our	21%	29%	17%

		strategies" & "We use our technology to validate what we are doing"			
3	Current Lack of Technology	"My resources are already limited" & "Budget constraints limit what I can use"	11%	14%	8%

Coaches that indicated their practices would be substantially different without technology were not included. Some coaches were categorised into more than one theme depending on their response.

Physical Testing & Periodization

Undulating (37%) and block (32%) were the most utilized periodization models among all coaches during the off-season and undulating (63%) was the most utilized periodization model during the season. Eleven percent indicated that they did not utilize any formal periodization model during the season. Sixteen percent stated that they used a combination of periodization models, with responses including “undulating block combination”, “vertically integrated block”, and “rules-based system”. These trends remained similar regardless of whether the coach was at the professional or collegiate level.

Muscular power (95%), linear speed (90%), and body composition (84%) were the most commonly tested qualities prior to the season, while muscular power (95%), body composition (74%), and muscular strength (63%) were the most commonly monitored qualities throughout the competitive season across all leagues. Prior to the season, body composition (100%), muscular power (86%) and the anaerobic system were the most commonly tested qualities in professional leagues, while muscular power (100%), linear speed (100%), and muscular strength (92%) were most commonly tested at the collegiate level. Only 26% (29% professional, 25% collegiate) of coaches utilized on-ice testing for either the anaerobic or aerobic system. During the season, muscular power (86%), body composition (86%), and internal load (57%) were most the most monitored qualities at the professional level and muscular power (100%), muscular strength (83%), and linear speed (67%) were the most monitored qualities among collegiate levels.

Finding a repetition maximum for a given exercise was the most common method for strength testing (58%), countermovement jump (90%) was the most popular power testing

method, timed accelerations (84%) were the most common speed testing method with 58% of coaches saying they tested speed both on-ice and off-ice. Modified Reactive Strength Index (RSImod) (32%) was the most utilized method for testing the stretch shortening cycle, however, 42% of coaches indicated that they seek to specially examine the stretch shortening cycle (Table 2).

Table 2: Physical Testing Methods Used

Testing Method	All	Professional	Collegiate
Strength Testing Methods			
RM	58%	43%	75%
MIFP	26%	29%	17%
MCP	11%	14%	17%
Other	11%	0%	8%
None	5%	14%	0%
Power Testing Methods			
CMJ	90%	86%	92%
SJ	32%	29%	33%
OLY	26%	0%	42%
Movement Velocity	21%	29%	17%
None	5%	14%	5%
SSC Testing Methods			
None	42%	29%	50%
RSImod	32%	29%	33%
RSI	26%	29%	25%
EUR	16%	14%	17%
Speed Testing Methods			
Timed Accelerations	84%	71%	92%
Timed Fly-ins	37%	57%	50%
RSA	37%	14%	25%
None	11%	29%	0%
Off-ice	31%	14%	42%
Combined	58%	57%	58%
None	11%	29%	0%

RM = Repetition Maximum, MCP = Muscle Capacity Testing, MIFP = Maximum Isometric Force Production, CMJ = Counter Movement Jump, SJ = Squat Jump, OLY = Olympic lifting (or derivatives), RSI = Reactive Strength Index, RSImod = Modified Reactive Strength Index, EUR = Eccentric Utilization Ratio, RSA = Repeated Sprint Ability, SSC = stretch shortening cycle

Sixty eight percent of coaches stated that they took neuromuscular fatigue into consideration with their monitoring protocols. This was more prevalent at the collegiate level (83%) than the professional level (43%). The most common method used to monitor neuromuscular fatigue was heart rate variability (16%). A thematic analysis uncovered that the top methods for mitigating neuromuscular fatigue were seen as proper

planning/load management (47% overall, 29% professional, 58% collegiate) and rest/sleep (37% overall, 57% professional, 25% collegiate) (Supplementary Digital Content 2; Table 3).

When asked to rank the importance of seven different qualities, average rankings indicated the following from most to least important: (1) recovery/fatigue management, (2) power development, (3) flexibility/mobility development, (4) strength development, (5) anaerobic system development, (6) stretch shortening cycle development, and (7) aerobic system development. During the off-season, the perceived order of importance shifted to: (1) strength development, (2) power development, (3) anaerobic system development, (4) aerobic system development, (5) stretch shortening cycle development, (6) flexibility/mobility development, and (7) recovery/fatigue management (Supplementary Digital Content 2; Table 4).

