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Responsiveness and Relationships of Shooting Performance to On-Ice Physical Performance Tests

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Featured Application: The ice hockey-specific complex test (IHCT) is a field test battery which was designed to test players' on-ice performance and ice hockey-specific skills. Slap shots and wrist shots are performed on an empty goal before and after the linear and change of direction (COD) speed tests. This study was designed to uncover the effects of physical on goal-shooting performance.

Abstract: The aim of this investigation was to quantify the acute effects of the execution of the physical performance tests within the ice hockey-specific complex test (IHCT) on shooting performance. Thirty-four professional male ice hockey players with an average of 6.9 years of playing experience were recruited. The slap shot (SS) was found to accelerate the puck with a higher speed and greater precision. After the IHCT, the maximum puck speed of successful goal shots decreased considerably ($p < 0.001$, $d > 1.5$). The puck speed percentage decrement after the IHCT did not differ between the SS (6.1, SD = 4.4, −5.5–17.9) and the wrist shot (WS, 6.0, SD = 3.5, −0.9–12.2, $p = 0.86$, $d = 0.03$). The magnitude of puck speed reduction in the WS was inversely related to the functional heart rate reserve ($r = -0.44$, $p = 0.02$) and the blood lactate elimination rate ($r = -0.43$, $p < 0.02$). The linear and COD speed tests on-ice resulted in a higher amount of successful goal shots. These findings highlight the interaction of intense on-ice testing and goal-shooting performance.

Keywords: on-ice performance diagnostic; ice hockey; team sports; intermittent exercise

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1. Introduction

Shooting performance is a crucial factor for many sports. Despite differences in specific conditions (e.g., size of ball or goal, net) and whether upper or lower extremities accelerate the device, shooting distance and players' expertise will influence shooting performance. Focusing on games where the upper extremity is used to propel the device, different instruments (e.g., rackets, clubs, bats) and their mechanical characteristics additionally affect shooting performance. Ice hockey is an intermittent contact sport that requires whole body conditioned players who overscore their opponent team at the end of the three 20-min periods of a professional match. Extensive research has been conducted on physical characteristics measured off-ice [1–3] as well as on-ice [4,5], aimed at delineating positional differences as well as on-ice performance. Some physical characteristics were found that differed by playing position; however, the most meaningful differences were linked to the goaltenders [1,3]. Data on the overall pre-season fitness profile of one team which was available over a period of 26 years could only be partially related to team success on-ice [3]; this underscores the fact that physical and physiological potentials are only a small part of a skillful ice hockey player [2].

By examining matched on-ice and off-ice performance protocols, Durocher and colleagues [6] proved considerably higher maximum aerobic capacities in 12 male collegiate ice hockey players on-ice compared with off-ice tests. Moreover, the maximum aerobic capacity measured on-ice was not related to the values obtained off-ice. These results indicate that performance diagnostics in ice hockey would benefit from sport-specific parts. Data from top-level Polish [7] and Danish [5] ice hockey players revealed that a mix of performance tests executed on- and off-ice best explained proficiency of ice hockey players.

The ice hockey-specific complex test (IHCT) is a field test battery reflecting the intermittent load characteristics of a match which was designed to test players on-ice performance [4] according to linear speed, change of direction (COD) speed, as well as puck speed and goal shot accuracy. The total duration of the IHCT was reported to last approximately 200 s [8] with on-ice maneuvers, performed with and without a puck.

Research on goal scoring or shot accuracy, however, is less frequently conducted; wrist shots are considered more accurate, while slap shots are more powerful. Data from 192 competitive matches collected from one elite male Swedish team showed that only 13% of all shots on goal were successful [9]. Michaud-Paquette and colleagues analyzed scoring accuracy of the wrist shot with a 3D motion capture [10], and substantial differences for top versus bottom goal targets were found for the kinematics of the hockey stick, which predicted shot accuracy.

Findings on how shooting performance (speed, accuracy) in ice hockey is affected by a standardized preload could help coaches to optimize their training programs. Thus, we aimed at quantifying acute effects of the execution of the physical performance tests within the IHCT on shooting performance. We hypothesized that the demands of the physical performance tests will result in a reduction of puck speed and shooting accuracy, and if so, the decrement of shooting performance will relate to athletes' physical capacity.

