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Examining the Determinants of Skating Speed in Ice Hockey Athletes: A Systematic Review

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Examining the Determinants of Skating Speed in Ice Hockey Athletes: A Systematic Review

Ice hockey is a physically demanding sport that requires athletes to maintain high skating speed for optimal performance. This systematic review examines existing research on testing ice hockey athletes in relation to skating speed and identifies key metrics to inform future decisions on the most suitable testing regimes. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed for the literature search. After the literature search and application of inclusion and exclusion criteria, nineteen studies were deemed eligible. The identified measures which showed a significant correlation with ice skating performance were on-land sprinting, jumping, body composition, and anaerobic power. These findings highlight the multifactorial nature of skating performance and suggest that a range of tests may be necessary to identify critical factors to overall skating performance; however, further research is needed to confirm this hypothesis.

Key words: sprinting, jumping, body composition, anaerobic power

1. INTRODUCTION

The sport of ice hockey is a physically demanding sport, in which skaters perform repeat bouts of sprint like activities creating a reliance upon the anaerobic glycolytic system and aerobic metabolism for recovery (6). The most important characteristic of highly skilled ice hockey athletes is the ability to skate at high rates of speed, which is why an athlete's skating speed capacity is arguably the most important factor that separates highly skilled players from less skilled players (5,15). The acceleration speed of an ice hockey player, has the potential to influence success in performance due to the ability the athlete will possess to cover distances faster than their opponent (21). During a National Hockey League (NHL) game, players have been observed to perform 19 sprint like bouts, with an average length of 26 metres, at an average speed of 28.6km/hour (16). In total ice hockey players perform about 113 high intensity bouts during a single game (16). This knowledge, can help strength and conditioning coaches, sport performance coaches, and technical skills coaches in training an ice hockey player to be well prepared for the physical demands of the sport and in creating a training approach that mimics the physical demands of the sport.

Off ice measures and tests can be used to understand and better predict how an ice hockey athlete will perform during on-ice skating speed assessments. The use of off ice testing has been and continues to be a means to assess the physical capacities of ice hockey athletes in relation to the physical demands of the sport (14). Having off ice tests that correlate with the on ice demands of the sport is of upmost importance (14). Ice hockey athletes rely heavily on anaerobic metabolism

to produce energy within sprint like activities, therefore off ice movements and testing mechanisms need to be able to stimulate this metabolic pathway in order to be able to predict on ice skating abilities (11). The biomechanics of skating, the technique and skill needed to skate, as well as the frictionless environment of the sport combined with the athletes' use of a skate to propel themselves forward, all create an increase in the challenge for finding a best suited off ice assessment to correlate well with on ice skating speed (4). With this in mind, the ice hockey community is in need of an applicable and reliable means to measure and assess the physical qualities of ice hockey athletes with a direct relationship to the physical demands of the sport. The purpose of this review is to identify the current available and best suited methods used to predict the on ice skating ability of an ice hockey athlete through the various means available to sport coaches, sport scientists, and allied team staff.

2. METHODS

In order to effectively retrieve and find articles to examine in a non-biased manner, the authors registered the review with the online research registry platform entitled Research Registry (registry number:1477). In the present study the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed and adhered to.

2.1 Literature Search Strategy

In finding the articles to review, the research team used three search engines – Pubmed, Sportdiscus, and Google Scholar. Three search engines were used in order to limit the amount of duplicates and non relevant articles extracted. On all three search engines the following search terms were used – ice hockey AND skating speed, determining skating speed, hockey skating,

hockey speed, hockey skating AND speed, and, predicting skating speed AND hockey. The search terms were decided by the lead author, based upon common themes arising in the literature within this specific domain. The original date of the search was December 20, 2022, with a subsequent search done in April of 2024. Additionally, the reference lists of the included studies meeting the inclusion criteria after title and abstract screening, were examined for additional relevant sources.