Strength & Power Development

The average repetition range for strength exercises across all leagues was 2 - 10, with a slightly higher range at the professional level (3 - 13) and slightly lower at the collegiate level (2 - 7). For exercises targeting power, the average repetition range across all leagues was 1 - 7. Power repetition ranges differed at the professional (1 - 10) and collegiate (1 - 6) levels. To determine load for strength exercises, coaches used percentage of one repetition maximum (%1RM) (32% overall, 0% professional, 50% collegiate), autoregulation (32% overall, 57% professional, 17% collegiate), mean velocity (26% overall, 43% professional, 17% collegiate), or a combination of %1RM and mean velocity (11% overall, 0% professional, 17% collegiate). To determine load for power exercises, coaches used maximum velocity (42% overall, 71% professional, 25% collegiate), autoregulation (26% overall, 29% professional, 25% collegiate), %1RM (21% overall, 0% professional, 33% collegiate), or a combination of %1RM and maximum velocity (11% overall, 0% professional, 17% collegiate).

Both levels of play had similar splits between lower body (60% ± 9%) and upper body (40% ± 9%) training focus. On average, professional S&C coaches allotted 59% of their

training to unilateral movements and 41% to bilateral movements, while collegiate coaches allotted 49% to unilateral and 51% to bilateral. Isolation exercises were used sparingly with over 80% of the program being comprised of compound exercises, regardless of if the coach was at the professional (83%) or collegiate (81%) level. Strength and/or power was typically trained twice per week during the season (84%) and four days per week during the off-season (58%) (Supplementary Digital Content 2; Table 5).

Flexibility & Mobility Development

All coaches implemented stretching in their programming. Dynamic stretching was used by 100% of coaches, static was the second most utilized among collegiate coaches (92%), while both static (86%) and proprioceptive neuromuscular facilitation (PNF) (86%) stretching were tied for second most utilized by professional coaches. Dynamic (90% overall, 86% professional, 92% collegiate) was the most used type of stretch prior to games or training and static (90% overall, 86% professional, 92% collegiate) was the most used type of stretch post-game or training. Static (79%), dynamic (47%), and PNF (37%) were the most commonly used types of stretches on off-days with static being most popular at both the professional (86%) and collegiate (75%) levels. Most coaches (53% overall, 57% professional, 50% collegiate) instructed their athletes to hold a static stretch for >30 seconds, with 20-30 second holds (32% overall, 29% professional, 33% collegiate) and 10-20 second holds (11% overall,14% professional, 8% collegiate) being the other utilized time frames. When asked to rank the importance of mobility in four anatomical areas from most to least important average rankings indicated that hip mobility was most important, thoracic spine mobility was second most important, ankle mobility was third most important, and shoulder mobility ranked at least important.

Speed Development

All coaches believed that off-ice speed transfers to on-ice speed, with 32% believing it transfers highly, 58% believing it transfers moderately, and 10% believing it transfers

trivially. Eighty-nine percent included dedicated speed training during the season and 100% included dedicated speed training during the off-season. Most coaches dedicated 1 day per week to speed training during the season (63% overall, 71% professional, 58% collegiate) and 2 days per week during the off-season (58% overall, 43% professional, 67% collegiate) (Supplementary Digital Content 2; Table 6). The most utilized off-ice training methods to develop speed were running mechanics (100%), resisted sprinting (100%), and timed accelerations (90% overall, 71% professional, 100% collegiate). The most utilized on-ice training methods to develop speed were resisted skating (47% overall, 57% professional, 42% collegiate), skating mechanics (42% overall, 71% professional, 25% collegiate), and timed accelerations (37% overall, 43% professional, 33% collegiate). On-ice speed training made up 16% (29% professional, 8% collegiate) and 43% (40% professional, 44% collegiate) of all speed training during the in-season and off-season periods respectively.