2. Materials and Methods

2.1. Participants and Study-Design

In this cross-sectional study, 34 male ice hockey players were recruited from two teams of the Third German Professional League. The sample composed 13 defensemen and 21 forwards (Table 1). Based on the very different load profile and ice hockey-specific requirements (e.g., flexibility [3,11]), goaltenders were fundamentally excluded from the IHCT and the current investigation. The athletes had on average 6.9 (SD = 6.0) years of playing experience in the first, second or third ice hockey leagues.

Table 1. Age and anthropometric characteristics of ice hockey players by playing position. Values presented as mean (one standard deviation, minimum and maximum).

	Defensemen (n = 13)	**Forwards (n = 21)**	**p Value**	**Cohen's d**
Age [years]	25.6 (6.2, 19–39)	26.9 (6.2, 20–42)	0.57	−0.20
Body mass [kg]	87.2 (8.5, 72.8–106.3)	86.7 (9.4, 67.4–103.4)	0.88	0.06
Body height [cm]	186 (5, 176–194)	182 (6, 171–192)	0.04	0.74
BMI [1] [kg/m^2]	25.3 (2.5, 21.3–30.4)	26.3 (2.6, 20.9–31.1)	0.28	−0.39
Body fat [%]	16.5 (4.0, 9.5–22.0)	17.4 (5.1, 6.6–28.0)	0.59	−0.19
Fat-free mass [kg]	72.6 (5.5, 62.7–82.9)	71.4 (6.5, 58.8–80.0)	0.56	0.21

[1] Body mass index. p values are based on Student's unpaired t tests.

2.2. The Ice Hockey-Specific Complex Test (IHCT)

Efficiency in ice hockey is highly dependent on the ability to interact fast, precise passes and goal shots. Linear and multidirectional speed actions on-ice as well as shots on goal are core elements of the IHCT. The IHCT was designed to test players' on-ice performance and ice hockey-specific-skills [4]. The athletes performed the IHCT after a short general warm-up on a bicycle ergometer and an independently executed specific warm-up on-ice. Except for the slap shots, each part of the IHCT had to be executed from a resting standing position without any pre-acceleration. For the slap shots, skating was allowed (maximum 8.5 m). The time for the linear speed tests (30 m forward, 30 m forward with puck, 30 m backward) was recorded using photoelectric cells (AF Sport, Wesel, Germany) placed at the start, at 10, 20 and 30 m. The time for the COD speed tests (transition agility test, weave agility test) was registered using a stopwatch. The puck speed of three slap shots (SS) and wrist shots (WS), respectively, performed on empty goal before and after the speed tests, was recorded by a radar gun system (Stalker Solo 2, Stalker, Plano, TX, USA).

2.3. Data Collection and Performance Outcomes

Test duration, heart rate and metabolic responses as well as puck speed served as outcome measures. Before starting, the athletes were equipped with the Polar Team Pro System (Polar Electro, Kempele, Finland) and the resting heart rate (RHR) as well as resting blood lactate (RBL) levels (SUPER GL compact, Dr. Müller, Freital, Germany) were recorded. The elapsed time of the speed-related IHCT components (linear forward and backward sprints and the two COD tests) was extracted from the PTPS data file.

The maximum heart rate (MHR) was captured directly after the last COD test and before the shots on goal were repeated. The difference between MHR and RHR (range) served as functional heart rate reserve (fHRR). Further, the relative heart rate recovery (HRR) 2 min after finishing the IHCT (short-time recovery) was used as a cardiac fitness indicator. The blood lactate levels were recorded 2, 6 and 10 min after the IHCT. The blood lactate elimination (BLE) rate was calculated as the difference between the blood lactate levels at six and ten minutes divided by four.

