Mittuniversitetet
MID SWEDEN UNIVERSITY

Master´s thesis

Sport Science MA, IV005A, 30 hp VT 2018

Kinetic and kinematic factors influence on ice-hockey skating sprint performance

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Abstract

Skating is considered to be an important skill for ice-hockey players. The aim of this study was to examine different kinetic and kinematic variables and their association to speed during short distance skating. Twelve male elite ice-hockey players participated in the study. Pedar mobile system insoles were placed in both skates. The participants performed three maximal skating performance trails from the icing line to the first blue line. The best time of the three trials was used for analyzes. The force data were collected to calculate mean force, peak force, relative mean and peak force, impulse, contact time, stride frequency and inter-limb mean force asymmetry and then correlated against the skating performance. Stride frequency showed a significant correlation with skating performance (r= -0.586; p<0.05) All other variables failed to show a relationship with the skating performance test. According to this study, stride frequency is an important factor for ice-hockey player`s ability to generate speed over a short distance.

Keywords: Asymmetry, Contact time, Force, Impulse, Stride frequency

Abstrakt

Skridskoåkning är en viktig färdighet för ishockeyspelare. Syftet med denna studie var att undersöka olika variabler inom kinetik och kinematik och dess association med hastighet på skridskoåkning över en kort distans. Tolv manliga elit ishockeyspelare deltog i studien. Pedar mobile system inläggssulor placerades i båda skridskorna. Deltagarna genomförde tre maximala försök där det åkte så snabbt de förmådde mellan den förlängda mållinjen och den närmsta blålinjen. Den bästa tiden av de tre försöken användes vid analysen. Kraftdata insamlades för att räkna ut medelkraft, högsta kraft, relativa medelkraft, relativa högsta kraft, impuls, kontakttid, rörelsefrekvens för skridskoskären och asymmetri mellan extremiteterna, därefter korrelerades data mot åktiden. Frekvensen på skären visade en signifikant korrelation med åktiden (r= -0,586; p<0,05). Övriga variabler visade inget samband med åktiden. Enligt denna studie så är rörelsefrekvens en viktig faktor för att ishockeyspelare ska kunna generera skridskohastighet över en kort sträcka.

Nyckelord: Asymmetri, Frekvens, Impuls, Kontakttid, Kraft

Contents

Introduction

Physical demands of gameplay in ice-hockey are sparsely studied. A recently published study described the game activity during an official National Hockey League game (NHL) in which the total time the players were on the ice was 17.3±1.1 min, and the total distance they covered was 4606±219 m. The distance covered by high-intensity skating was 2042±97 m. Of that distance, 24% was performed by sprint skating (>24 $km \cdot h^{-1}$) and they covered 31±3 $m \cdot min^{-1}$ using sprint skating. During the game the players performed on average 19±1 sprints with an average length of 26±1 m. The average sprint speed was 25.5±0.1 $km \cdot h^{-1}$ and the peak speed was 28.6±0.1 $km \cdot h^{-1}$ (Lignell, Fransson, Krustrup & Mohr, 2017). Another recently published study described game activities of University ice hockey players. They found that for all players, forward gliding was the activity where the most time was spent (60%). Skating forward at a moderate intensity was the second most common game activity, with 17% of the time. This was followed by standing 9%, gliding backwards 8% and struggling 2% of the time. Forward sprints start and forward maximal sprinting accounted for 2% and 1%, respectively (Jackson, Snydmiller, Game, Gervais & Bell, 2017).

Skating is considered by the International ice hockey federation to be the most important skill to be learnt by any player (International Ice Hockey Federation, 2007). The first push-offs in skating is a running-like motion as it takes places against a fixed location on the ice. The running-like motion then develops into a gliding motion (de Koning, Thomas, Berger, Groot & van Ingen Schenau, 1995). The acceleration strides show a great emphasis on hip extension, which merges to a larger emphasis on hip abduction as the strides becomes more of a gliding motion (Buckeridge, LeVangie, Stetter, Nigg & Nigg, 2015). With increased skating velocity muscle activation patterns for the hip-muscles is changed, leading to increased activation magnitude and activation time (Chang, Turcotte & Pearsall, 2009). With increased velocity and number of strides, knee and ankle range of motion are increased. The amplitude of knee flexion is greater with increased number of strides, and on the ankle joint eversion were the angle that changed the most (Lafontaine, 2007).

