International Journal of Strength and Conditioning

The Priming Effect of Heavy Resisted Sled Sprints on Skating Sprints in Ice Hockey Players: Impact of Neuromuscular Status and Timing of the Priming Intervention

Lassi A. Laakso[1,2]*, Dr. Daniel J. Cleather[1,3] and Dr. Stephen D. Patterson[1]

[1]Faculty of Sport, Technology and Health Sciences, St Mary's University, Twickenham, United Kingdom; [2]Hockey Club Lugano, Lugano, Switzerland; [3]Institute of Globally Distributed Open Research and Education (IGDORE)

Corresponding Author: lassi.laakso@hclugano.ch

ABSTRACT

The primary aim of this study was to assess the objective and the perceived priming effect of resisted sled sprints (RSS) on 30 m skating sprint performance in under-20 elite male ice hockey players. Further aims were to determine the impact of pre-priming exercise neuromuscular status on the priming effect of RSS, and whether RSS affects initial acceleration (0-10 m) and high-speed skating (20-30 m) differently in skating sprints. Twenty-one national-level ice hockey players (17.8 ± 0.9 yr) performed 4x15 m RSS with a resistance equating to 50% velocity decrement (Vdec), 1 h (1h-PRE) and 24 h (24h-PRE) before performing a 30 m skating sprint. Neuromuscular status was determined with the mean reactive strength index modified (RSImod) of three countermovement jumps. A repeated measures analysis of variance (ANOVA) yielded no differences in skating sprint times in either timing condition for 0-30, 0-10, and 20-30 m. RSImod was significantly lower (p = 0.01) in the 1h-PRE intervention group (1h-INT) compared to baseline, showing a large effect size of neuromuscular fatigue in 1h-INT (g = 0.89). There was no difference in readiness to perform and ratings of perceived performance in either timing condition. These results suggest that 4x15 m RSS at 50% Vdec provides no priming effect in non-fatigued junior ice hockey players following 1 and 24 h. A possible priming effect exists after 1 h in fatigued athletes. Skating sprint performance was not affected in any condition.

Keywords: delayed potentiation, countermovement jump, RSImod, skating speed

INTRODUCTION

Skating sprint speed is a fundamental quality for ice hockey players and performance in 10 and 30 m skating sprints is related to playing level (46). Lower-body strength, rate of force development, relative maximal horizontal power and effective horizontal force production have been identified as the determinants of skating sprint performance in ice hockey players (4,25,35). While qualities such as strength, power and speed are developed over time with various training methods, short-term strategies such as warmup (3,15), post-activation performance enhancement (PAPE) (39,43), and priming exercise, also referred to as delayed potentiation (19,29), have been shown to maximize these qualities for a given time frame, with the potential to increase athletic performance in competition.

Priming exercise interventions have been shown to improve both objective sport performance and perceived readiness 1-48 h after exercise (8,13,18,19,27,29,37,38,44). However, different priming exercise methods and protocols result in varied responses, particularly with consideration of the time course. A positive response to heavy- and moderate-load resistance priming has been found 4-33 h after resistance priming in lower-body neuromuscular performance (8,18,19,29,37,44). Negative neuromuscular and hormonal responses have also been reported following resistance priming performed with excessive intensity or volume, particularly 1-3 h after priming exercise (29). In sprint-based priming interventions consisting of 2-6 repetitions of 40-50 m linear or change-of-direction sprints, an increase in sprint performance has been reported after 5-6 h but not following 2 h (8,13,27,38). Improvements following priming exercise have been linked to neuromuscular, hormonal, psychophysiological or perceptual responses (8,13,18,19,27,29,38,44). However, the exact mechanisms are not fully understood yet and research on priming exercise protocols is required.