Goal-shooting performance was quantified as shooting accuracy and puck speed. For pre-post comparisons, only the maximum puck speeds of successful shots were considered. Due to the limited number of shots, shooting accuracy was categorized into three different classes separately for each shot type: 3, three successful goal shots; 2, two successful goal shots and one miss; 1, one or no successful goal shot with two or three misses, respectively. Correspondingly, the associated puck speed within the three classes is presented. Puck speed decrement was calculated as a percentage of the speed before the IHCT. Therefore, negative values represent an increase of the puck speed after the execution of the IHCT.

2.4. Statistical Analyses

Results are reported as mean with one standard deviation and minimum and maximum in the text and tables. In figures, values are mean with 90% confidence intervals. Normal distribution of data was examined visually and verified using the Shapiro–Wilk test. Athletes' characteristics and changes in puck speed within the three shooting accuracy categories were verified with Student's t tests as well as Cohen's d. Frequency analyses were performed descriptively and by applying the Chi-squared test (exact, two-sided). Pearson's product-moment (r) or Spearman's rank (ρ) correlation coefficients were computed to examine relationships between interval or ordinal data, respectively. The thresholds for magnitudes of effect size values and correlations were set at <0.2 (trivial), 0.2 to 0.5 (small), 0.5 to 0.8 (moderate) and >0.8 (large), respectively.

3. Results

3.1. Study Participants

The 34 participants enrolled were on average 26 (SD = 6) years old, weighed 87 (SD = 9) kg, sized 183 (SD = 6) cm, and had a body mass index of 25.9 (SD = 2.5) kg/m^2. Athletes' body mass was positively related to maximum and successful SS puck speed ($r = 0.51$, $p < 0.01$, $n = 31$) but not to WS puck speed ($r = 0.11$, $p = 0.54$, $n = 31$) before the IHCT. After completing the linear and COD sprints of the IHCT, there were moderate positive associations of maximum SS ($r = 0.58$, $p < 0.001$, $n = 33$) and WS ($r = 0.43$, $p < 0.05$, $n = 33$) puck speed with participants' body mass. The demographic characteristics of the participants by their playing position are reported in Table 1. Players differed moderately in terms of their body height ($p = 0.04$, $d = 0.74$). The defensemen were on average taller than forwards. No differences were found concerning age, body mass, body mass index, or body fat.

3.2. Performance Outcomes

The total duration of the three speed tests and the four COD tests (including a pause between the tests) lasted on average 167 (SD = 16) seconds. For a detailed overview of the heart rate and metabolic responses, please refer to Table 2.

Table 2. Heart rate and metabolic responses with the abbreviations used and associated measurement units of the study participants. Values presented as mean (one standard deviation, minimum and maximum).

			Ice Hockey Players (n = 34)
Resting heart rate	(RHR)	[bpm]	64 (9, 49–83)
Resting blood lactate	(RBL)	[mmol/L]	1.19 (0.33, 0.56–2.17)
Maximum heart rate	(MHR)	[bpm]	180 (7, 169–198)
Maximum blood lactate	(MBL)	[mmol/L]	14.9 (2.1, 10.1–20.6)
Functional heart rate reserve	(fHRR)	[bpm]	116 (8, 95–127)
Heart rate recovery	(HRR)	[%]	22 (6, 13–38)
Blood lactate elimination	(BLE)	[mmol/L/min]	0.18 (0.25, −0.35–0.65)

Overall, after the IHCT the maximum puck speed of successful goal shots decreased considerably (Table 3). It should be noted that the sample size in these paired comparisons has decreased due to participants who failed all three attempts.

Table 3. Maximum shooting speed of successful goal shots before and after the IHCT. Values presented as mean (one standard deviation, minimum and maximum).

	Pre (n = 30)	**Post (n = 30)**	**p Value**	**Cohen's d**
Slap shot speed [km/h]	133 (8, 117–150)	124 (10, 101–146)	<0.001	1.52
Wrist shot speed [km/h]	110 (7, 98–132)	103 (8, 86–119)	<0.001	1.72

p values are based on Student's paired t tests.

The puck speed percentage decrement after the IHCT did not differ between both shot types (SS: 6.1 (SD = 4.4, −5.5–17.9), WS: 6.0 (SD = 3.5, −0.9–12.2), $t(26) = 0.18$, $p = 0.86$, $d = 0.03$). No linear association between the puck speed decrement of both shot types could be verified ($r = 0.13$, $p = 0.52$, $n = 27$).