Plyometric Development

All coaches utilized plyometric exercises during the off-season and 90% (86% professional, 92% collegiate) utilized them during the season. Plyometric exercises were most likely to be included 2 days per week during both the in-season (53% overall, 57% professional, 50% collegiate) and off-season (53% overall, 43% professional, 58% collegiate) periods (Supplementary Digital Content 2; Table 7). A thematic analysis identified that S&Cs perceived rate of force development (63%) along with speed and agility (32%) as the top benefits of including plyometric exercises in their programming (Table 3).

Table 3: Perceived Benefits of Plyometric Exercises

Rank	Theme	Exemplar Responses	Overall (n=19)	Professional (n=7)	Collegiate (n=12)
1	Rate of Force Development/Power	"Ability to produce force at a high rate" and "High threshold motor unit recruitment".	63%	29%	83%

2	Speed & Agility	"Increased speed and agility" and "improve speed"	32%	29%	33%
3	Force Transfer	"Power transfer through the hips" and "helps with transfer of power from the ground (Ice) through the body"	16%	29%	5%
4	Elasticity	"Elastic properties" and "Increase SSC"	16%	43%	0%

Aerobic & Anaerobic Conditioning

The anaerobic system was most frequently not trained (32% overall, 29% professional, 33% collegiate) or trained just once per week (32% overall, 43% professional, 25% collegiate) during the season. During the off-season, the most reported frequencies for anaerobic training were twice (32% overall, 29% professional, 33% collegiate) or four times per week (32% overall, 43% professional, 25% collegiate). The methods used for developing the PCr system were sprints/interval training (90% overall, 71% professional, 100% collegiate), hockey games/practices (58% overall, 57% professional, 58% collegiate), and strength/power training (53% overall, 14% professional, 75% collegiate). The most utilized methods for developing the glycolytic system were sprints/interval training (58% overall, 57% professional, 58% collegiate), hockey games/practices (42% overall, 43% professional, 42% collegiate), and lactate threshold training (32% overall, 29% professional, 33% collegiate).

Similarly, the aerobic system was commonly not trained (42% overall, 43% professional, 42% collegiate) or trained just once per week (42% overall, 43% professional, 42% collegiate) during the season. During the off-season, the most reported frequency for aerobic training was twice per week (47% overall, 14% professional, 67% collegiate) (Supplementary Digital Content 2; Table 8). The methods used for developing the aerobic system were sprints/interval training (37% overall, 29% professional, 41% collegiate), long slow distance training (37% overall, 71% professional, 25% collegiate), resistance-

based circuit training (32% overall, 14% professional, 41% collegiate), and hockey games/practices (21% overall, 14% professional, 25% collegiate).

Rehabilitation

All coaches stated that they continued to train healthy regions of the body when a player sustained an injury. When asked to rank the top three injury sites they see with their athletes, coaches identified that the shoulder (32% overall, 14% professional, 42% collegiate), head (26% overall, 29% professional, 25% collegiate), and hip/groin (21% overall, 14% professional, 25% collegiate) were the most injured anatomical regions (Supplementary Digital Content 2: Table 9). Fifty-three percent (43% professional, 58% collegiate) of coaches indicated that they played a moderate role and 37% (57% professional, 25% collegiate) indicated they played a large role in the rehabilitation process. The most utilized methods of training during rehabilitation were isometric training (90% overall, 86% professional, 92% collegiate), eccentric training (90% overall, 100% professional, 83% collegiate), and proprioceptive training (74% overall, 71% professional, 75% collegiate).

Challenges and Areas of Improvement

All coaches were asked to predict future trends in the field of ice-hockey over the next 10 years as well as identify the greatest challenges that they currently face in their position. Thematic analysis was used to identify common themes. Results can be found in Table 4 and Table 5 respectively.