Buckeridge, LeVangie, Stetter, Nigg & Nigg (2015) found a difference in the distribution of force between ice-hockey players of different playing standards. High level players had greater force at the forefoot segments, while the low-level players had greater force at the mid-foot as the strides shifted from acceleration strides to steady state strides.

Some experiments have tried to find an off-ice test that could predict on-ice skating performance. Studies have shown that vertical jump test was a good predictor of on-ice skating speed (Mascaro, Seaver & Swanson, 1992; Runner, Lehnhard, Butterfield, Tu & O´Neill, 2016), while other studies found that off-ice sprint time was the best predictor of on-ice skating performance (Krause et al. 2012). Behm, Wahl, Button, Power & Anderson (2005) did not only found correlation between skating performance and off-ice sprint speed, but they also found a correlation between skating performance and balance. In addition to this, it has been reported that horizontal leg power production is the strongest predictor of on-ice skating sprint performance (Farlinger, Kruisselbrink & Fowles, 2007).

Underlying variables contributing to skating speed for ice-hockey are not clearly defined. Therefore, the aim of this study was to examine different kinetic and kinematic variables and their association to speed during short distance skating.

Method

Participants

Twelve male elite players (Age: 22.8±5.2 years, height: 185.6±5.0 cm, weight: 86.9±6.2 kg) from the Swedish Hockey League (SHL) participated in the study. Four of the players were defenders and eight players were forwards. Test was carried out in an indoor ice hockey rink. The period of the test was in mid-May. All participants were informed about the study and signed an informed consent before the experiments. At the time of the test all the players were free from injury.

Protocol

The participants performed a warm-up that was at minimum 20 min in duration, and also included specific skating drills. The test started with the player standing behind the timing gates placed on the icing line with a hockey stick to mimic a game situation (Fig.1). The player started with either lateral or anterior body position in the skating direction and was chosen by individual preference. When they were ready they started the acceleration and skated past the timing gates placed on the first blue line (Fig.1). Each player performed three attempts, with 3 min of rest between them, and the best time was selected for analyzes. Only one player was tested in each occasion.

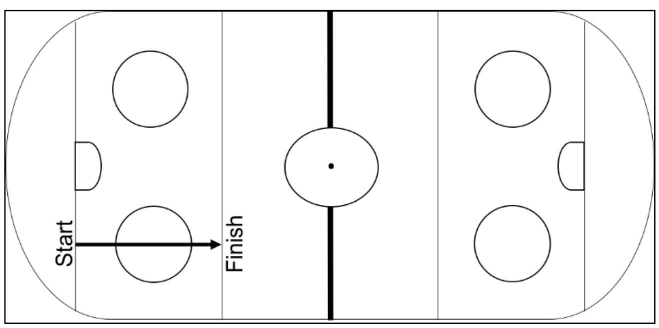

Figure 1. The start and finish for the skating test protocol.

Measurements

Pedar mobile system (Novel GmbH, Munich, Germany, 100 Hz) was used to measure the force in both skates for every stride, which were calibrated with the Pedar calibration device. The insoles were calibrated when the players had the skates on. Skating time performance between the icing line to 1st blue line was measured with timing gates (Brower Timing system, Draper, UT, USA). The timing gates were placed with the height to capture the movement of the hips.

Data collection

All force data were collected from the second to the seventh stride. Force measurement data from the insoles was used to identify the strides. Ice contact was set in the start of the force curve when it increased over 100 N between two measuring points (0.02 s; Fig. 2). Toe-off was set to the end of the force curve when the drop was less than 100 N between two measuring points (0.02 s; Fig. 2).
For one participant, one stride was not able to meet the criteria of increased forced for identification of initial ice contact. For this stride the initial ice contact was set were the force curved increased 99.9 N between two measuring points (0.02 s). All force data was calculated between initial ice contact to toe-off for all six strides (Fig. 2).
For one player, parts of the force measurement data were not recorded in five of the six strides and that data was interpolated to meet the criteria for analyzes. The total time that was interpolated for each stride was as following: 1st: 0.14 s, 2nd: 0.06 s, 3rd: 0.06 s, 4th: 0.08 s and 6th: 0.1 s.