3.3. Frequency of Goal Shot Success with Associated Puck Speed

In total, 408 shots (3 SS and 3 WS by 34 participants) were fired on the empty goal before and after the IHCT. Of the 204 shots after the individual warm-up and before the IHCT, 69 over 102 (68%) SS and 66 over 102 (65%) WS were successfully placed. After executing the IHCT, the shot accuracy increased in both shot types (SS: 81/102 (79%), Figure 1; WS: 79/102 (78%), Figure 2). The shot accuracy was independent of athletes' playing position for either shot type and whether the shot was performed before or after the IHCT ($\chi^2(2) < 4.4$, $p > 0.15$).

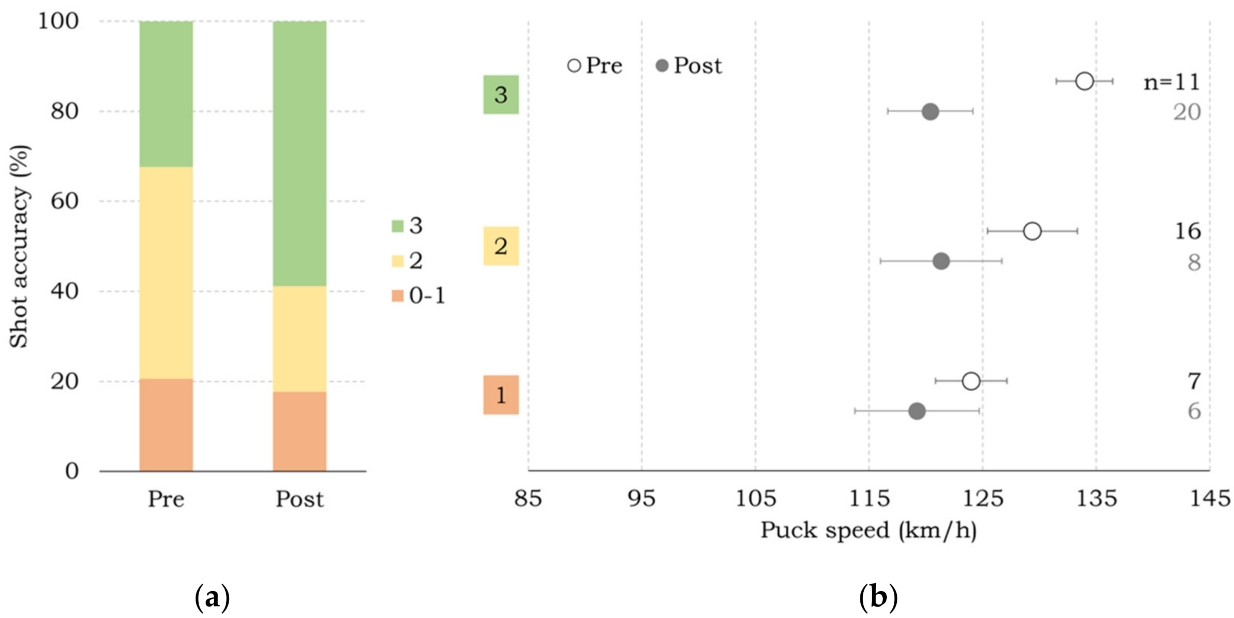

Figure 1. Slap shot accuracy and associated puck speed on three attempts before (Pre) and after (Post) the IHCT: (**a**) Relative occurrence of successful goal shots; (**b**) Puck speed with the number of athletes within the respective subgroup. Values are mean with 90% confidence intervals.

