



# KANDIDATUPPSATS

## **Abstract**

**Introduction:** The National Hockey League Entry Draft Combine (NHLED Combine) is considered one of the toughest physical fitness tests an ice hockey player has to go through. The NHLED Combine consists of several fitness tests evaluating the athlete's aerobic- and anaerobic capacity; lower body power, upper body strength and power, flexibility and anthropometrics; no lower body strength test are employed. Squats are the only exercise used by all National Hockey League (NHL) strength and conditioning coaches yet it is not included in the NHLED Combine.

**Purpose:** The purpose of this study was to determine which off-ice test correlates best with on-ice performance measured as forward skating speed. We hypothesised that squat one repetition maximum (squat 1RM) would be a better or equal predictor of on-ice performance compared to the current NHLED Combine tests standing long jump (SLJ) and Wingate anaerobic test (WAnT).

**Method:** Eleven male subjects, aged  $17.8 \pm 0.8$  years, performed an on-ice sprint followed by the off-ice tests SLJ, WAnT and squat 1RM.

**Results:** A correlation was found between sprint time on-ice and SLJ ( $r = -0,727, p = 0.006$ ), Wingate anaerobic test mean power/ body weight (WAnT MP/BW) ( $r = -0,607, p = 0,024$ ), squat 1RM ( $r = -0,600, p = 0.026$ ) and squat 1 repetition maximum/body weight (squat 1RM/BW) ( $r = -0,609, p = 0.023$ ).

**Conclusion:** The results indicate that squat 1RM and squat 1RM/BW are equally good predictors of hockey performance as SLJ and WAnT MP/BW.

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# 1. Background

## 1.1 Introduction

Ice hockey is a physically demanding sport characterised by short bouts of intense anaerobic work. A shift typically lasts for 30 seconds which primarily utilize the anaerobic energy system. Hockey is a fast paced sport with lots of starts and stops as well as change of direction. This makes speed, strength and power some of the most important physical attributes for an ice hockey player. All playing positions require these physical attributes but to a varying degree (1-3).

NHL is considered the best hockey league in the world (for a complete list of all abbreviations see appendix 1). Almost every young ice hockey player strives for a contract allowing them to play in the NHL. The most common way to acquire such a contract is through the NHL Combine. Every year approximately 200 young hockey players age 18-20 are drafted by different teams in the NHL. Almost every drafted player gets offered a contract although this does not guarantee a spot in the team. During the NHL Combine the 110-120 top players undergo vigorous physical off-ice testing to assess physical fitness level and hockey playing potential. This physical testing battery, called NHL Combine, consists of several fitness tests evaluating the athlete's aerobic- and anaerobic capacity, lower body power, upper body strength and power, flexibility and anthropometrics. No lower body strength test is currently included in the NHL Combine.

Skating performance is considered the single most important skill for an ice hockey player. Even though high intensity skating only stands for 4.6% of the time on ice, its effect on skating performance are still essential since the subsequent two foot glide, which stands for 39% of the game time, will be affected by a faster skate (4). Having the ability to skate faster than your opponents will put you ahead when chasing the puck, which in turn will increase your chance of scoring. In order to achieve a higher skating speed, the stride frequency or the stride length must increase. A stride consists of three phases, the single-support propulsion phase, the double-support propulsion phase and the single-support glide/recovery phase (4). There are different views on how to achieve a higher velocity during skating. One being that stride length remains almost the same across different velocities. This means that the key to increase skating velocity would be stride frequency (5). The other viewpoint states that even though velocity increases the contact time still remain at about 0.34-0.38 seconds, meaning that there's another aspect to increase skating speed (6). That aspect being stride length. In either case, skating puts a lot of emphasis on power production.

## 1.2 Power

Power is the product of force and distance divided by a change in time.  $P = F \times d / \Delta t$  (Formula  $P$  = power,  $F$  = force,  $d$  = distance and  $\Delta t$  = change in time). This means, if two athletes with different mass travelled the same distance they could still both have produced the same power, depending on how fast they were moving. This is applicable to every variable in the same way. If two athletes, athlete A weighing 100kg and athlete B weighing 50kg, travelled the same distance at the same velocity, athlete A would have to produce twice as much power as athlete B indicating power relative to body weight might be a good predictor of skating speed. Applying the formula for power to a skating stride it would mean that, seeing as the mass is constant for a skater, if power were to increase, either the time for push-off would shorten and there of an increase in frequency or the stride would lengthen and the force production increase which both would improve speed on-ice. These two alternatives to increase on-ice speed put different demands on the athlete's rate of force development (RFD). RFD is the ability to generate as much force as possible during a given time.