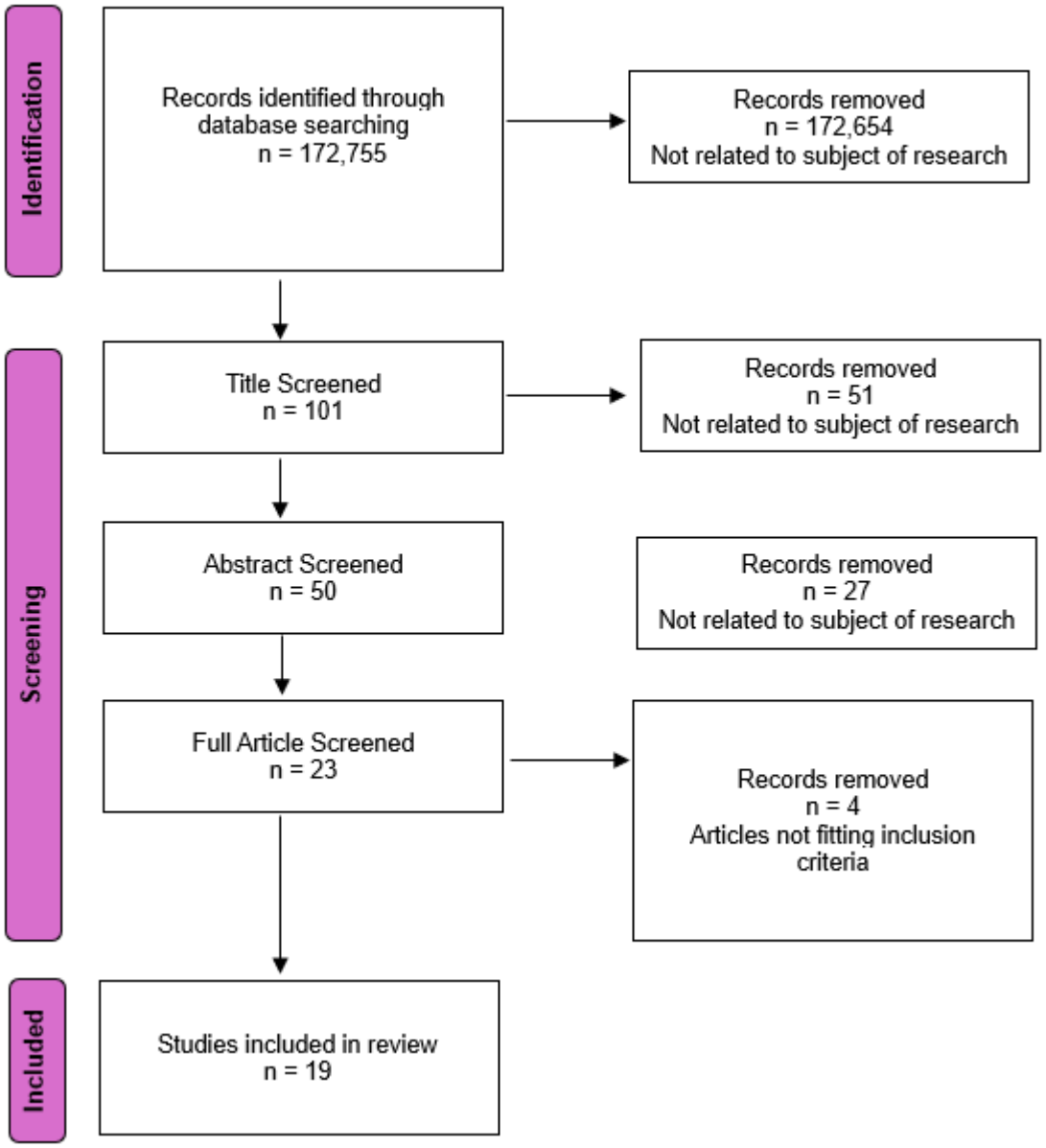
2.2 Inclusion and Exclusion Criteria

For a study to be deemed eligible, the following inclusion criteria must have been met – the research must have been primary and peer reviewed, published after 1990, originally published in English, the article must discuss ice hockey only, participants must have been 16 years of age or older, the article could include both male and female participants, and the main idea must be determining skating speed in ice hockey. For a study to be deemed ineligible, the following exclusion criteria would have had to be met – unclear if the participants were over 16 years of age, non primary research, systematic review or meta analysis, and examined multiple sports. The publication date of 1990 was decided upon in order to eliminate old information that is no longer relevant, and the age of 16 at minimum was decided upon in order to eliminate any articles which used children as subjects, as well, the Western Hockey League (major junior ice hockey) has an age eligibility of 16 years of age, therefore, the research team did not want to indirectly eliminate these athletes with a high minimum age requirement.

2.3 Study Selection

Figure 1 is an overview of record collection, identification, and the process involved in eliminating or carrying forward articles in the research process.

FIGURE 1 – PRISMA Flow Diagram



PRISMA Flow Diagram showing the article collection, screening, elimination, and selection process.

Through the three search engines used, a total of 172,755 articles were extracted. The first screening method used was by title, in which the title of the article was read to ensure the given

article fit the intended study subject matter. From this screening, a total of 172,654 articles were removed. With the remaining 101 articles, these were then filtered by abstract content, which resulted in 50 articles remaining. From this point the final screening process was to read the full text of the article to ensure the article met the review criteria, in which 23 articles remained. As the final step in the study selection process two authors (MS and JP) independently read the remaining 23 articles and concluded on which articles would be best fit for the review given the inclusion and exclusion criteria, as well as the quality of the article using the STROBE checklist. In order for an article to be deemed eligible, the article had to achieve a STROBE checklist score of 75% or greater. The final result was 19 articles remaining to be thoroughly examined. In the review process, there were 4 disagreements on article selection, which were solved by consensus and discussion in the discrepancies to determine the quality and applicability of the article. The articles were filtered through using Zotero and a custom-built Microsoft Excel document.