Table 4: Predicted Future Trends in Strength & Conditioning Over the Next 10 Years

Rank	Theme	Exemplar Responses	Overall (n=19)	Professional (n=7)	Collegiate (n=12)

1	Communication / Buy In	"Have more input in the coaches circle with regards to practice structure/scheduling" and "More integration between our field with the medical side and the coaches"	42%	29%	50%
2	Continued Research / Technology Integration	"Better utilization of technology/data" and "continue to explore the relationship between fatigue and performance, explore shorter more purposeful on ice practices"	32%	43%	25%
3	Increased Staffing	"Increase overall support staff" and "additional staffing"	21%	14%	25%
4	Education	"Educated strength coaches" and "increased level of education"	11%	0%	17%
5	Development Pathways	"I feel strength and conditioning is fairly advanced for hockey and sometimes overemphasized. Quality athlete development pathways would be helpful" and "Better educated trainers for youth so they are set up for success"	11%	0%	17%

Table 5: Greatest Challenges Faced by S&C's in Elite Hockey

Rank	Theme	Exemplar Responses	Overall (n=19)	Professional (n=7)	Collegiate (n=12)
1	Impacting Physiological Qualities	"Individualizing programs to meet the needs of each player" and "depending on where a player is training in their off-season, you may be coming back with completely different athletes than when they left"	37%	57%	25%

2	Time	"I work with multiple sports so time is a challenge" and "Coaches and players wanting to spend an unnecessary amount of extra time on the ice after practice or before games"	32%	29%	33%
3	Staffing	"Antiquated and outdated medical staff"	21%	14%	25%
4	Player Training History	"Youth development, so many athletes show up to college with overuse injuries because they play hockey year round" and "Most junior programs are also terrible for training"	16%	14%	17%
5	Communication	"It is up to us to communicate adequately with the coaching staff so there is no confusion on what we are doing and why" and "Coaching changes and old school philosophies"	11%	0%	17%
6	Other Duties	"Administration" and "wearing of many hats (Operations, S&C, Sport Science, Rehab)"	11%	0%	17%

Discussion

To the authors knowledge, this is the first study to examine the practices of S&C coaches across multiple high-level North American ice hockey leagues. The study aimed to provide an updated view of common practices, ideologies, education levels, and professional environments in which coaches are currently employed. The study reports that most S&C coaches held a graduate degree and were certified as a CSCS. Technology was seen as a likely avenue for continued development over the next decade and was available and utilized by all S&C coaches. Most indicated that they do not feel as if increasing the availability of technology would increase the value they provide to their athletes due to a lack of available resources (time & staff) to adequately make use of the collected data or simply the belief that they are able to do the job well enough without more data points. Periodization was widely used, with an emphasis placed on reducing the frequency of training for all physiological qualities during the competitive season.

The current study reports that S&C coaches in male ice hockey were more likely to hold a strength and conditioning certification than S&Cs in professional soccer, swimming, and rugby union (5, 19, 35). They were also more likely to hold multiple professional certifications and a master's degree, but less likely to hold a doctorate than S&C coaches in professional soccer (35). The high levels of education and certification are likely a reflection of the increasing employer expectations and quality of the candidates for positions in professional sport settings (12). The average tenure of S&C coaches in elite hockey in 2022 seems to have dropped compared to 2004 (6.3 years) and is less than what has been reported in professional basketball and football (9, 11, 31).

Despite the evidenced usefulness of load monitoring in ice hockey (1, 2), only 29% of professional and 33% of collegiate S&C coaches in the current cohort indicated that they utilized player positioning systems with their athletes. One major reason for this could be that the current collective bargaining agreement in the NHL does not allow for positioning systems to be worn during games. Three factors noted in the study as potential roadblocks to the introduction of new technology may further contribute to this finding. Specifically, a lack of financial commitment from stakeholders, lack of time to collect and

comprehend the data, and inability to obtain buy-in from coaches and/or players. Further research examining the use of local positioning systems to quantify game and practice demands of elite ice hockey cohorts is recommended to aid S&C coaches when attempting to convince stakeholders of their value and to assist with programming at the individual level.

All S&C coaches at the professional level agreed that rest and recovery was the most important consideration during the season. However, collegiate level coaches were more likely to monitor neuromuscular fatigue than their professional counterpoints. Whilst the most common method used to monitor neuromuscular fatigue was heart rate variability, this was only employed by 16% of the cohort. Such findings highlight the lack of consensus regarding monitoring in this area. Whitehead et al. (37) found that total fatigue scores were significantly increased after air travel and that total scores of fatigue were negatively correlated with lower body power in NCAA D1 hockey players. These players only required air travel to attend three games throughout the entire season, which is much less than is typically required at the professional level. Although it has been identified as an important factor during the season, there does not seem to be a consensus method of monitoring neuromuscular fatigue in elite North American ice hockey. Future research should explore this area further, particularly within professional level sides with a more demanding travel schedule.