### **1.3 Off-ice power tests**

There are a number of off-ice tests designed to evaluate the athlete's power production, all with different demands on RFD. Many studies have been done comparing different off-ice power tests to on-ice performance. There has been no clear consensus on what type of off-ice tests predicts on-ice performance best. WAnT is one of the off-ice tests used during the NHLED Combine. WAnT measures leg power and anaerobic capacity (7, 8). However it remains unclear whether a correlation exists between the WAnT and the anaerobic capacity and power on ice. What's more, on-ice tests and off-ice ergometer bicycle tests have been found to have no correlation in regards to both  $VO_2$  max and blood lactate levels (9). Studies comparing the WAnT and different anaerobic tests on ice have also been done however the evidence does not fully support WAnT being able to predict on-ice performance (10-13). SLJ is another test in the NHLED Combine. Its purpose is to evaluate the athlete's leg power and has been shown to predict performance in various types of on-ice tests (1, 11, 14). The last test for leg power in NHLED Combine is the vertical jump, which seems to correlate well with forward skating speed (11, 15, 16).

### **1.4 Strength**

Strength, or force, is defined as the product of mass times acceleration.  $F = m \times a$  ( $F$  = force,  $m$  = mass and  $a$  = acceleration). Applied to strength training with a barbell, this would mean that the athlete has to overcome the barbell's mass multiplied by the gravitational force to be able to move it upward. Since the gravitational force is always constant, the force produced by the athlete is directly proportional to the mass of the barbell in a successful lift. Therefore, in theory, it is possible to increase the skating speed of the athlete by increasing force production through strength training. If force were to increase, so would power, see figure 1.

### **1.5 Off-ice strength tests**

In NHL today, strength and conditioning coaches all reported to employ different variations of barbell training, including squats, in their strength programs (17). Despite being one of the more widely used strength training exercises for ice hockey players there are no known studies investigating the relationship between squats and on-ice performance. Squats have been found to correlate with sprint performance off-ice (18-21) which in turn have shown to be the strongest predictor for on-ice performance (6, 11, 14).

## **2. Purpose**

Therefore, the purpose of this study was to determine which off-ice test correlates best with on-ice performance measured as forward skating speed. We hope to update the NHLED Combine test battery with a lower body strength test that correlates well with on-ice performance.

### **2.1 Hypothesis**

Previous literature has shown that WAnT, SLJ, vertical jump and off-ice sprints all could correlate with on-ice performance. The primary hypothesis is that squats have equally or better correlation with forward skating speed than the current NHLED combine tests; SLJ and WAnT. Additionally we hypothesise that WAnT peak power (WAnT PP) and WAnT peak power/body weight (WAnT PP/BW), utilizing the same energy system and producing high power during a similar timeframe, will correlate the best with on-ice sprint times of all WAnT parameters.

### **3. Method**

#### **3.1 Subjects**

Eleven male (N=11) competitive hockey players age  $17.8 \pm 0.8$  years participated in the study. Subjects' mean ( $\pm$  SD) weight was  $79.8 \pm 0.75$  kg. Every participant regularly plays in J18 and J20 division 1 hockey league in Sweden with a training background of  $9.5 \pm 2.6$  years. The tests were performed 1-2 weeks after the completion of the competitive hockey season. Goaltenders were excluded from this study due to the unique equipment required for their playing position, which gives them an unfair disadvantage on forward skating speed when compared to forwards and defensemen. No written consent were given to the subjects due to tests being performed during scheduled school hours. Consent was given by the supervising teacher.

#### **3.2 Procedures**

The tests were divided into three separate test days. The on-ice test was performed on day one followed by the NHLED Combine tests SLJ and WAnT on the second day. The subjects had six days of rest before the third and last test day, which consisted of the one repetition max barbell back squat. All participants were instructed to refrain from heavy physical activity 24 hours before each test. The tests were performed between 8.00a.m and 11.00a.m. All tests were supervised by trained professionals.