Mean force was calculated as the mean of all measuring points, from initial contact time to toe off, for all strides (Fig. 2). Peak force was calculated as the mean of all push-off peaks for all strides (Fig. 2). Mean and peak force was normalized to body mass for comparison of relative force output. Impulse was calculated for each stride from initial contact time to toe off and analyzed as the mean of six strides (Fig. 2). Symmetry between the legs was calculated on the mean force of three strides on left leg and three strides on the right leg. The calculation was done with the following formula: Asymmetry= ([Right limb-Left limb)/$^{1/2}$ (Right limb+Left limb])×100% (Bell, Sanfilippo, Binkley & Heiderscheit, 2014). If the value was negative, the left limb had greater force and a positive value showed that right limb had greater force. Contact time was recorded as the time between initial contact time and toe off for each stride and analyzed as the mean time of six strides (Fig. 2).

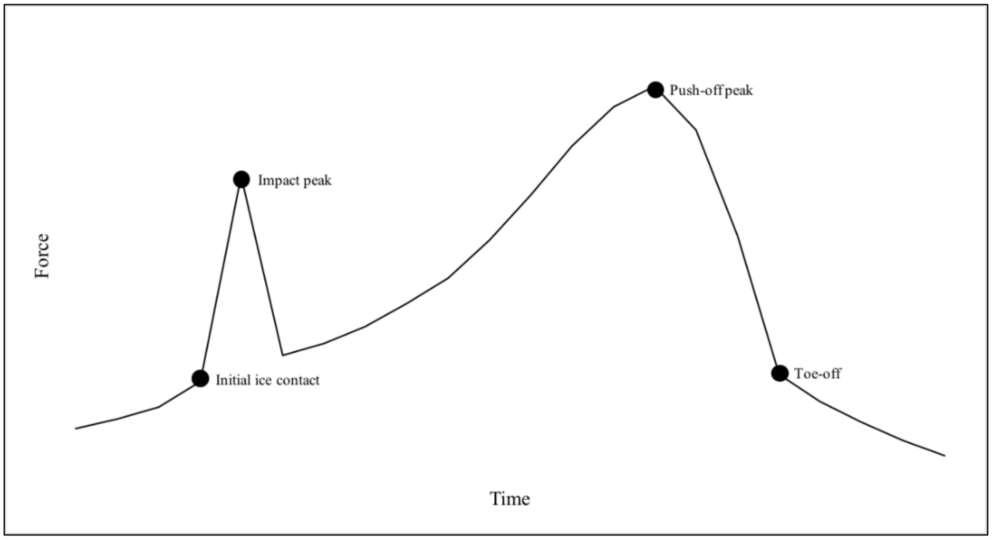

Figure 2. Definitions of the different characteristics within the strides.

For the analyzes of stride frequency the start was identified at the lowest value when the force curve started to increase for the first stride, and the final time was calculated from adding the time from the skating test. If the finish line was reached during a stride it was only counted if the push-off peak was reached before the player had passed the last timing gates (Fig. 3). The number of strides was divided by the skating performance time, and the result was analyzed as strides per second (Strides/s).

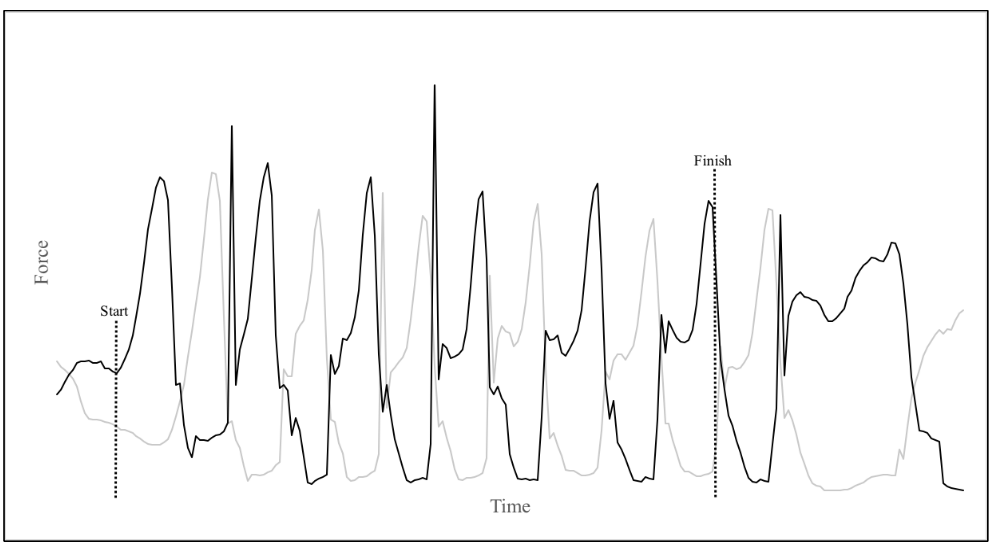

Figure 3. Example of strides with the identification of the start and the finish during skating performance.