2.4 Analysis of Results

To determine the quality of each article, the STROBE checklist was followed. The STROBE checklist requires that each article possess the following information – indication of study design, abstract, scientific background/rationale, study objectives, study design, participant information, variables clearly defined, relevant data sources, efforts to address bias, study size, quantitative variables, statistical methods, descriptive data, outcome data, results of study, further analyses, limitations, interpretation of data, as well as funding disclosure. This information can be seen in the subsequent table, Table 1. In order for a study to be deemed of high quality, a score of 75% or greater on completion of the STROBE checklist must have been achieved.

Upon completion of study selection and further analysis of each paper based upon the STROBE checklist, a conclusion was agreed upon by both authors (MS and JP) in relation to common themes across all studies. The common themes that revealed themselves through the literature were the use of sprinting, jumping, body composition, and anerobic power all in relation to determining on ice skating speed. The themes that arose will all be further discussed and analyzed in the subsequent sections of this paper.

Table 1: STROBE Checklist

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total Y	% Completion
Behm [1]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	19	86%
Blanar [2]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	17	77%
Boland [3]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	19	86%
Boucher [4]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	19	86%
Burr [6]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	18	82%
Byrkjedal [7]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	17	77%
Chiarlitti [8]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	20	91%
Curro [9]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	17	77%
Daigle [10]	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	20	91%
Delisle-Houde [11]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	17	77%
Gilsenstam [12]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	19	86%
Gupta [13]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	19	86%
Janot [14]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	18	82%
Mascaro [17]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	17	77%
Perez [18]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	19	86%
Peterson [19]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	18	82%
Potteiger [20]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	19	86%
Runner [21]	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	18	82%
Thompson [22]	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	18	82%

Y = Yes, the study had the item. N = No, the study did not have the item. 1 = title and abstract. 2 = background/rationale. 3 = objectives. 4 = study design. 5 = setting. 6 = participants. 7 = variables. 8 = data sources/management. 9 = bias. 10 = study size. 11 = quantitative variables. 12 = statistical methods. 13 = participants. 14 = descriptive data. 15 = outcome data. 16 = main results. 17 = other analyses. 18 = key results. 19 = limitations. 20 = interpretation. 21 = generalizability. 21 = funding.

3 RESULTS

3.1 Participant Characteristics

A summary of participant characteristics can be seen in the presented Table 2. Data from the included studies was extracted onto a custom made Excel document, which included study design, intervention details, participant characteristics, statistical measures, performance

variables, and results. Through the 19 studies analyzed, a total of 1386 participants are included, with an average age of 19.5 years old. Amongst the studies, nine studies had male participants only (2,4,6,8,10,11,18,19,20). Two studies had female participants only (3,17). Four studies combined both male and female participants (9,12,14,21). The level of play across all studies varied. A total of five studies looked at junior level or high school level athletes (1,2,10,13,18). Nine studies had collegiate level athletes (3,8,9,11,14,18,19,20,21). Four studies used professional level athletes (4,6,7,16). One study used national team level athletes (17).

Table 2: Participant and Study Overview

Article	Participants	Off ice test
Behm [1]	30 high school and junior level players 16-25 years old	40 yard sprint
Blanar [2]	29 players from Slovakia, mean age of 16.79	Vertical jump & standing long jump
Boland [3]	20 NCAA division 1 female ice hockey players, average age 19.95	Percent body fat (DXA), anaerobic power
Boucher [4]	33 National Hockey League Players (3 goalies)	Vertical jump & standing long jump
Burr [6]	853 elite junior level hockey players at NHL combine from 1998-2006	Standing long jump
Byrkjedal [7]	14 players competing at the National level, average age of 17.8	Countermovement jump
Chiarlitti [8]	37 males from Canadian College Hockey Programs	Body composition, percent body fat (DXA)
Curro [9]	51 NCAA division 3 ice hockey players, 32 males and 19 females	20 yard and 40 yard sprinting
Daigle [10]	21 QMJHL players, average age 18.9	Standing long jump
Delisle-Houde [11]	18 male ice hockey players from University level, age 20-25	Wingate peak power, standing long jump, off ice pro agility, vertical jump
Gilenstam [12]	Division 2 professional Sweden teams, 1 male and 1 female team	Body weight & percent body fat (DXA)
Gupta [13]	25 junior ice hockey players from Poland, average age of 18.7	Depth drop jump, countermovement jump, squat jump
Janot [14]	NCAA division 3 hockey, 19 men and 11 women	40 yard sprint, vertical jump, & percent drop jump
Mascaro [17]	16 professional ice hockey players	Vertical jump
Perez [18]	17 elite female players from French national team	30 metre sprint
Peterson [19]	45 male ice hockey players aged 18-24, in NCAA division 1 and 3 or junior hockey	Vertical jump & wingate
Potteiger [20]	21 male varsity ice hockey players	Percent body fat (Bod Pod) & wingate
Runner [21]	40 NCAA division 1 males	Vertical jump
Thompson [22]	Canadian University varsity athletes, 24 males and 22 females	Resisted Sprint