#### **3.3 On-ice test**

The on-ice test performed was a 17.5 m forward skating sprint. Timing gates (Muscle Lab Ergotest 4000) were placed on respective blue line 1.25 m above the ice to measure sprint times. The subjects started 0.5 m behind the first timing gate. All participants wore full hockey gear with exclusion of the hockey stick since the timing gates were fitted with only one infrared transmitter and the hockey stick risked crossing the timing gates prematurely. The participants were informed of the test procedures before the warm up. They were all responsible for their own warm up but were given guidelines in form of low intensity skating and lighter sprint starts. Three trials were performed with a rest period of 2-3 minutes between each trial. The fastest time for each subject were used for further analysis.

#### **3.4 Off-ice tests**

The day following the on-ice test the off-ice tests SLJ and WAnT were conducted in an indoor setting. All participants were instructed to wear shorts, t-shirt and appropriate footwear for all off-ice tests. The SLJ was the first test performed and the participants were asked to stand behind a line with toes touching the line. Arm swing and counter movement was allowed in the jump. The participants were asked to stand still when they land and the distance jumped was measured between the line and the heel of the foot closest to the line. The participants were informed about the test procedures before engaging in the general and specific warm up of their own choosing in preparation for the SLJ. Three jumps were performed with a rest period of approximately two minutes between each jump. After 15 minutes of recuperation the WAnT were commenced. The test was conducted on a Monark ergonomic 834-E. The seat height was adjusted so that at the bottom of the pedal stroke the knee was in a  $5^\circ$  flexion while the ankle was kept in a  $90^\circ$  angle. Every participant got five minutes of standardised warm up consisting of low intensity bicycling with a short all out sprint at the third and fifth minute mark. The tests were performed with a load of 9% of bodyweight and the results were recorded manually. The third off-ice test was the 1RM back squat and was conducted six days later. Since faster skaters uses a greater hip angle during speed skating the back squat was chosen over the front squat because it generally also produces a greater hip angle (4, 22). As on previous test days the athletes chose their own

warm up consisting of low intensity drills coupled with a more specific warm up involving the barbell. To standardize the test the squat depth was set to just below parallel with the caput femur below the lateral epicondyle of the knee. In order to keep the reliability between each attempt a plastic covered pillow was used to give the athlete feedback when the desired depth was reached. The pillow was placed at the correct height under the hips to give both sensory and auditory feedback when the individualized squat depth had been reached. The subjects were given unlimited tries to reach their 1RM squat load but they all reached it within 3-5 attempts. Every subject was given approximately five minutes of rest between each attempt.

### **3.5 Statistical analysis**

The results were analysed in IBM SPSS Statistics 20 using Spearman's correlation coefficient. Weak correlation was set at 0-0.39, moderate correlation was set at 0.4-0.79 and strong correlation was set at 0.8-1. The level of statistical significance was set at  $p \leq 0.05$ .

### **4. Results**

All subjects individual test results including mean  $\pm$  SD are reported in Table 1. SLJ ( $r = -0.727, p = 0.006$ ), WAnT MP/BW ( $r = -0.607, p = 0.024$ ), squat 1RM ( $r = -0.600, p = 0.026$ ) and squat 1RM/BW ( $r = -0.609, p = 0.023$ ) was found to have a moderate correlation to on-ice sprint. All correlations are reported in Table 2.