Statistical analysis

All data was tested for normality using the Shapiro-Wilk´s test. Skating performance was correlated against all variables. Correlation for normally distributed data was tested with Pearson´s correlation coefficient, and for non-normally distributed data Spearman´s rank correlation coefficient was used. Mean values and standard deviation were used in calculation and presentation of the results. Z-score were calculated for the skating performance. Statistical test was performed in SPSS (version 24, IBM Corp., Armonk, N.Y., USA). For all test the level of significance was set at $p<0.05$.

Results

The mean skating time from the icing line to the 1st blue line was 2.94± 0.13 seconds (Fig. 4).

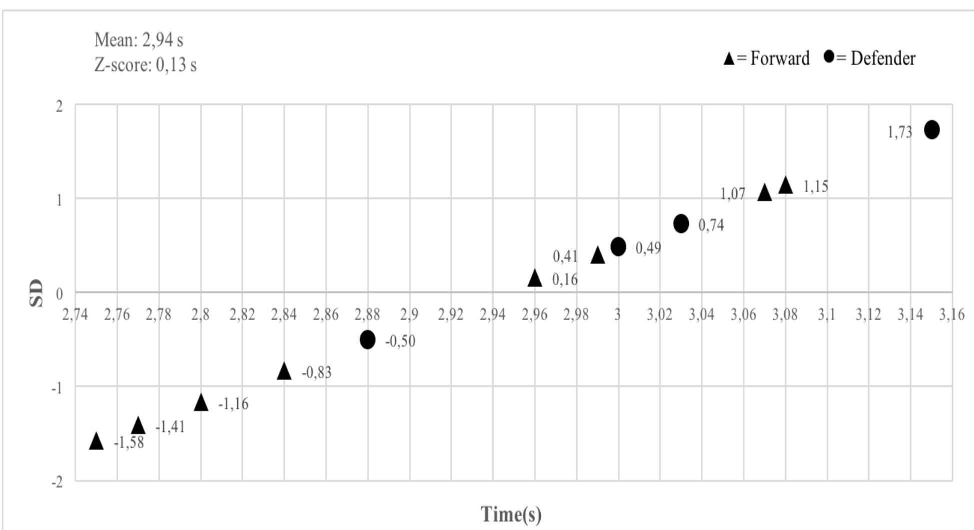

Figure 4. Time, z-score and playing position from the icing line to 1st blue line.

Kinetic variables

Mean force output was on average 844±152 N, and mean peak force output was 1335±224 N for the second to seventh stride. Skating performance was not associated to mean (r= 0.035, p= 0.0914) or peak force (r= 0.259, p= 0.417).

When the force output was normalized to body weight the relative mean force was on average 9.7±1.7 N/kg, and relative peak force had a mean value of 15.4±2.4 N/kg for the second to seventh stride. Skating performance was not associated to relative mean force (r= -0.035, p= 0.914) or relative peak force (r= 0.189, p= 0.557).

Impulse had a mean value of 230.2±52.9 Ns for the second to seventh stride. Skating performance was not associated to impulse (r= 0.378, p= 0.226).

The group showed greater mean force value for the left leg with a negative asymmetry value of -2.1±9.1% for the second to seventh stride. Skating performance was not associated to asymmetry (r= 0.327, p= 0.300).

Kinematic variables

Mean contact time was 0.26±0.04 s for the second to seventh stride. Skating performance was not associated to mean contact time (r= 0.467, p= 0.126).

Frequency had a group mean value of 3.35± 0.38 strides/s. Figure 5 shows the relationship between frequency and skating performance.