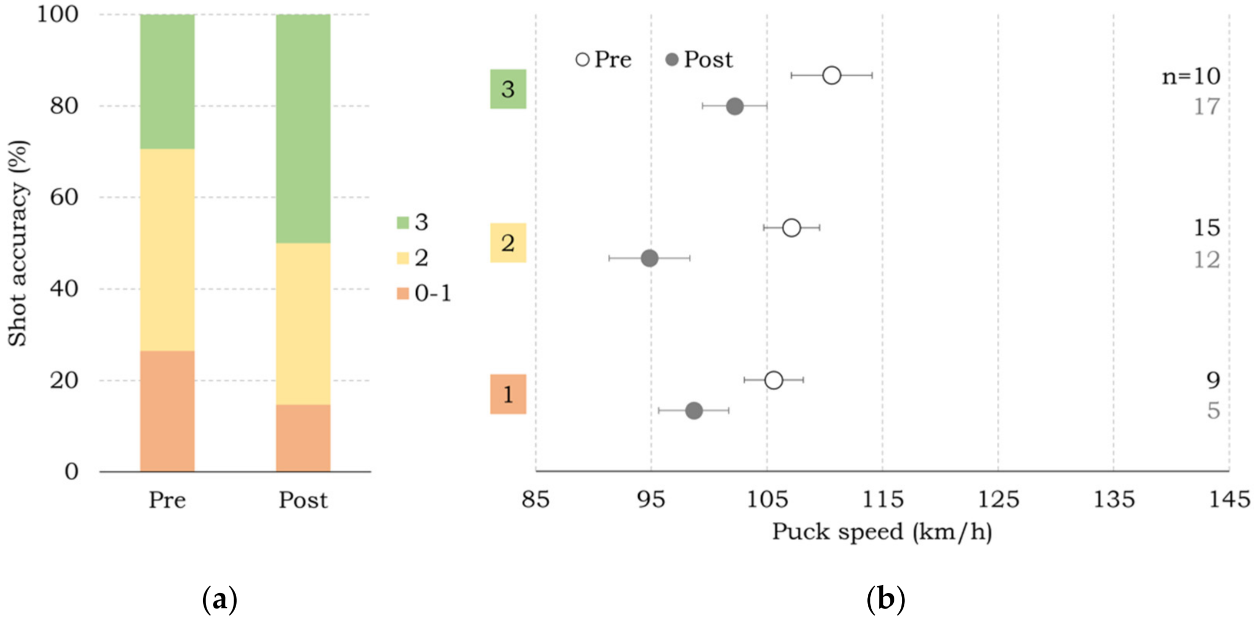

Figure 2. Wrist shot accuracy and associated puck speed on three attempts before (Pre) and after (Post) the IHCT: (**a**) Relative occurrence of successful goal shots; (**b**) Puck speed with the number of athletes within the respective subgroup. Values are mean with 90% confidence intervals.

The percentage of athletes who made each slap shot successful increased by 26% after the IHCT. Interestingly, the subgroup (n = 11) that shot with the highest speed on average before IHCT was associated with the top accuracy.

Figure 2 clearly shows that the shot accuracy is positively affected by IHCT execution (class 3: +21%). Irrespective of shot type or accuracy class, the maximum puck speed markedly decreased after completion of the IHCT. The relative puck speed decrement (sum of all shots) over an overall shot success score (six shots before, six shots after the IHCT) is displayed for each athlete in Figure 3. The Spearman's rank coefficient revealed no association (ρ = 0.15, p = 0.39, n = 34) between shot success and the IHCT-related puck speed decrement. However, this kind of shot success view is limited to those players who scored equally before and after the IHCT (n = 8). Moreover, the puck speed decrement assumes a similar shooting speed decline in both shot types.

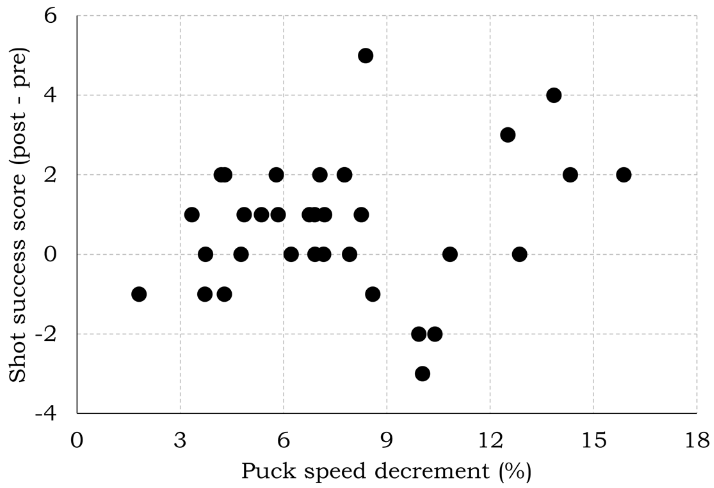

Figure 3. Relative puck speed decrement (sum of all SS and WS trials) over an overall shot success score (positive values represent a higher shot accuracy after the IHCT).