National Collegiate Athletic Association (NCAA), National Hockey League (NHL), Quebec Major Junior Hockey League (QMJHL)

3.2 Study Design

Seventeen studies were of correlational study design (1,2,3,4,7,8,9,10,11,12,13,14,17,18,19,20,21). One study was longitudinal correlation base (6). One study was a random order crossover correlation study design (22). With the studies involved in the review, six studies looked at off ice sprinting (1,9,11,14,18,22). Eleven studies looked at jumping (2,4,6,7,10,11,13,14,17,19,21). Four studies looked at body composition (3,8,12,20). Four studies looked at anaerobic power (3,11,19,20). It is important to note, some studies looked at multiple topics and will be seen as crossing over between various subcategories within the paper.

3.3 Off ice tests

Amongst the 19 studies analyzed for the review, the off ice assessments can be categorized into four areas: sprinting, jumping, body composition and anaerobic power. Within the category of sprinting, various off ice sprint tests were analyzed. Three studies analyzed 40 yard sprint performance (1,9,14), one study analyzed 20 yard sprint (9), one study looked at pro- agility testing (11), one study was built around 30 metre sprint performance (18), and one study looked at resisted sprint performance (22). In relation to jumping ability, 7 studies analyzed vertical jump performance (2,4,11,14,17,19,21), five studies looked at standing long jump (2,4,6,10,11), two studies looked at counter movement jump performance (7,13), one study looked at depth drop jump (13), one study looked at squat jump (13), and one study looked at percent drop jump performance (14). With respect to body composition, 4 studies looked at percent body fat (3,8,12,18), and one study looked at body weight (12). The subcategory of anaerobic power had

one study look at Wingate relative peak power (18), two studies looked at Wingate average power (3,19), and one study looked at Wingate peak power (11).

3.4 Off ice Sprinting

Table 3 represents all the studies that examined off ice sprinting in relation to predicting on ice skating speed. With off ice sprinting, there are four sprinting related tests that have shown to be reflective of on ice skating speed. 40 yard sprinting was shown to be related to maximum skating speed ($p = 0.05$, $r = 0.035$) (14). 40 yard sprinting was also able to explain variability in 25 percent of maximum skating related changes ($p < 0.005$, $r = 0.51$) (1). The 20 yard ($p \leq 0.05$, $r = 0.54$) and 40 yard ($p \leq 0.05$, $r = 0.62$) sprint were both shown to relate with maximum on ice skating speed for men, but no relationship was shown to exist with women (9). The 30 metre sprint is shown to correlate well with a 40 metre on ice skating sprint ($p < 0.001$, $r = 0.80$) (18). The pro-agility test, in the left right left direction only, had a relationship with on ice skating speed in the forward direction ($p < 0.05$, $r = 0.51$) (11). The resisted sprint test with 30kg ($p = 0.01$, $r = 0.74$) of resistance for males and 15kg ($p = 0.01$, $r = 0.70$) of resistance for females, was the best predictor for on ice sprint performance (22).

Table 3: Summary of Sprinting Based Studies

Study	Main Test(s)	Main Findings
Behm [1]	40 yard sprint	Variability of 25% in maximum skating speed can be explained by changes to 40 yard sprint times. Maximum skating speed correlated significantly with 40 yard sprint time ($p<0.005$, $r=0.51$).
Curro [9]	20 yard & 40 yard sprint	In males, a significant relationship was present between 20 yard ($p\leq0.05$, $r=0.54$) and 40 yard ($p\leq0.05$, $r=0.62$) off ice sprinting with on ice maximum skating speed in females, no relationship exists.
Delisle-Houde [11]	Pro agility	Pro-agility in the left direction exhibited a significant correlation with on ice forward skating sprint speed ($p<0.05$, $r=0.51$).
Janot [14]	40 yard sprint	40 yard sprint speed is one of the best predictors of on ice skating performance and on ice skating speed ($p=0.05$, $r=0.035$).
Perez [18]	30 metre sprint	A large correlation exists between 30 metre off ice sprinting with 40 metre on ice skating sprint time ($p<0.001$, $r=0.80$).
Thompson [22]	Resisted sprint	For men, 30kg ($p=0.01$, $r=0.74$) resisted off ice sprint was best predictor of on ice sprint performance and for women, 15kg ($p=0.01$, $r=0.70$) resisted off ice sprint was best predictor of on ice sprint performance.