The most tested physiological qualities by coaches in this study were lower-body muscular power, linear speed, and body composition. The most popular assessment modality was a countermovement jump, utilized by 90% of coaches. Ebben et al. (9) found that an NHL cohort also tested muscular power (most frequently using a vertical jump) and body composition, but few tested speed. Since these findings were reported in 2004, there has been an increased emphasis on faster pace of play. Moreover, research investigations have demonstrated that linear speed is linked to likelihood of selection by elite clubs or can distinguish between levels of performance (17, 28). A study examining an elite polish league team found that on-ice 30m sprint time was one test that held predictive value in determining whether the player would make or be cut from the final team roster (28). Additionally, 10m off-ice sprint times were found to be one of the major

differences between elite level senior and junior Norwegian players, with seniors being the faster of the two cohorts (17). The combination of these factors validate the rising popularity of testing linear speed for elite hockey cohorts. It is interesting that a higher percentage of S&Cs chose to assess body composition versus muscular strength. Body composition has been shown to have low predictive value for on-ice success, while muscular strength has been shown to have high predictive value (17, 20, 27). Only 26% of S&C coaches chose to test either the anaerobic or aerobic system on-ice which is perhaps surprising. Given that off-ice $\dot{V}O_2$ and lactate threshold has been shown to differ from on-ice values, Nightingale et al.'s review (25) suggested that testing protocols for hockey athletes should include a combination of on-ice and off-ice methods.

All respondents indicated that they trained strength and power throughout the entirety of the year. Coupled with the fact that 95% of S&C coaches reported testing strength and power attributes, this would appear to highlight the perceived value of gym-based training within ice hockey. Strength and power training frequencies were altered at different points throughout the season with 2-4 sessions per week being the most popular frequencies during the competitive season and off-season respectively. These training frequencies are similar to what has been seen across other team sports, where strength and power are most likely to be trained twice per week during the season and three times per week during the off-season (9, 10, 19, 31, 35). Jones et al. (19) suggested that S&Cs in Rugby Union have more time with players and fewer stressors to consider during the off-season, allowing them to shift the focus from strength maintenance during the season to strength development during the off-season. This theory likely holds true for elite ice hockey as well, where it would appear as if the off-season involves increased frequency and volume of strength training in order to prepare the athletes for the high strength and power demands experienced during the competitive phase. Similar to other team sports, the most common method for prescribing load for strength training was through %1RM (9, 10, 19, 31). Velocity based training (VBT) was the most utilized method for load prescription for exercises targeting power production. VBT is a contemporary training method that has been shown to produce similar or increased strength and power adaptations when compared to more traditional methods of load prescription (34).

All S&C coaches included speed training in their programming, similar to findings from other team sports (10, 11, 19, 31, 35). Where the current study differed from past findings is in the more frequent utilization of resisted sprinting; this was implemented by no more than 70% of coaches in previous investigations (9, 10, 19, 31, 35). The popularity of resisted sprinting drills could be due to the fact that the frictionless environment of the ice surface results in ground contact times during skating being longer that those seen in traditional sprinting (24). Multiple studies validate the S&C coaches belief that off-ice speed transfers either moderately or highly to on-ice speed (16, 18, 21). All S&C coaches included plyometric training in their programming, with the main perceived benefits falling under higher order themes of rate of force development/power and speed. Aside from the NFL, where only 73% of S&C coaches used plyometrics, both the percentage of S&C coaches that use plyometrics and perceived benefits are similar to those seen in other team sports (9-11, 19, 31, 35).