**Table 1.** Total test results for all test subjects including mean  $\pm$  SD.

Subjects	Sprint time (S)	SLJ (CM)	WAnT PP (W)	WAnT PP/BW (W)	WAnT MP (W)	WAnT MP/BW (W)	WAnT FI (%)	Squat 1RM (KG)	Squat 1RM/BW (%)
Subject 1	2,754	254	1166,6	15,8	855,5	11,6	60,0	110	149,1
Subject 2	3,202	214	1348,0	13,8	916,0	9,4	53,8	100	102,7
Subject 3	2,924	263	1319,8	16,9	893,6	11,4	56,3	110	140,5
Subject 4	2,891	245	1378,7	15,9	903,8	10,4	53,3	130	150,3
Subject 5	2,955	224	803,7	11,7	633,2	9,3	45,5	120	175,2
Subject 6	2,846	241	1164,3	13,9	791,1	9,4	53,8	140	166,7
Subject 7	2,912	269	1286,8	14,8	1072,3	12,3	42,9	135	155,4
Subject 8	2,750	273	1055,8	14,7	879,9	12,3	42,9	120	167,6
Subject 9	3,099	215	890,9	12,7	631,0	9,0	50,0	95	135,5
Subject 10	2,847	230	1055,8	14,7	791,9	11,1	50,0	125	174,6
Subject 11	3,109	227	1018,1	12,7	791,9	9,8	50,0	100	124,4
Mean	2,935	241,36	1135,31	14,32	832,74	10,54	50,77	116,82	149,27
$\pm$ SD	$\pm$ 0,146	$\pm$ 21,18	$\pm$ 189,57	$\pm$ 1,56	$\pm$ 127,04	$\pm$ 1,24	$\pm$ 5,42	$\pm$ 15,05	$\pm$ 22,46

SLJ = Standing long jump, WAnT PP = Wingate anaerobic test peak power, WAnT PP/BW = Wingate anaerobic test peak power/body weight, WAnT MP = Wingate anaerobic test mean power, WAnT MP/BW = Wingate anaerobic test mean power/body weight, WAnT FI = Wingate anaerobic test fatigue index, Squat 1RM = Squat one repetition maximum, Squat 1RM/BW = Squat one repetition maximum/body weight

**Table 2.** Correlation and *p* value between on-ice and off-ice tests.

Off-ice tests	SLJ	WAnT PP	WAnT PP/BW	WAnT MP	WAnT MP/BW	WAnT FI	Squat 1RM	Squat 1RM/BW
Correlation to sprint on-ice, <i>r</i>	-0,727	-0,087	-0,511	-0,027	-0,607	-0,005	-0,600	-0,609
<i>p</i> value	0,006	0,400	0,054	0,468	0,024	0,495	0,026	0,023

SLJ = Standing long jump, WAnT PP = Wingate anaerobic test peak power, WAnT PP/BW = Wingate anaerobic test peak power/body weight, WAnT MP = Wingate anaerobic test mean power, WAnT MP/BW = Wingate anaerobic test mean power/body weight, WAnT FI = Wingate anaerobic test fatigue index, Squat 1RM = Squat one repetition maximum, Squat 1RM/BW = Squat one repetition maximum/body weight

## 5. Discussion

### 5.1 Result discussion

The results of this study indicate that squat 1RM is an equally good predictor of hockey skating speed compared to more established tests. Our first hypothesis, that squats would be an equal or better predictor, was confirmed by the results; squat 1RM ( $r = -0.600$ ) and squat 1RM/BW ( $r = -0.609$ ) compared to SLJ ( $r = -0.727$ ) and WAnT MP/BW ( $r = -0.607$ ). Our second hypothesis of WAnT PP and WAnT PP/BW being the best predictors of skating speed among the Wingate parameters was not supported by the findings, WAnT PP ( $r = -0.087$ ) and WAnT PP/BW ( $r = -0.511$ ).

SLJ was found to have a moderate correlation to on ice sprint test, which is supported by previous studies (11, 14). Burr et al (1) found that SLJ was one of the few tests from the NHLED Combine that could predict draft order, indicating the need for the test battery to be revised.

Only one of five parameters for the WAnT showed a correlation to the on ice test. WAnT MP/BW was correlated with the on ice sprint results which is supported by Farlinger et al (11) although the distance covered in the sprint differed; 17,5 and 34,5 respectively. Our hypothesis that WAnT PP would correlate the best of the WAnT parameters did not hold up, possibly due to the difference in the start procedures between the two tests. The WAnT is performed with a rolling start without resistance meanwhile the sprint starts while standing still. Another factor is the biomechanical differences between a sprint on ice and WAnT. In ice-skating there is a greater ankle, knee and hip angle as well as an added abduction.