3.4. Relationships of Puck Speed Decrement to Heart Rate or Metabolic Responses

The linear associations between percentage slap shot or wrist shot puck speed decrement to absolute (MHR, MBL) or relative (fHRR, HRR, BLE) indicators of physical capacity are reported in Table 4. Neither heart rate nor metabolic responses could be related to the percentage reduction of slap shot puck speed. In contrast, the decrement of wrist shot puck speed was inversely associated with the functional heart rate reserve (fHRR, r^2 = 0.19) as well as the blood lactate elimination (BLE, r^2 = 0.18) rate (Table 4). Thus, the lower the fHRR or the BLE, the greater players' puck speed loss with the wrist shot.

Table 4. Relationships between percentage slap shot (SS) or wrist shot (WS) puck speed decrement and indicators of players (n = 27) physical capacity.

		SS Puck Speed Decrement	WS Puck Speed Decrement
Maximum heart rate (MHR)	[bpm]	−0.01 (0.96)	−0.20 (0.32)
Maximum blood lactate (MBL)	[mmol/L]	−0.08 (0.70)	0.08 (0.70)
Functional heart rate reserve (fHRR)	[bpm]	−0.22 (0.26)	**−0.44 (0.02)**
Heart rate recovery (HRR)	[%]	0.04 (0.86)	0.11 (0.59)
Blood lactate elimination (BLE)	[mmol/L/min]	−0.09 (0.68)	**−0.43 (0.02)**

Pearson correlation coefficients with p values in brackets. Relevant results ($|r| > 0.4$) marked with bold.

No linear inter-relations were observed for either indicator of physical capacity ($|r| < 0.36$, $p > 0.05$, n = 27).

4. Discussion

Acute effects of the execution of the physical performance tests within the IHCT on shooting performance have not yet been addressed systematically. We hypothesized that performing the IHCT will affect puck speed and shooting accuracy. Additionally, we expected the reduced shooting performance to be related to athletes' physical capacity. The results of our study show that the puck speed was affected considerably by the standardized physical performance tests. However, the magnitude of puck speed reduction in the wrist shot was inversely related to the fHRR and the BLE. Surprisingly, shooting accuracy increased after the IHCT; this was not expected.

The findings of the present study on puck shooting speed confirm our hypothesis and are in line with previous investigations [12–15]. The SS puck speed was found to be substantially higher compared with the WS puck speed. Wu and colleagues [12] measured puck speeds using a radar gun and detected, on average, 108 or 71 km/h for SS or WS puck speeds, respectively, achieved by the skilled males. By utilizing a different methodology, Worobets et al. [13] analyzed the effect of different hockey stick shaft stiffnesses on SS and WS puck speeds, respectively. Their averaged results for the distinct shot types (SS: 125 km/h, WS: 96 km/h) are comparable with our puck speeds after the IHCT. The slightly lower puck speeds found by Wu et al. [12] and Worobets et al. [13] can be explained by either the applied off-ice laboratory setup, the advances in material composition and technological developments, or the lower level of professional experience compared with our participants. Since the puck shot speed was shown to be related to players' upper body muscle power [14], it may be reasonable to assume that our participants had higher upper body strength qualities.