Most S&C coaches chose to train both the anaerobic and aerobic energy systems sparingly during the season (0-1 days per week) before increasing the frequency to twice per week for the aerobic system and between 2-4 days per week for the anaerobic system during the off-season. Although aerobic performance has been shown to remain stable throughout an elite ice hockey season, the same cannot be said for the anaerobic system (13, 15). The anaerobic system seems to improve during the first half of the competitive season only for these improvements dissipate over the second half of the season (6-8). Although speculative, it possible that hockey coaches may shift from more physiologically demanding practices in the first half of the season to more tactically driven practices in the second half of the season. Thus, S&C coaches may wish to consider increasing the amount of anaerobic conditioning included in their programming during the latter half of the season to avoid a detraining effect prior to the important playoff period. Coaches should also consider if any reductions in anaerobic performance over the second half of the season are consequential of accumulated hockey load (i.e. fatigue) and if activities with reduced neuromuscular loading (e.g. repeated sprints with fewer directional changes or collisions) may be beneficial. College S&C coaches were more in favor of utilizing resistance training to develop the anaerobic system than professional coaches. The reason for this is unknown but could speak to the potential difference in training ages

between the two levels of elite ice hockey included in the current study. A point that potentially validates this theory is that two collegiate S&C coaches identified quality “youth development pathways” as an area for improvement in the industry over the next decade. One coach specifically called for “more focus on basic strength as opposed to sports specificity”.

Dynamic stretching was used by all S&C coaches and was very popular prior to games and training. These findings are similar to those found in professional soccer, baseball and rugby union, but differ from the NBA and NHL specifically, where static stretching was most utilized (9, 10, 19, 31, 35). The hip and thoracic spine were ranked as the two most important areas of mobility for hockey players. This makes sense given the hip abduction, external rotation and extension necessary for the hockey stride and thoracic rotation necessary for shooting and handling the puck (24). However, whilst the S&C coaches ranked shoulder mobility as the least important of the four factors (behind the hip, thoracic spine, and ankle), the shoulder was reported as the most injured area of the body. Future research may wish to consider if deficits in shoulder mobility are a potential risk factor for shoulder injury within ice hockey players.

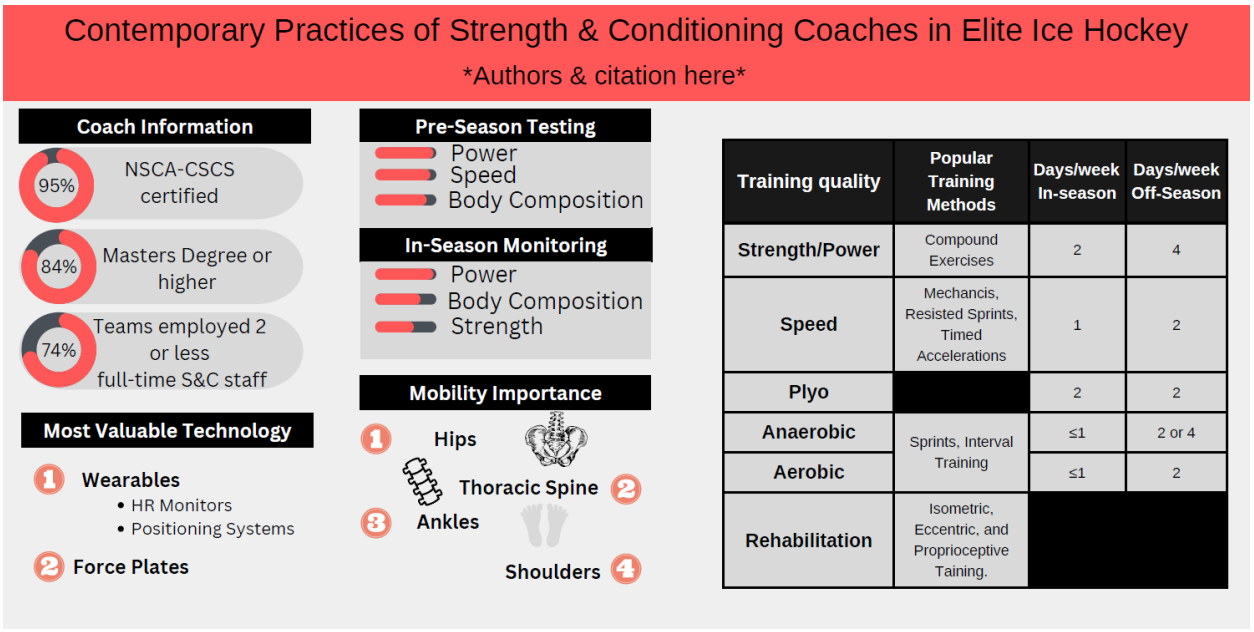
Impacting physiological qualities, time, staffing, player training history, communication, and other duties were all seen as challenges that S&C coaches face in their roles. Aside from player training history, these challenges are similar to those seen by S&Cs working in professional soccer (35). Many professional soccer clubs have youth academy systems with appropriate strength and conditioning practices in place, which could be a reason for them omitting player training history as a challenge. Although the drafting and development process in professional ice hockey does not operate in the same manner as professional soccer, creating a standardized long-term athletic development plan may help to increase athlete performance across the lifespan and reduce S&C responsibilities at the highest levels, allowing them to focus more time and effort to other areas of the profession.

