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Analysis of Strength and Conditioning Demands in Ice Hockey

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Abstract: As winter sports in China continue to grow and gain popularity, more and more people are engaging in and showing interest in these activities. Among the winter sports, ice hockey stands out as the only team ball sport in winter, capturing the public's attention and enjoying widespread popularity. Despite the early development of ice hockey in China, there are still big differences compared to foreign levels, mainly in physical fitness, technical and tactical differences. This paper discusses the research on strength and conditioning training of ice hockey in China and abroad through the literature method. The strength and conditioning requirements of ice hockey are examined through the lens of strength and conditioning assessment and body composition, based on the unique characteristics of the sport. This approach enables the head coach, strength and conditioning coach, and research personnel to gain a comprehensive understanding of ice hockey training and effectively apply strength and conditioning methods, providing valuable guidance and reference for the development of ice hockey strength and conditioning programs.

Keywords: Ice hockey; Assessment of strength and conditioning; Demand of strength and conditioning

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1. Introduction

The successful hosting of the 2022 Winter Olympic Games has sparked unprecedented growth in winter sports in China. Driven by national policies, the expansion of winter venues, and the booming market economy, an increasing number of people are becoming aware of and participating in ice and snow sports. Ice hockey, as the only team sport in winter sports, has made significant development in our country. However, on the international stage, China's ice hockey performance has been relatively mediocre. For example, in the past five years at the World Ice Hockey Championship, the Chinese men's ice hockey team has consistently competed at the B Group B level, while the women's ice hockey team has played in the B Group A level [1]. The development of ice hockey in China is constrained by multiple factors. From the perspective of the players, issues such as player selection and the physical gap in confrontational skills highlight a significant deficiency in the physical conditioning and reserves of Chinese ice hockey players. From the perspective of physical training, the lag and lack of scientific rigor in physical evaluation, monitoring, training theories, and methods indicate that China's ice hockey physical

training system is incomplete and non-standard. After comparing the relevant research on ice hockey physical training inside and outside China, it is found that there is a lot of research on ice hockey physical training in foreign countries, and most of them are empirical research. These studies often offer a comprehensive analysis of training for different age groups and skill levels. In contrast, research on ice hockey physical training theory in China is primarily theoretical, with few empirical studies available. There are many researches on national ice hockey team, and there are few researches on physical training in different age groups. This phenomenon may be limited by the slow development and popularization of ice hockey, the lack of comprehensive multi-level leagues, and the lack of professional researchers. Therefore, the purpose of this paper is to review the relevant researches on both domestically and internationally through a literature review, and to analyze the existing deficiencies. This paper discusses and summarizes key aspects of physical fitness assessment, screening, and training methods to highlight the research frontiers and emerging trends in ice hockey physical training. The goal is to provide both theoretical and practical guidance for those involved in ice hockey physical training research.

2. Analysis of the characteristics of ice hockey

Ice hockey is a team-based, competitive sport. The players of both sides frequently contact the opponent and the protective plate around the ice at high speed. According to the classification of competitive sports based on the dominant factor of competitive ability, ice hockey falls under the category of skill and rivalry sports [2]. In this game, each team consists of six players, with three forwards, two defenders, and one goalie. Players wear heavy protective equipment and perform a range of technical actions, such as quick starts, stops, and turns (direction changes), while skating and using sticks in both offensive and defensive situations at high speeds and under unstable conditions. They execute technical skills such as skating, blocking, dribbling, passing, and shooting. To win the game, athletes must possess a strong physical foundation, solid skill reserves, excellent team tactical execution, and psychological endurance.

Ice hockey shares many similarities with other adversarial sports, but there are notable differences, particularly in the playing field, protective gear, and substitution rules. Unlike most similar sports, which are typically played on solid surfaces like wood or grass, ice hockey is played on smooth ice. Additionally, while players in other sportswear sports shoes, ice hockey players use skates, which are designed for movement on the slippery surface. In addition, ice hockey players primarily adopt a half-squat posture with their upper bodies leaning forward, using their legs to generate alternating sideward force [4]. This body movement combines actions on both the sagittal and frontal planes to propel the player forward. The protective gear worn by ice hockey players is the most extensive and complete among similar sports, which directly contributes to the high intensity of the game. Players can engage in more physical and rough movements while attacking or defending. A distinctive feature of ice hockey is its rotation style: regular-season games are divided into three 20-minute periods with 15-minute breaks in between. To maintain the game's intensity, players are rotated in groups, with each group typically playing for about 72 seconds per shift [3].