Neuromuscular priming exercise strategies are commonly prescribed to athletes in high-performance sports in the two days preceding competition, with a majority of strength and conditioning (S&C) coaches implementing some type of priming exercise on the day of competition (20,29). It has been suggested that kinematic similarity of the priming exercise, specifically in loaded conditions, may elicit a greater neuromuscular priming response and be better accepted psychologically by athletes on the day of competition (19,29,38). Given the “running-like” kinematics of skating starts (4,12), resisted sled sprints (RSS) performed off-ice, characterized by greater impulse projected horizontally and mean force production relative to unresisted sprints (2), fulfil the loaded specificity criterion. RSS have been used to enhance PAPE with conflicting results. PAPE was found with 1x20 m at 35% velocity decrement (Vdec) (5), i.e., the decrease in velocity relative to an unresisted sprint, with 1x15 m at 75% body mass (BM) (50), with 1x20 m at 75% BM (40) and with 3x15 m at 50% BM (23), but not with 1x7.5 m at 150% BM (50), 1x20 m at 125% BM (40), or with 3x10 m at 25-30% BM (48). Sled load therefore appears to be a critical factor of PAPE effect. Since RSS resistance is determined by the combination of external load and force of static friction (9), it has been recommended to use percentage of Vdec to quantify resistance in RSS (5,50). Despite the research on PAPE following RSS, there is currently a lack of research on the priming effect of RSS performed earlier relative to the time of competition, which could provide a practical and better accepted pre-game priming exercise method in team sports.

Given the short-term potential of PAPE that appears to enhance neuromuscular performance for up to 20 min and the existing research on priming exercise, Harrison et al. (19) suggested that two windows of neuromuscular potentiation may exist (0-30 min and >6 h). Mason et al. (29) reported benefits in a time window of 2-6 h after resistance priming and 5-6 h after sprint-based priming. However, it is unclear whether the priming effect disappears momentarily between PAPE and delayed potentiation or if this hypothesis results from a gap in research on a 1-5-hour time window of priming effects on neuromuscular performance (19). Given the high competition density of a professional ice hockey season with games every 2-3 days (33), it is increasingly common for teams not to have any intense activity in the morning of a game day to maximize rest time between games. In the context of a junior team where players are not full-time professionals, players are typically not available to implement game day morning or afternoon activities. Therefore, priming exercise performed prior to the game or the day before the game may be more adapted to sports with a congested competition calendar such as ice hockey. It may even be further hypothesized that the training volume included in priming exercise could be part of an in-season micro-dosing strategy in team sports (11). The current evidence on the lack of priming effect on lower-body performance in a 1-3-hour window may result from the use of suboptimal protocols, most commonly with excessive volume, and a positive effect should therefore not be excluded a priori. Measuring the effects of priming exercise in sport-specific performance, such as sprinting rather than a countermovement jump (CMJ), should also provide more valid data to determine its usefulness in competition environments (19).

The primary aim of this study is therefore to assess the objective and the perceived priming effect of RSS performed at maximal horizontal power resistance on 30 m skating sprint performance in U20-Elite male ice hockey players based on two different timing conditions, 60-75 min (1h-PRE) and 24 h (24h-PRE) before, used for the priming intervention. The second aim of the study is to determine the impact of pre-priming exercise neuromuscular status on the priming effect of RSS. The third aim of the study is to determine whether the priming effect of RSS affects initial acceleration and high-speed skating differently in skating sprints. It is hypothesized that in both timing conditions RSS will provide both an objective and subjective priming effect on 30 m skating sprint performance. Secondly, it is hypothesized that there will be a priming effect both with regular and fatigued neuromuscular status.

METHODS

Experimental Approach to the Problem

To determine the priming effect of resisted sled sprints performed 24 or 1 h before a 30 m skating sprint, a repeated measures crossover design was used (Figure 1). The study was completed during the regular season 2021-22. Baseline testing was performed in the two weeks prior to the start of the intervention. Players were then randomized into two groups of similar lower-body strength level measured with an isometric mid-thigh pull (IMTP) test. Within the crossover design, a control group, that included a group of players who performed a 30 m skating sprint test without a prior priming intervention, was used on each intervention day and allowed to assess any change in skating sprint performance across the group independent of the priming intervention.

With a regular weekly schedule during the study (Figure 2), the 30 m test was performed on Wednesdays every week. 24h-PRE and 1h-PRE priming interventions were therefore performed respectively on Tuesdays and Wednesdays.