3.5 Jumping

Jumping based testing with relation to on ice skating speed can all be seen in Table 4. Vertical jump proved to be non-significant in relation to 10 metre forward skating time ($p = 0.090$, $r = -0.320$) however it demonstrated a significant moderate relationship to on ice pro-agility testing ($p = 0.001$, $r = -0.576$) (2). Vertical jump also related well with time trial skating for defense players ($p <0.001$, $r = -0.57$) (4). Vertical jump testing was shown to be a predictor for on ice skating speed and on ice skating times regardless of playing position ($p <0.05$, $r = 0.744$) (14). In relation to on ice acceleration, vertical jump also showed to have a moderate positive correlation between the two metrics ($p = 0.025$) (21). Both vertical jump impulse ($p <0.01$, $r = 0.60$) and standing long jump ($p <0.05$, $r= -0.45$) showed moderate and strong positive correlation with on ice forward skating speed (11). The standing long jump showed to have a moderate and strong positive correlation for on ice weave testing ($p = 0.016$, $r = -0.649$) (2). The standing long jump

was also able to show a strong relationship with time trial for forward players only ($p < 0.001$, $r = -0.57$) (4). The standing long jump was also a test that had a strong positive relationship with all measures of playing abilities (6). On ice forward and backward skating speed also were shown to correlate in a strong positive manner with the standing long jump ($p < 0.05$, $r = -0.536$) (10). Countermovement jumping was shown to have a positive correlation with forward skating sprint speed, the number of sprints a players performs in a game (Bayes Factor Moderate Correlation) (7). Backward skating speed was also shown to correlate with countermovement jump performance ($p < 0.05$, $r = 0.68$) (13). The depth drop jump is shown to correlate with forward and backward skating speeds ($p < 0.05$, $r = 0.62$), while a squat jump has only shown to be comparable with backward skating speed ($p < 0.01$, $r = 0.82$) and maximum skating speed ($p < 0.01$, $r = 0.76$), both in a strong positive manner (13). Percent drop jump has also shown to be a moderate positive predictor of on ice skating performance ($p < 0.05$, $r = 0.375$) (14).

Table 4: Summary of Jumping Based Studies

Study	Main Test(s)	Main Findings
Blanar [2]	Vertical jump & standing long jump	The vertical jump proved to be significant in predicting 10 meter skating time (p=0.090, r=-0.320) as well as 5-10-5 on ice change of direction (p=0.001, r=-0.576). The standing long jump was significant with on ice skating weave test (p=0.016, r=-0.649).
Boucher [4]	Standing long jump	The standing long jump correlated significantly with the SAS-40 time (p<0.001, r=-0.57).
Burr [6]	Standing long jump	Standing long jump can be used for both forwards and defense in predicting overall playing abilities (p and r not reported).
Byrkjedal [7]	Countermovement jump	Countermovement jump has a correlation with forward skating sprint speed and the number of sprints performed in game play (Bayes Factor Moderate Correlation).
Daigle [10]	Standing long jump	The standing long jump is correlated with on ice forward skating speed and backward skating speed (p<0.05, r=-0.536).
Delisle-Houde [11]	Standing long jump & vertical jump impulse	Standing long jump (p<0.05, r=-0.45) and vertical jump (p<0.01, r=0.60) impulse showed significant correlations with on ice forward skating sprint speed.
Gupta [13]	Depth drop jump, countermovement jump & squat jump	Depth drop jump is correlated with forward (p<0.05, r=0.62) and backward skating speeds (p<0.01, r=0.81), countermovement jump is correlated only with backward skating speed (p<0.05, r=0.68), and squat jump is correlated with backward skating speed (p<0.01, r=0.82) and maximum skating speed (p<0.01, r=0.76).
Janot [14]	Vertical jump & percent drop jump	Both vertical jump (p<0.05, r= 0.744) and percent drop jump (p<0.05, r=0.375) were significant predictors of on ice skating performance.
Mascaro [17]	Vertical jump	Vertical jump has been determined to be the best predictor of 54.9metre on ice skating speed for forwards and defense (p and r not reported).
Peterson [19]	Vertical jump	Vertical jump was significantly correlated with on ice acceleration (p<0.01, r=-0.42), velocity (p<0.01, r=-0.58), and speed skating course time (p<0.01, r=-0.59).
Runner [21]	Vertical jump	Vertical jump has a significant correlation with forward acceleration skating speed (p=0.025).

3.6 Body composition

The results of the studies in relation to body composition and on ice skating performance can be seen in Table 5. Athletes with a lower body percentage of fat had a non-significant weak relationship with faster 10 metre sprint skating speed on ice (p = 0.12, r = -0.36) and 85.6 metre

skating speeds on ice (p = 0.11, r = 0.37) (3). In contrast, a lower body fat percentage correlated with greater peak power output (p = 0.05, r = -0.580) (8). On ice skating speed was also correlated with athletes who have a lower body mass (p = 0.005, r = -0.773) (12). Percent body fat for an athlete correlated with 89 metre skate time (p = 0.013, r = 0.53) (20). Having a lower body weight in kilograms had a weak positive correlation with a faster on ice acceleration skating time for women only (p = 0.03, r = 0.639) (12).