3. The physical requirements of ice hockey players

Physical fitness forms the foundation for athletes to develop and sustain their competitive abilities. While ice hockey is a skill-driven sport, strong physical conditioning is essential for executing precise technical movements and completing effective technical sequences. Therefore, without good physical fitness as the foundation, it

is difficult to maintain a high level of competitive performance in ice hockey. From the characteristics of ice hockey, it is clear that the sport is a typical high-intensity intermittent activity. Except for the goalie, every player on the team rotates in and out of the game, engaging in intense bursts of activity followed by short periods of rest. The high-intensity and high-confrontation game environment requires the players to constantly improve their physical ability to optimize their sports performance. Multi-element training is important for ice hockey players. The players are required to have good strength, speed, endurance, and other physical qualities. Additionally, factors such as the sports venue, player positioning, and the intensity of physical confrontations must also be considered, as they directly impact the demands placed on the players during the game.

3.1. Physical fitness assessment

Physical fitness assessment is a comprehensive evaluation of an athlete's physical capabilities. It serves as the foundation for an athlete's involvement in a sport, helping to assess their potential, strengths, and areas of weakness. By analyzing scientific data from these evaluations, it provides valuable insights and guidance for designing targeted physical training programs to optimize the athlete's performance [4].

3.1.1. Position difference

Burr conducted land-based physical tests on 853 NHL Draft participants from 1998-2006. These land-based physical tests included: Body composition test (height, weight, body fat), 30s Wingate anaerobic power test (peak power, fatigue index), power bike VO_2 max test, gripping power (grip apparatus), bench press, push-ups, sit-ups, standing jumps, vertical longitudinal jumps, sitting forward bend, push, pull, and other length strength. The test data showed that the results of the land test had a low correlation or no correlation with the performance of the competitors. However, when the data for goalkeepers were excluded, the correlation improved, indicating that there are positional differences in physical fitness tests within ice hockey. This suggests that different positions require distinct physical attributes and training considerations.

Among them, the standing long jump test results are positively correlated with forwards and defenders. After the combination of components, the correlation between the forward and the back is higher. At the same time, peak power and fatigue rate in Wingate test are more important for the selection of defenders [5]. Boucher conducted land-based tests on NHL players, including the vertical jump, standing long jump, and on-ice performance tests (such as the anaerobic ability test on ice, which includes 40 m straight-line sprints, SAS-40 m, and the Modified Repeated Skate Sprint Test, RSSm). The study found that for defenders, there was a strong correlation between vertical jump performance and SAS-40 scores. However, forwards showed no significant difference in this regard. On the other hand, forwards demonstrated a high correlation between their long jump scores and SAS-40 scores, while no such correlation was found for defenders [6].

3.1.2. Predictions of skating performance on ice from land tests

In terms of physical fitness test on land, Paov *et al.* conducted a comparative analysis of physical fitness test on land (40 m sprint run, beep test, Illionis run) and physical performance on ice (40 m sprint speed skating, beep test on ice, Illionis test on ice). He found a large linear relationship between the land test and ice performance in 40m sprint ($r = 0.86$, $P \leq 0.05$) and beep test ($r = 0.87$, $P \leq 0.05$), while the Illinois (-0.49, $P \leq 0.05$) sensitivity test showed a moderate negative correlation [7]. Similar results have been confirmed in several studies [8–10]. Roczniok found in his experimental studies exploring the Wingate test's relevance to the hockey program: Relative peak power was significantly correlated with 30 m sprints, 6x9 m turns and 6x30 m endurance tests