The squat 1RM was found to correlate with the sprint on-ice and continued to do so relative to body weight. Although no studies supports the results of the present study they are not surprising. Several studies have found a correlation between squats and athletic performance, i.e. sprints, various jumps and other movements requiring power (18-21, 23, 24), indicating the need for strength in power movements such as the skating stride. Also, the correlation could be due to force production around the same joint angles seeing as both the squat and the on-ice sprint involves a triple extension; hip-, knee- and ankle. A below parallel back squat produces similar joint angles as forward skating, with a closed hip angle at about 40-45° and a more open knee angle (4, 22), which also could explain the correlation between the two of them.

## 5.2 Method discussion

Both the SLJ and WAnT was recorded manually, which might be a source of error. To ensure reliability of the WAnT it should have been performed with a digital recorder as well as manually. Additionally the subjects had never performed the WAnT before which could have distorted their test values. To minimize any sources of error regarding squat depth a pillow was placed at the correct individual height, which would function as a cue for the subjects to stop the eccentric phase and start the concentric phase at the correct depth. Another source of error might be that every subject was playing in the same hockey team, meaning that they undergo roughly the same workout regimen. This could affect the rates of correlation between the tests. By taking subject from different teams with different strength and conditioning programs you minimize the risk of subjects being more accustomed to one of the exercises thus making the population of the study more heterogenic. Since the subjects are accustomed to a high training volume, the results of the study were deemed not to be affected by having only 24 hours of rest between the on-ice test and the first off-ice test nor having both the SLJ and WAnT at the same test day.

## 5.3 Further research

Marino (5) analysed the kinematics of ice-skating. The results showed a higher stride frequency with increasing velocity whilst stride length remained the same. Also, both the single- and double-support propulsion phase did significantly decrease with an increase in velocity. Indicating that the skating velocity depends on the time used for push-off during a skating stride. Behm et al (6) on the other hand examined the EMG activity in the quadriceps and hamstring during a 30m sprint on ice and found the push-off phase to vary between 0.324-0.387 seconds. There was no correlation between a faster push-off phase and skating speed meaning a faster push-off phase did not increase skating speed. The results of these studies contradict each other. In practise, this means that an off-ice test assigned to mimic a longer contact time, in line with Behm (Ibid.) results, could fail to predict skating speed for the faster skaters according to the results of Marino (5). To pick an off-ice test that is supposed to predict on-ice skating based on the contact time would therefore be spurious.

The squat 1RM does not put any emphasis on contact time yet a correlation could be found between forward skating speed and the 1RM squat, suggesting there are other factors than contact time that affect the correlation between off-ice and on-ice. Such a factor could be, as previously mentioned, maximal strength and its impact on power production. Another one of these factors might be the similar joint angles produced in a squat compared to a skating stride. Therefore, further investigation is needed to establish whether a correlation between on-ice and off-ice is determined by similarities in joint angles rather than contact time.

## 5.4 Practical application

Even though a correlation between on-ice and off-ice tests were found it should be noted that it's still only a correlation and only adds to the already existing data of potential tests for on-ice performance. A moderate to strong correlation ( $r= 0.410$  to  $r= 0.809$ ) has been shown between on-ice performance and various off-ice tests ranging from power tests such as sprints and jump protocols, upper body strength tests in the form of benchpress/pushups to conditioning tests like the WAnT (1, 6, 9, 11-16, 25-30). There are no existing studies supporting an actual causation between off-ice exercises and on-ice performance.

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## 7. Appendix

### 7.1 Appendix 1

A complete list of abbreviations.

NHL	National Hockey League
NHLED	National Hockey League Entry Draft
NHLED Combine	National Hockey League Entry Draft Combine
SLJ	Standing Long Jump
WAnT	Wingate Anaerobic Test
WAnT PP	Wingate Anaerobic Test Peak Power
WAnT PP/BW	Wingate Anaerobic Test Peak Power / Body Weight
WAnT MP	Wingate Anaerobic Test Mean Power
WAnT MP/BW	Wingate Anaerobic Test Mean Power / Body Weight
WAnT FI	Wingate Anaerobic Test Fatigue Index
Squat 1RM	Squat 1 Repetition Maximum
Squat 1RM/BW	Squat 1 Repetition Maximum / Body Weight
RFD	Rate of Force Development