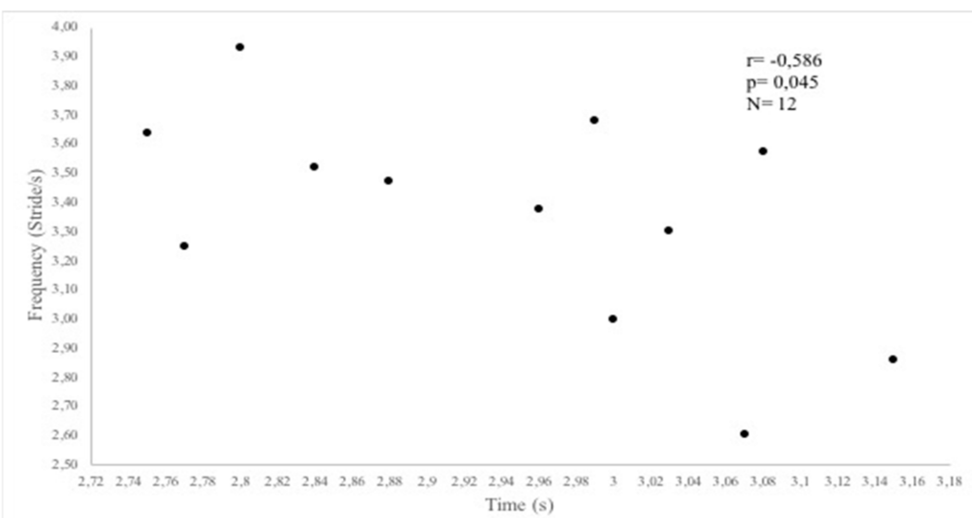

Figure 5. Frequency correlated with skating time from the icing line to 1st blue line.

Discussion

The aim of this study was to examine different kinetic and kinematic variables and their association to speed during short distance skating. The main finding in this study was that stride frequency significantly correlated with skating performance, explaining 34 % of the skating performance. This finding is in line with the study of Behm, Wahl, Button, Power & Anderson, 2005 who found that stride length and stride rate had a great effect on skating performance.

The results in the current study showed no significant correlation between skating performance and short contact time with the ice. To be able to have a high stride rate and high stride frequency, without shorter contact time and compromised stride length, something else must be of importance. This could be explained by faster leg recovery speed, since stride rate has been indicated by leg recovery speed (Farlinger, Kruisselbrink & Fowles, 2007). Furthermore, it has been reported that off-ice sprint time could be used as a predictor of forward skating performance (Krause et al., 2012), because it identifies both leg power and leg speed (Farlinger, Kruisselbrink & Fowles, 2007). Buckeridge, LeVangie, Stetter, Nigg & Nigg (2015) found that high caliber players, at initial ice contact, exhibit greater hip adduction angels than low caliber players. They suggest that this could lead to that the faster players, at the initiation of each skating stride, bring in their leg towards the midline more rapidly. This would in return enable the players to generate greater hip abduction velocity because they utilize a greater range of motion.

In contrast to this study, Upjohn et al., (2008) found that high-caliber players could reach a higher skating speed than low-caliber players, but the stride rates between the groups were similar. Instead, high-caliber players had both greater stride width and stride length. High-caliber players had a greater rate and range of joint motion in the frontal and sagittal planes. If strides with both width and length could generate a higher skating speed, this could also be one reason partly explaining the lack of correlation with contact time. On the contrary, with greater stride width and stride length without increased stride rate, the contact with the ice could in theory be longer and increasing the total impulse. This study failed to display any correlation between mean impulse and skating performance. Turcotte et al. (2001) reported that impulse was reduced with increased velocity due to shorter contact time. It is possible that the impulse in the current study was directly affected by the absence of shorter contact time when it was correlated against skating performance. Another possibility is that impulse can distinguish between different velocities, but not separate players within fast velocities. Among sprinters it has been shown that faster sprinters produced higher amount of horizontal net impulse per unit body mass, but the vertical ground reaction force impulse was not related to sprint performance (Morin et al., 2015). In this study, only the total amount of impulse was investigated, and it is possible that the outcome had been different if the impulse had been normalized to body mass or measured in a horizontal direction.