Table 5: Summary of Body Composition Based Studies

Study	Main Test(s)	Main Findings
Boland [3]	Percent body fat	A lower percent body fat is correlated with 10metre sprint speed (p=0.12, r=-0.36) and 85.6metre sprint speed (p=0.11, r=0.37).
Chiarlitti [8]	Percent body fat	A lower percent body fat correlated with farther standing long jump distance (p=0.01, r=-0.633) and a greater peak power output (p=0.05, r=-0.580).
Gilenstam [12]	Body weight & lean body mass percent	Body weight in Kg was correlated with on ice acceleration (p=0.03, r=0.639) and speed (p=0.002, r=0.831). Lean body mass correlated to on ice speed (p=0.005, r=-0.773).
Potteiger [20]	Percent body fat	Percent body fat correlated with the average of first length skate and total length skate (p=0.013, r=0.53).

3.7 Anaerobic Power

Anaerobic power main conclusions can be seen in Table 6. Wingate testing average power was shown to correlate with 85.6 metre fatigue index (p = 0.34, r = 0.22) (3). As well as a faster 54 metre skating time (p = 0.027, r = -0.48) (20). Wingate peak power showed strong positive relationship with on ice forward skating sprint speed (p <0.01, r = -0.62) (11). Wingate peak power had a moderate positive relationship on ice acceleration (p ≤0.05, r = -0.32), skating velocity (p ≤0.05, r = -0.33), and speed course time (p <0.01, r = -0.48) (19).

Table 6: Summary of Anaerobic Power Based Studies

Study	Main Test(s)	Main Findings
Boland [3]	Anaerobic power	Wingate average power ($p=0.34$, $r=0.22$), fatigue factor drop off ($p=0.26$, $r=-0.27$), and distance ($p=0.39$, $r=0.20$) are all correlated with total length skate fastest time.
Delisle-Houde [11]	Wingate power	Wingate relative power showed a significant correlation with on ice forward skating sprint speed ($p<0.01$, $r=-0.62$).
Peterson [19]	Wingate	Wingate relative peak power and Wingate relative mean power correlated with acceleration ($p\leq0.05$, $r=-0.32$) ($p<0.01$, $r=-0.43$), velocity ($p\leq0.05$, $r=-0.33$) ($p\leq0.05$, $r=-0.34$), and speed skating course time ($p<0.01$, $r=-0.48$) ($p\leq0.05$, $r=-0.38$).
Potteiger [20]	Wingate	Wingate anaerobic power was associated with the fastest first length skating speed ($p=0.027$, $r=-0.48$). Wingate peak power was correlated to the average first length skating speed ($p=0.05$, $r=-0.43$).

DISCUSSION

As presented in this paper, the current literature provides a variety of which off ice test, as well as testing method, suitable for predicting on ice skating speed. It is evident that a large challenge does exist when looking for ways to test ice hockey athletes in an off ice manner and a wide array of information is available in this domain. Through this review, it is evident no best off ice test has been established to date, and there are many ways in which we can test for on ice skating speed. The studies chosen in this review were required to achieve greater than 75% rating on the STROBE checklist in order to be eligible, as described in the methods, in which the information they provide holds good standing in the world of ice hockey performance.

4.1 Off ice sprinting

The act of sprinting is similar to the act of skating in ice hockey, given the relationship that exists between both acts of locomotion in generating horizontal force as well as horizontal power, which can explain the reason in which many forms of sprinting have been shown to be predictors of on ice skating speed (18). One of the most well-known sprinting based test, the 40 yard dash, requires the athlete to sprint 40 yards in which a time is recorded for how fast the athlete achieves this desired distance. In biomechanical comparisons between the muscles at use during both sprinting and on ice skating, similarities are seen between the hamstrings and quadriceps use, as well as the vastus medialis and lateralis, which are all highly active in generating force during both movements (9). Being able to skate at a high velocity has been shown to establish a relationship with also being able to sprint at higher rates of speed and this could potentially explain why sprint based testing has been shown to have applicability to determining on ice skating ability (14). The 40 yard sprint test has been shown to have significant correlations with skating at max speeds and for various on ice skating speed tests (1,9,14). The athletes that can perform a faster sprint time in off ice testing for the 40 yard and 20 yard dash are able to skate at higher velocities when on the ice (1,9,14). 30 metre sprint is also related, and the suggested mechanisms are similar to that of 40 yard and 20 yard sprint (18).

These results further establish the idea of the horizontal force development relationship between off ice sprinting and on ice skating, however it is key to note, no relationship has been seen during the acceleration phase for both actions (18). It is evident thus far, that some relationship does exist between off ice sprinting and on ice skating speeds, due to the abilities to maximize muscular contraction and trainability with the desire to improve on ice skating speeds 91).