on ice ($P \leq 0.05$) while maximum oxygen intake (VO_2 max) was significantly correlated with 30 m sprints, 6x9 m stops and 6x30 m endurance tests on ice ($P \leq 0.05$). Therefore, it is concluded that the aerobic and anaerobic capacity index in Wingate test is correlated with the special test of ice hockey, and can be used as one of the evaluation methods [11,12]. Bracko believes that the 40-yard dash is the best predictor of speed in female hockey players between the ages of 8 and 16 [13]. After testing 45 ice hockey players, Peterson found that vertical jump (r = -0.42; r = -0.58), relative peak power in the Wingate test (r = -0.32; r = -0.43), and relative mean power (r = 0.34; r = -0.48, $P \leq 0.05$) were correlated with on-ice acceleration and maximum speed, but were not related to repeated sprint performance. It is also concluded that although land tests can predict single acceleration and maximum speed ability, they cannot predict athletes' repeated sprint ability on the court, let alone their performance on the ice [14]. Martin believes that maximum force has a significant effect on the ice performance of athletes of different ages, indicating that maximum force has a predictive effect on the ice performance of athletes of different ages [15]. Although Boucher found a relationship between certain on-land tests (Wingate tests) and on-ice performance, in his study, the Wingate test only predicted on-ice performance to a certain extent (24 %), and 76 % of on-ice performance had to be explained in other ways [6].

Based on a review of the literature, Nightingale recommends a reliable set of recommendations for physical fitness tests, including both land and ice skating tests, as shown in **Table 1** [16]. The aim is to provide a more realistic reflection of an athlete's physical condition.

Table 1. Recommended physical fitness test contents of ice hockey events

Test Objectives	Test content	Testing venue	Intraclass R	Literature Sources
Acceleration ability	6.1 m sprint	On ice	0.80	Bracko
Speed	35 m sprint	On ice	0.98	Farlinger *et al*.
Ability to change direction	"S" test	On ice	0.95	Farlingeret *et al.*
Aerobic capacity	30-15 IIT	On ice	0.96	Buchheit *et al.*
Body Composition	Height/weight/body fat percentage	Land-based	≥0.96	Geithner *et al.*
Anaerobic metabolic capacity	Reverse longitudinal jump (CMJ)	Overland	0.99	Burr *et al.*
Upper body strength	1RM bench press	Onshore	No records	Ransdell and Murray
Lower limb strength	1RM front squat	Overland	No records	Ransdell and Murray

*30 -15 IIT= 30 -15 intermittent ice test; CMJ= reverse longitudinal jump; 1RM= maximum number of repetitions.

Currently, there are still debates surrounding certain fitness testing methods for ice hockey, with variations in testing protocols based on factors like gender, age, and skill level. There is no universally accepted standard for ice hockey physical fitness assessments. In evaluating ice hockey players, it is essential to consider the unique characteristics of the sport, account for individual differences among players, and tailor the testing plan according to the players' positions and specific needs. This personalized approach will ensure more accurate and relevant fitness evaluations.

3.2. Body shape characteristics

Body form refers to the external and internal shape characteristics of the human body. The indicators that reflect the external body shape characteristics are: height, length, circumference, width, and fullness. At the same time, body shape reflects the corresponding growth and development level, skill level and competitive ability level to

some extent. In different positions of ice hockey, Burr found in his big data analysis that the height of defensemen and goalies was significantly higher than that of forwards ($P \leq 0.01$), but there was no significant difference between the first two [5]. In terms of weight, defensemen are significantly heavier than forwards and goalies ($P \leq 0.01$), with no significant difference between the latter two. In terms of weight, goalkeeper and defender were significantly heavier than striker ($P \leq 0.01$) and there was no significant difference between the former two. The evaluation of athletes' body shape provides insight into their physical development, helping to assess their current condition and predict their potential for training. It also allows for a comparison of the physical differences between athletes, highlighting areas where improvement is needed and identifying strengths that can be further developed. Body shape evaluation is one of the key factors in selecting athletes and determining their suitability for training. This article primarily focuses on three aspects: height, weight, and body fat, to discuss how these factors influence the physical development and potential of athletes.

With the development of ice hockey, the competition in the game has become increasingly intense, with stronger confrontations and more frequent physical contact between players. Body weight is a shape index that reflects the horizontal development level of bones and muscles of athletes. It provides insights into the body's nutritional status, overall body composition, and potential for strength. Additionally, body weight plays a crucial role in determining a player's ability to withstand physical confrontations, particularly in contact sports like ice hockey, where physical strength and mass are essential for effective body contact. Ice sports require athletes to maintain an optimal body weight. Being too light can negatively impact muscle strength and overall physical power, while excessive weight may hinder speed, sensitivity, and coordination.