This study did not find any significant correlation between skating performance and any of the measured, absolute or relative, force variables. An earlier study found that total plantar force was least effective at identifying differences between players on a higher playing level and players from a lower playing level (Buckeridge, LeVangie, Stetter, Nigg & Nigg, 2015). The players that participated in the current study were, at the time of the testing protocol, players at the highest level of play in Sweden. Therefore, it is a reasonable assumption that the amount of force produced, and skating time performed by these players is of relatively high standard among ice-hockey players. Further, it is of relevance to analyze the mechanics of the strides as it differs between the first strides and the subsequent strides during speed skating. As described earlier, the first push-offs is a running-like motion as it takes place against a fixed location on the ice, and then the running-like motion develops into a gliding motion (de Koning, Thomas, Berger, Groot & van Ingen Schenau, 1995). There are various reports when this transition between strides occurs. de Koning, Thomas, Berger, Groot & van Ingen Schenau, (1995) reported that the transitions between running-like motion and gliding motion happens around the sixth push-off in speed skating. Lafontaine (2007) described the first push-off as pushing against a fixed point, the second push-off as a combination of pushing and gliding and the third as "pure glide".

A study on track and field sprinters showed that elite sprinters where able to produce higher horizontal force than sub-elite sprinters at any given velocity (Rabita et al., 2015). Anteroposterior ground reaction force in ice skating is considerable restricted due to the low surface friction on the ice, which in turn is good for gliding but detrimental to acceleration (Shell et al., 2017). A difference between running, where the horizontal force production is vital, and skating is that every step has is push-off against a fixed point which is not the case in skating. Even if force production might be important to skating performance it not distinguish, in this study, the faster skaters from the slower skaters. This might be due to the different characteristics of the strides and to the low friction of the ice surface. This means that the skater must produce force in different directions depending on the characteristic of each stride. The only thing in contact with the ice is the blade of the skate. Due to low friction of the ice surface, the player needs to put the blade on the ice in such an angle that it increases the friction between the skate and the surface. This would allow a greater ground reaction force to enhance the players skating performance in the desirable direction. This could maybe be referred to as 'skating skill' or 'skating technique'. The game itself makes the players to react more on external stimuli. If the player can anticipate or react to certain situations more quickly, the player might compensate, the lack of physical abilities to some extent.

This study did not found a correlation between-limb asymmetry and skating performance. Bell, Sanfilippo, Binkley & Heiderscheit, (2014) reported that power asymmetry greater than 10% impairs jumping performance, and they suggest restored power asymmetry between limbs would have a positive impact on athletic performance. Different jump tests are often used as a measure of leg power, as power production is considered as an important factor for team sports players. It has been reported that it could exist a negative relationship between inter-limb asymmetry in strength and kicking, jumping and sprint cycling performance (Bishop, Turner &

Read, 2018). To the author`s knowledge, there are no studies on inter-limb force asymmetry with ice-hockey players and the subsequent effect on skating performance. Exell, Irwin, Gittoes & Derwin (2017) found that, although kinetic inter-limb asymmetry existed among sprinters, kinetic asymmetries did not show a significant relationship and mean sprint velocity. Further, Exell, Irwin, Gittoes & Derwin (2017) suggested that asymmetry may be dysfunctional for some athletes, limiting performance, but rather be functional for other athletes because of the interaction between related kinetic and kinematic variables also varied. This could be a possible explanation in this study, although the only kinematic variables in this study was stride frequency and contact time, and the interaction between these variables never was investigated.

High stride frequency is not equal to a faster skating time for some of the participants, so coaches might use these types of tests to develop individual training programs for the players. If a player struggles to generate high skating speed over a short distance, but has a high stride frequency, attention in training might be directed to some other variables. In contrast, if a player can produce a large amount of force but struggles to generate high skating speed over a short distance, attention might be directed to stride frequency or to trying enhance other kinematic characteristics or important biomechanical variables.

This study was successfully performed with high level ice-hockey players in a naturally on-ice setting for the players. Even so, some things should be taken into consideration when interpreting the results of this study. The total number of participants in this study was reduced from fifteen to twelve players due to corrupt data files. Correlation and significance are more likely to be affected by the individual results when the number of participant are lower. Furthermore, in the testing procedure the players started when there was standing completely still and initiated the start of the skating performance test of their own choosing. To make the test situation more game compatible with real game characteristics, the start could be preceded by an external stimulus. To further ensure that the players perform the test protocol with maximal effort, testing procedure could include testing of two participants at the same time competing with each other.

Conclusion

The results of this study indicate that skating performance is complex. Stride frequency showed significant correlation with skating performance.

Future studies could investigate the importance of the direction of the force, not only thru insoles to measure different segments of the foot, but also how the force is distributed in correlation with angels of the blade, to potentially increase the friction and maximize the ground reaction force and horizontal force production.

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