It is important to note some of the key limitations of the current study. First, the reliability and validity of the questionnaire was not explicitly examined. The questionnaire was developed in line with previous investigations (9-11, 31, 35, 36) and piloted within a small

cohort of three S&C coaches. Nonetheless, it is recommended that future studies examine concepts of reliability and validity directly. For example, hockey coaches noted neuromuscular fatigue as an important consideration in-season. However, A definition was not provided to the coaches in the current survey, and they could therefore interpret this term how they wished. It is recommended that a clear operational definition for the term is used in future investigations. When the survey sought to determine coaches' testing practices, it provided no distinction between bilateral and unilateral assessments for tests such as jumps, nor did it specify upper versus lower body measurements. Similar limitations are present in the evaluation of training practices. No specific distinctions were made regarding definitions of particular periodization strategies employed (e.g., "block", "undulating", etc.) or the structure of the training microcyle (e.g., upper versus lower splits, high versus low days, etc.). Further, coaches were only able to note the use of VBT for load prescription as a binary option; no details regarding implementation such as velocity target zones or velocity cut-offs were sought. Lastly, it must be emphasized that the current study did not seek respondents from women's hockey, leagues outside of North America, lower levels of competition, or junior academies. Thus, any findings from this investigation should not be generalized to other populations.

Key findings of the current study are summarized in Figure 3. In conclusion, S&C coaches working in high-level male North American ice hockey are likely to hold a master's degree and hold a professional S&C qualification. Heart-rate monitoring is common practice in the sport, however, positioning data is not widely used. Assessments of muscle power (vertical jump), linear speed and body composition appear used throughout the year. During the off-season, coaches prioritize the development of physical qualities with strength and power rated as the most important capacities. During the in-season, management of neuromuscular fatigue is noted as the most important consideration. However, there is little agreement on how this is monitored.

Figure 3 – Infographic summarizing the contemporary working practices of S&C coaches in elite ice hockey.



Training quality	Popular Training Methods	Days/week In-season	Days/week Off-Season
Strength/Power	Compound Exercises	2	4
Speed	Mechancis, Resisted Sprints, Timed Accelerations	1	2
Plyo		2	2
Anaerobic	Sprints, Interval Training	≤1	2 or 4
Aerobic		≤1	2
Rehabilitation	Isometric, Eccentric, and Proprioceptive Taining.		

Practical Applications

The current study outlines contemporary practices of S&C coaches working with high-level male North American ice hockey teams. S&C coaches and employers may utilize the data outlined in this study to formulate a baseline level experience, education, certification, and core competencies required to obtain a professional S&C coaching position within ice hockey. S&C coaches are likely to require a master's degree, professional S&C certification, and several years' coaching experience to obtain a role at this level.

S&C coaches may use this information to compare their current practices to those that are used by their peers, as well as to guide future testing, monitoring, and programming protocols. Educational institutions may use this to align teaching to current practice and to inform future research. S&C coaches should have a good understanding of physiological monitoring practices to monitor internal load and fatigue responses; utilization of positional tracking systems may provide further detail regarding external load. The capability to enhance multiple physical capacities – including strength, power, body composition, and both aerobic and anaerobic fitness – is considered a fundamental requirement in hockey. To ensure success in this regard, it is imperative that coaches possess a high level of expertise in the implementation of various training methodologies.

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