On all priming intervention days, players completed an off-ice training program that included a dynamic warmup and submaximal upper-body resistance training before on-ice practice. All players also performed three submaximal 15 m sprints at the end of their warmup. CMJ was tested directly after the warmup. The intervention group then completed four repetitions of 15 m RSS at 50% Vdec with 3 min inter-sprint rest 60-75 min before ice time. Figure 3 illustrates the timeline of a 1h-PRE testing day. On weeks when 24h-PRE was assessed, the same dynamic warmup was performed 45 minutes before on-ice practice, followed by 30 minutes rest. Players were asked to avoid caffeine intake for three hours before on-ice testing (16,41).

Subjects

Twenty-one national-level players of a Swiss U20-Elite male ice hockey team (Table 1) participated in the study. Inclusion criteria were (a) to have played at least one regular season game for the U20-Elite team and (b) to practice with the U20-Elite team during the study. Players who reported an injury that would compromise safe and regular participation were excluded from the study. Given their different activity profile on-ice, goalkeepers were also excluded from the study. In accordance with the Declaration of Helsinki, ethical approval for the study was granted by the university ethics committee. The subjects were informed of the

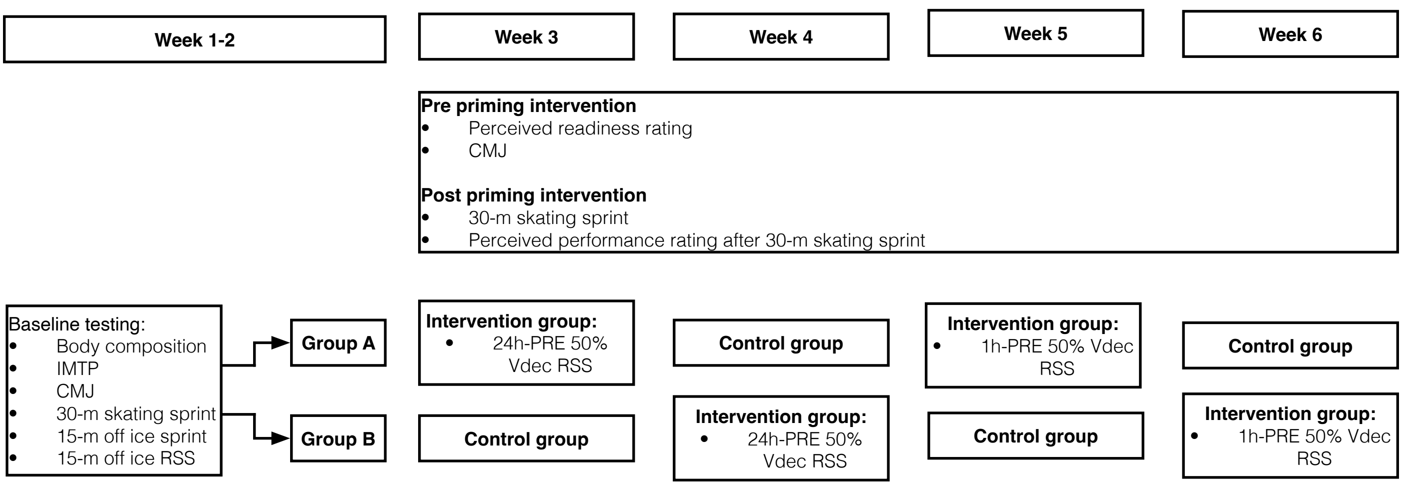

Figure 1. Timeline of the study. IMTP: isometric mid-thigh pull; CMJ: countermovement jump; RSS: resisted sled sprint. Vdec: velocity decrement.

Week / Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 3 & 4 (24h-PRE)	Off	Off-ice: • CMJ • RSS 24h-PRE • UB strength On-ice practice	On-ice: • 30-m test • Practice	Off-ice: • Power On-ice practice	Game	Off or light practice on-ice	Game
Week 5 & 6 (1h-PRE)	Off	Off-ice: • LB Strength On-ice practice	Off-ice: • CMJ • RS 1h-PRE • UB strength On-ice: • 30-m test • Practice	Off-ice: • Power On-ice practice	Game	Off or light practice on-ice	Game

Figure 2. Weekly training and competition schedule during the study. CMJ: countermovement jump; RSS: resisted sled sprints; UB: upper body; LB: lower body.