The linear and COD speed tests considerably influenced the puck speed of both shot types. Specifically, for the WS, the degree of puck speed reduction after preload was influenced by players' cardio-metabolic fitness (fHRR, BLE). Stanula and colleagues [16] observed a negative association of elite players' aerobic capacity measured off-ice with the amount of fatigue occurring after six maximum efforts of 89 m linear skating on-ice. The ability to recover quickly from intense actions is crucial for intermittent sports such as ice hockey. The observed inverse relationships of the functional heart rate reserve (fHRR) or the blood lactate elimination (BLE) rate with the WS puck speed decrement suggest that players with a greater fHRR and a more rapid BLE cope better with the intermittent physical stress applied; this underpins the importance of whole body physical fitness when playing ice hockey [16]. A reduction in WS puck speed in advanced phases would limit game performance in critical game situations and thus the team's success. Contrary to previous research [14], our data showed that heavier athletes shot the puck with a higher speed. This relationship will become more meaningful after the execution of the linear and COD speed tests. The impact of players' body mass on puck speed increased after speed testing with a common shared variance of at least 18%.

In ice hockey, the team aims to project the puck into the opponent's goal. Although for shots on goal the WS is considered the most accurate shot technique [10], our results revealed the SS to be more accurate, irrespective of the submaximal preload performed. An early investigation on shot type accuracy in ice hockey players of different levels revealed that, for the professional team, skating slap shot was the most accurate [17]. Contrary to our expectations, the execution of the on-ice performance tests led to increased shooting accuracy. After preload (speed testing), the accuracy of both shot types increased. In line with this finding, Lignell et al. [9] observed a greater probability to score in the two last game-periods. Based on the small size of an ice hockey goal (1.83×1.22 m) and especially related to the dimensions of an ice hockey goaltender, the shot speed is more important than the shot accuracy. The combination of higher shot speeds, shorter distances and hard-to-see shots for the goaltender promises the highest probability of a successful goal shot. From this point of view, the shot workout on-ice should primarily address the shooting speed. Further, the player should be able to realize a high shot speed repeatedly and under fatigue conditions (e.g., at the end of a period or a match). This would require a certain amount of strength endurance training combined with a technical on-ice shot workout. The technical shot workout should differ between positions. Forwards need more WS than defenders because they are in close contact with the opponent and the goal. In contrast, defenders perform shots on goal from a greater distance (blue line) and thus need more SS than forwards.

This study comprises some limitations that need to be addressed. First, the players executed an individual warm-up before the IHCT. From a methodological point of view, a standardized warm-up would be desirable. Possibly the higher accuracy after the IHCT is the result of an insufficient warm-up in this direction (e.g., no shots or passes within the warm-up). Second, our results cannot necessarily be transferred to different younger or higher skilled players. Third, the evaluation strategy used highly influenced the results. The interaction between shot speed and accuracy is not fully understood. From a performance point of view, a higher shot speed is only valuable when the shot on goal was successful. Thus, the selection of the shot attempts to be included might lead to different results. Last, it is unclear whether the present results can be generalized to females, since female athletes were not included.

The findings of this investigation highlight the interaction of intense on-ice testing and goal-shooting performance. The slap shot was found to accelerate the puck with a higher speed and greater precision, regardless of the submaximal preload. Moreover, the linear and COD speed tests resulted in a higher amount of successful goal shots. These results suggest that training SS or WS with emphasis on shot accuracy might be beneficial after a sufficient amount of preload. Future research should delineate the relationship between shooting speed and accuracy under different preload conditions.