It is important to note that ice hockey is not always a sport of linear actions, the athletes are tasked to change direction in relation to make a desired play on the ice with relation to game success. A multitude of external factors are present within the sport of ice hockey, thus creating an environment that is unpredictable in relation to game play. Knowing this, it is important to discuss relationships between off ice pro agility tests with on ice change of direction skating performance. In a cohort of eighteen male ice hockey players at the University level, significant relationship was shown to exists between off ice pro agility testing and on ice pro agility testing speed (11). This study was able to exemplify the importance of change of direction within the sport of ice hockey, as well as the ability to predict how well an ice hockey athlete can change direction on the ice through the testing of change of direction off of the ice. With ice hockey athletes who can change direction faster, it will be expected that these athletes are able to move with the speed of play at faster rates and be of a higher likelihood in succeeding in game play.

An interesting as well as novel finding that presented itself within the literature came from the Thompson et al., group, in which resisted sprinting was examined in relation to predicting on ice skating speed. The group used 30Kg of resistance for males and 15Kg of resistance for females, attached behind the athlete, in which the athlete was then asked to sprint over a 15metre distance (22). This was designed to examine the acceleration phase, in comparison to on ice skating speed, in which a relationship did exist. The ideas revolve around a change in mechanics due to the resistance being added to the participants which requires the participant to exhibit greater trunk flexion and increase in stride frequency, which are very similar characteristics of the acceleration phase within ice hockey acceleration abilities (22). The external resistance added to the participants force the athlete to be in a position that better simulates the posture of an on ice

acceleration than does un-resisted sprinting, as established by kinematic principles. The group used novel thinking as a way to find a testing mechanism that better predicts on ice skating speed than an un-resisted sprint over the same distance, as well as a way to predict on ice acceleration abilities, which no study was able to show.

4.2 Jumping

Off ice testing for lower body anaerobic power and strength, through the use of lower limb power based exercises such as jumping based tests can be shown to correlate with many on ice skating metrics. Jumping based tests can be broken down into activities that resemble a vertical jump, horizontal jump, countermovement jump, or even a depth drop jump, all which will be further explained in relation to on ice skating mechanisms. If an off ice mechanism of testing can be shown to represent lower body power production, the given test will have the highest affinity in predicting on ice skating speed and performance based tests (14).

The squat jump has been shown to be representative of lower limb explosive strength based mechanisms, which are similar to the mechanisms of action at use during acceleration and top speed skating in ice hockey, which has shown a positive correlation between the two (2). Having an athlete perform a squat jump with 50% of the given athlete's body weight loaded onto a barbell on the athlete's back, was highly correlated with on ice change of direction ability the given athlete possesses (2). A vertical jump without the countermovement of a squat jump also had a high affinity with on ice pro agility based tests (2,14). Vertical jumping based tests have also been shown to have an ability to predict the given athlete's SAS-40 on ice test score, which holds a strong relationship with how fast an athlete will accelerate on the ice (4). However, it is

of note, that jumping ability of a given athlete, only has a 2% variance in predicting player abilities of on ice performance, while 76% of the athlete's on ice abilities is better predicted and explained through other performance measures (4). It is important to note that defense players were also better predicted than any other player on the ice through vertical jumping based testing (4). Although another group does confirm that vertical jumping based testing can be used to predict 54 metre on ice sprint ability regardless of position the given athlete does play (17). It is evident that no clear answer exists on if a given performance based test is better suited for one skating based position over another.

Ice hockey does entail many different forms of game play which were all analyzed in relation to vertical jumping abilities. Forward acceleration of 90 feet, backwards acceleration of 90 feet, and 50 foot flying top speed tests were all highly related to the athlete's ability to perform a vertical jump test, insinuating that the athletes who jump higher, can skate faster in all directions (21). Vertical jump based testing is a significant predictor of anaerobic power levels for a given athlete, which have been shown to correlate with acceleration, velocity, and faster skating times for each athlete (19). It is evident through the research that higher output levels of lower body anaerobic power, correlate better with the athlete's ability io accelerate fast and achieve higher velocities while performing on ice measures (19).

The broad jump or horizontal based jump is highly representative of ice hockey playing abilities due to the use of lower body vertical power, horizontal leg power, motor control, and body mechanics, which are all conducive of ice hockey playing abilities (6). An athlete's ability to perform the SAS-40 on ice test for acceleration, was also shown to be representative through the

athlete's ability to perform a broad jump (4). This can be further analyzed to state that broad jump testing, was shown to be more predictive of acceleration for forwards compared to defense players (4). The use of the broad jump can be a very good predictor of the athlete's power development abilities which is highly correlated to the physical demands of ice hockey (4). In a study of ice hockey athlete draft rankings in the National Hockey League (NHL) entry draft, the broad jump was seen to be highly correlated with how high an athlete was drafted in the NHL entry draft, for both forwards and defense (6). An athlete's ability to perform a broad jump of greater distance, was correlated with the ability to have a faster sprint skating time (10). This once again explains the ability of the broad jump to be predictive of lower body power and explosiveness, which is shown in acceleration and skating speed at higher levels while performing on ice performance based tests (10). In summary, any off ice test, specifically the broad jump, has been shown to demonstrate lower body power and can be strongly correlated in predicting the skating speed of a given ice hockey athlete on the ice (11).