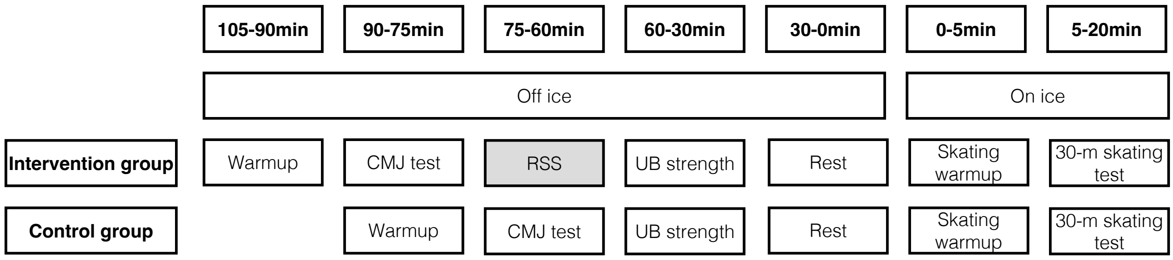

Figure 3. Timeline of a 1h-PRE testing day. CMJ: countermovement jump; RSS: resisted sled sprints; UB: upper body.

Table 1. Anthropometric characteristics of the subjects.

	Mean	SD	Minimum	Maximum
Age (years)	17.8	0.9	16	19
Height (m)	1.80	0.06	1.68	1.91
Body mass (kg)	79.2	9.7	63.4	97.7
BMI (kg/m^2)	24.5	2.3	20.8	28.9
Skinfolds (mm)	33	16	16	81

SD: standard deviation; BMI: body mass index; Skinfolds: sum of 3 skinfolds (chest, abdomen, thigh)

benefits and risks of the investigation before signing an institutionally approved informed consent document to participate in the study. Parental or guardian signed consent was obtained for subjects under 18 years of age. All participants completed a Physical Activity Readiness Questionnaire prior to the study. A priori sample size calculations were conducted using G*Power (version 3.1.9.6). Based upon a 0.15 s standard deviation in the 30 m skating sprint (46) and a strong correlation (r = 0.9) between repeated measures, an alpha level of 0.05 and beta of 0.9 were set to detect a medium effect size (f = 0.25). The minimum sample size required was calculated as nine participants.

Procedures

Players were familiarized with the tests and the intervention used in this study during their regular training program, no formal familiarization session was therefore necessary. All interventions were supervised by an accredited S&C coach.

Isometric mid-thigh pull

The IMTP was performed on dual force platforms recording at 1000 Hz (ForceDecks Lite, VALD Performance, Newstead, Australia) with a custom-built IMTP rack. Body mass (BM) was calculated from a stable 1 s weighing period. Participants performed two successful 5 s IMTP with maximal intensity interspersed with 30 s rest. The participants were instructed to stand with an upright trunk, a 140-150° hip angle and 125-145° knee angle (7). Lifting straps were used to avoid force output limitations due to grip strength and players were cued to "push as hard and fast as possible" (7). To define players' maximal strength, IMTP peak force (N) of the best attempt was divided by body weight (BM x 9.81). These values have shown excellent test-retest reliability (intraclass correlation coefficient [ICC]: 0.99; coefficient of variation [CV]: <5.0%) (24).

Countermovement jump

The CMJ was performed on the same force platforms. Participants were instructed to "jump as high and as fast as possible". They performed three CMJ dipping to a self-selected countermovement depth with hands akimbo and 10 s rest between jumps. Reactive strength index modified (RSImod) calculated as flight time divided by time to take off was used to determine neuromuscular status and the mean RSImod of three CMJ repetitions, which has demonstrated excellent within- and between-day reliability (ICC: >0.90; CV: 7.0%) (14,30), was used for statistical analysis.