Height does not play a decisive role in ice hockey, which does not require vertical movement, but can reflect to some extent the spatial position occupied by the player on the ice. The body shape of elite female ice hockey players is often characterized by several features, including tall stature, long finger distance, long torso, long legs, long Achilles tendon, wide shoulders, wide hips, thin ankles, large chest circumference, large hip circumference, high BMI, low body fat weight, and large lean body mass [3]. Wang C compared the data of women ice hockey players from Canada, the United States, Finland, and China in the 2010 Vancouver Winter Olympics, and found that the age, height, weight, and Quetelet index of Chinese elite women ice hockey players were lower than that of foreign elite players [13]. The height and weight of Chinese elite women ice hockey players are 168.06 ± 6.13 cm and 63.30 ± 7.22 kg [13]. Zhao G believes that the height of an excellent male ice hockey player should be about 180 cm and the weight about 80 kg [17].

Body fat percentage is a commonly used index of body composition measurement, referring to the percentage of body fat content in the total weight. It is generally believed that the body fat percentage of athletes is inversely proportional to their sports watch within a certain range. Ice hockey is a movement based on speed and strength, too high or too low body fat percentage will have an adverse impact on the performance of the athletes. In terms of dynamics, a relative high body fat percentage will reduce the skating speed of ice athletes, increase the skating resistance, so that the lower extremity movements is relatively reduced. In terms of metabolism, a higher body fat percentage increases the metabolic demands on the body during movement. This leads to greater oxygen consumption and an increased energy requirement to sustain physical activity. Excessively high body fat can negatively impact an athlete's strength, agility, and technical performance, particularly in ice sports where speed and precision are key. However, having too little body fat can also have adverse effects. Ice sports are typically performed in colder environments, and a very low body fat percentage can impair the body's ability to maintain warmth and regulate temperature. Adequate body fat is crucial for maintaining body temperature, supporting normal metabolism, and providing energy for prolonged physical

activity. Relevant studies pointed out that the body fat content of athletes was positively correlated with shooting and average changeover time ($r = 0.52$, $P \leq 0.05$; $r = 0.65$, $P \leq 0.001$), body weight was positively correlated with substitution time ($r = 0.43$, $P \leq 0.05$). Body fat percentage was positively correlated with high-intensity exercise time on the field ($r = 0.59$, $P < 0.01$). Boland found that body fat percentage was positively correlated with fatigue index ($r = 0.45$), maximum inspiratory pressure (MIP) was positively correlated with assist, score, fatigue index and number of shots ($r = 0.60$, $p = 0.005$; $r = 0.48$, $p = 0.034$; $r = 0.55$, $p = 0.012$) [16].

Body form is the carrier of physiological function and sports quality, and a body form suitable for special sports is the foundation of athletes' success. Currently, there is a noticeable gap between Chinese ice hockey players and their foreign counterparts in terms of body form. When selecting talent, it's essential to consider the specific needs of the sport and choose athletes who possess the appropriate physical attributes. At the same time, it's important to recognize racial differences and avoid simply copying the body model of foreign ice hockey players. Instead, studies should focus on identifying the body shape that best meets the requirements of Chinese ice hockey players, laying the groundwork for future training and development. This approach will ensure that talent selection and training programs are tailored to the unique needs of domestic athletes.

4. Conclusion

Ice hockey is a complex team ice sport. Although our country has already established a national team, the result is not ideal. The reason may be due to the popularity of ice hockey and the restrictions on the selection of players, training, and other internal and external comprehensive effects. When selecting physical fitness assessment methods for training, it is essential to consider whether the test aligns with the specific demands of the player's position, whether it accurately reflects the athlete's capabilities (i.e., retest reliability), and whether it can predict on-field performance by showing a strong correlation with athletic outcomes. In addition, during the preparation cycle, longitudinal tracking of physical fitness assessments is crucial for evaluating training progress. It provides valuable insights into the athlete's competitive state, helps adjust training plans, and offers a basis for ongoing improvements. Long-term tracking should be maintained to ensure continuous monitoring and refinement of the athlete's development. There is a noticeable gap between Chinese athletes and their foreign counterparts in terms of body shape, particularly in weight and muscle circumference. This highlights the importance for physical fitness coaches to focus on muscle hypertrophy exercises during the foundational training phase. These exercises can help improve athletes' strength and positioning on the ice. However, it is essential to manage body fat levels within an optimal range to prevent negative impacts on athletic performance. Balancing muscle development with body fat control will ensure that athletes achieve peak physical condition without compromising their agility and endurance.

Disclosure statement

The author declares no conflict of interest.

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