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References

1. Vescovi, J.D.; Murray, T.M.; VanHeest, J.L. Positional performance profiling of elite ice hockey players. *Int. J. Sports Physiol. Perform.* **2006**, *1*, 84–94. [CrossRef] [PubMed]
2. Burr, J.F.; Jamnik, R.K.; Baker, J.; Macpherson, A.; Gledhill, N.; McGuire, E.J. Relationship of physical fitness test results and hockey playing potential in elite-level ice hockey players. *J. Strength Cond. Res.* **2008**, *22*, 1535–1543. [CrossRef] [PubMed]
3. Quinney, H.A.; Dewart, R.; Game, A.; Snydmiller, G.; Warburton, D.; Bell, G. A 26 year physiological description of a national hockey league team. *Appl. Physiol. Nutr. Metab.* **2008**, *33*, 753–760. [CrossRef] [PubMed]
4. Schwesig, R.; Hermassi, S.; Edelmann, S.; Thorhauer, U.; Schulze, S.; Fieseler, G.; Delank, K.S.; Shephard, R.J.; Chelly, M.S. Relationship between ice hockey-specific complex test and maximal strength, aerobic capacity and postural regulation in professional players. *J. Sports Med. Phys. Fit.* **2017**, *57*, 1415–1423.
5. Vigh-Larsen, J.F.; Beck, J.H.; Daasbjerg, A.; Knudsen, C.B.; Kvorning, T.; Overgaard, K.; Andersen, T.B.; Mohr, M. Fitness characteristics of elite and subelite male ice hockey players: A cross-sectional study. *J. Strength Cond. Res.* **2019**, *33*, 2352–2360. [CrossRef] [PubMed]
6. Durocher, J.J.; Guisfredi, A.J.; Leetun, D.T.; Carter, J.R. Comparison of on-ice and off-ice graded exercise testing in collegiate hockey players. *Appl. Physiol. Nutr. Metab.* **2010**, *35*, 35–39. [CrossRef] [PubMed]
7. Roczniok, R.; Stanula, A.; Maszczyk, A.; Mostowik, A.; Kowalczyk, M.; Fidos-Czuba, O.; Zajac, A. Physiological, physical and on-ice performance criteria for selection of elite ice hockey teams. *Biol. Sport* **2016**, *33*, 43–48. [CrossRef] [PubMed]
8. Schwesig, R.; Lauenroth, A.; Schulze, S.; Laudner, K.G.; Bartels, T.; Delank, K.S.; Reinhardt, L.; Kurz, E.; Hermassi, S. Reliability of an ice hockey-specific complex test. *Sportverletz Sportschaden* **2018**, *32*, 196–203. [CrossRef] [PubMed]
9. Lignell, E.; Rago, V.; Mohr, M. Analysis of goal scoring opportunities in elite male ice hockey in relation to tactical and contextual variables. *Int. J. Perform. Anal. Sport* **2020**, *20*, 1003–1017. [CrossRef]
10. Michaud-Paquette, Y.; Pearsall, D.J.; Turcotte, R.A. Predictors of scoring accuracy: Ice hockey wrist shot mechanics. *Sports Eng.* **2009**, *11*, 75–84. [CrossRef]

11. Bell, G.J.; Snydmiller, G.D.; Game, A.B. An investigation of the type and frequency of movement patterns of national hockey league goaltenders. *Int. J. Sports Physiol. Perform.* **2008**, *3*, 80–87. [CrossRef] [PubMed]
12. Wu, T.C.; Pearsall, D.; Hodges, A.; Turcotte, R.; Lefebvre, R.; Montgomery, D.; Bateni, H. The performance of the ice hockey slap and wrist shots: The effects of stick construction and player skill. *Sports Eng.* **2003**, *6*, 31–39. [CrossRef]
13. Worobets, J.T.; Fairbairn, J.C.; Stefanyshyn, D.J. The influence of shaft stiffness on potential energy and puck speed during wrist and slap shots in ice hockey. *Sports Eng.* **2006**, *9*, 191–200. [CrossRef]
14. Bezak, J.; Pridal, V. Upper body strength and power are associated with shot speed in men's ice hockey. *Acta Gymnica* **2017**, *47*, 78–83. [CrossRef]
15. Schulze, S.; Laudner, K.G.; Delank, K.S.; Brill, R.; Schwesig, R. Reference data by player position for an ice hockey-specific complex test. *Appl. Sci.* **2021**, *11*, 280. [CrossRef]
16. Stanula, A.; Roczniok, R.; Maszczyk, A.; Pietraszewski, P.; Zajac, A. The role of aerobic capacity in high-intensity intermittent efforts in ice-hockey. *Biol. Sport* **2014**, *31*, 193–199. [CrossRef] [PubMed]
17. Alexander, J.F.; Haddow, J.B.; Schultz, G.A. Comparison of the ice hockey wrist and slap shots for speed and accuracy. *Res. Q.* **1963**, *34*, 259–266. [CrossRef]