Knowing this, the ability for an athlete to perform a countermovement jump, has the potential to be predictive of on ice skating metrics. One study did show a correlation between countermovement jump height, and the athlete's ability to perform skating based tests at higher speeds, while also performing more sprints in a game, and covering a greater total sprint skating distance (7).

A wide variety of plyometric based jumping tests have been correlated with many aspects of on ice skating ability (13). The depth drop jump has been shown to correlate well with skating speeds in both forwards and backwards skating, maximum skating speeds and backwards

average skating speeds (13). A percent drop jump test was also predictive of an athlete's ability to skate at higher speeds (14). With the prerequisite need for ice hockey athletes to possess the ability to demonstrate high levels of lower limb explosive abilities, the use of lower limb power-based testing has been able to simulate the relationship between plyometric testing and on ice skating speed (13).

4.3 Body composition

Body composition of ice hockey athletes can have an influence on playing abilities as well be used as a predictive measure in combine related testing to help allied health teams assess an athlete's playing abilities, as well as tailor programs to the athlete's needs (8). Ice hockey athletes who possess a higher percent body fat showed to have slower skating times and a greater drop between repeat sprint ability during on ice skating tests (3). A higher percent body fat was also correlated with shorter first length skating abilities and lower total length skating abilities, respectively (3). Overall, for athletes who had a faster skating time, the same athlete possessed a lower percent body fat (3). Having higher lean tissue mass was also shown to correlate with greater lower body explosiveness, which we know is a strong predictor of all on ice skating abilities, and most specifically the broad jump (8). Agility and aerobic based ice hockey tests, proved to be independent of all body composition based testing (8).

In women, it has been shown that faster acceleration and short-distance skating times are found in lighter athletes. Difference in skating time diminishes as distance increases (12). Female ice hockey players can enhance their on ice skating performance by improving body composition to possess an increase in muscle mass (3).

For male ice hockey athletes, a significant correlation is present in body composition and skating speed for all physiological based tests, both absolute and relative to body weight, except for lean body mass testing (12). Having a higher fat free mass for male's can be correlated with a decrease in on ice sprint skating times (20).

4.4 Anaerobic power

Wingate testing has been shown to be a valid measure to demonstrate an athlete's abilities of anaerobic power output while cycling. Wingate peak power was shown to be a good predictor for 30 metre forward skating sprint speed as well as on ice agility based testing and 54 metre on ice sprint abilities (11). Peak power outputs derived from Wingate testing is a strong predictor of on ice sprint speed abilities, acceleration and maximum skating speed (11,19). Findings in relation to Wingate testing also show a relationship with shorter skating speed distances, such as 30 metres, and higher outputs in peak power the athletes can achieve while performing the Wingate based tests (11). Wingate relative peak power in relation to body weight and relative mean power in relation to body weight were both significantly correlated with on ice acceleration abilities, overall velocities while skating, and fastest skating course times (19). These results suggest that Wingate based testing is capable to predict those athletes who can achieve higher power outputs, which allow for the athlete to possess an advantage over players who cannot, due to their ability to accelerate at faster rates and reach higher top end speeds while performing on ice skating based tests (19).

4.5 Limitations

As with all studies and investigations, limitations do exist. The most notable limitation within this review relates to the idea of no set methods to test ice hockey athletes. Each study examined has different methods used, different distances used, different equipment used, or a different group of participants used to test the theories presented. The wide array of methodology, equipment, and participants within this review are limitations that do exist within this body of research. In relation to the methodology, many studies use correlational statistics, which creates a challenge to draw strong conclusions from. Better experimental designs can be looked into, in order to elicit a more clear conclusion on the best off ice test for determining skating speed. These limitation does express and present the need for a consensus method to test ice hockey players, a method that can be used across various participant ranges, and a method that accounts for the biomechanical considerations of the sport in a better respect.

5 PRACTICAL APPLICATIONS

In reviewing the available literature, it is evident there are off ice tests that can show a relationship with on ice skating speed, such as linear sprinting, resisted sprinting, vertical jumping, body fat percentage, and anaerobic power, which all can be used as a valuable tool for sport coaches, strength and conditioning coaches, sport scientists, and scouting teams. Off ice sprinting, jumping and plyometrics, body composition and anaerobic power testing, all in their unique ways, have shown relationships with on ice speed based testing metrics. However, it is important to note the unique physical and biomechanical demands of the sport that do require special attention. The current literature does support a means to test and predict on ice skating speed with off ice testing mechanisms, however the research team believes further investigation

should be done to conclude on a best suited practice for determining skating speed through off ice measures.

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