Sprints

A single-beam timing system (SmartSpeed Lite, FusionSport, Brisbane, Australia) was used for the timing of all sprints recorded with 0.01 s accuracy. Timing gates were set up at a height of 52 cm at the start line and 108 cm at all other distances. In all off-ice sprints, players started from a standing position with their front foot on a line 50 cm behind the first timing gate and no posterior-anterior upper body momentum prior to start was allowed. Players could start whenever they were ready. For on-ice sprints, the start line was 1 m behind the first timing gate and no crossover step was allowed. The best sprint time was recorded.

For running sprints, timing gates were set up at 0 and 15 m. Following a standardized warmup that included dynamic stretching, running drills and three submaximal 15 m accelerations, players performed two 15 m sprints with 5 min rest on a concrete surface. An 80% BM load, calculated as the sum of the sled and the additional load in plates, was attached around the waist and initially tested to find 50% Vdec in RSS (10). With a minimum of 3 min rest between each sprint, the load was adapted until the load at 50% Vdec was found. The load was accepted if the resisted sprint time was <0.1 s separated from 150% of the unresisted sprint time.

For 30 m skating sprints, timing gates were set up at 0, 10, 20, and 30 m. On the ice, players performed a 5 min standardized skating warmup that included skating patterns and three submaximal 15 m accelerations prior to the test. Players then performed two maximal 30 m sprints with minimum 5 min rest between repetitions. An excellent test-retest reliability (ICC: 0.92; CV: < 5%) has been reported for a similar 40 m test (17).

Perceptual ratings

Readiness to perform (RTP) was measured prior to off-ice warmup on priming exercise days with a 5-point Likert scale where players defined their perceived readiness: far worse than usual, worse than usual, as usual, better than usual, far better than usual. To assess a perceptual effect of priming, after their 30 m skating sprint, players were asked to rate their perceived performance (RPP) on a similar 5-point Likert scale. A higher result corresponds to a better feeling.

Statistical Analyses

Within-subjects repeated measures analyses of variance (ANOVA) with Bonferroni post hoc analysis were conducted to determine any significant differences in RSImod, 30 m skating sprint time, 0-10 m skating sprint time, and 20-30 m skating sprint time between groups with both timing conditions of the priming exercise intervention (24h-PRE and 1h-PRE). All data were assessed for sphericity using Mauchly's Test of Sphericity, and if the assumption of sphericity was violated the Greenhouse-Geisser correction was reported. Additionally, Hedge's *g* effect sizes (ES) with 95% confidence intervals (CI) were calculated with the following criteria to infer the magnitude of difference in neuromuscular status and skating sprint performance in both timing conditions: <0.2 (trivial), 0.2-0.5 (small), 0.5-0.8 (medium), >0.8 (large) (6). Given the small sample size, normality of data of subjective ratings was assessed with the Shapiro-Wilk test. Student's t-tests were performed on RTP and RPP with both timings. To assess test-retest reliability, ICC was calculated for RSImod and 30 m skating sprint splits. All statistical analyses were conducted using SPSS version 28.0 (IBM Corp., Armonk, NY) and statistical significance was set at $p \leq 0.05$.

RESULTS

Descriptive data of baseline testing is presented in Table 2. Test-retest reliability was excellent for RSImod (ICC: 0.96; CV%: 14.7). For 30 m skating sprint splits, reliability was excellent for 0-30 m (ICC: 0.91; CV%: 4.3), good for 0-10 m (ICC: 0.75; CV%: 6.2) and good for 20-30 m (ICC: 0.87; CV%: 4.1).

Table 2. Means ± standard deviation of baseline testing results.

Test	Result
IMTP peak force (N)	3626 ± 511
IMTP relative peak force (kg/kg)	4.68 ± 0.53
Off-ice sprint 15 m (s)	2.36 ± 0.09
RSS sled load (kg)	62.4 ± 8.3
RSS relative sled load (% BM)	78.8 ± 4.5
CMJ RSImod (m/s)	0.56 ± 0.08
Skating sprint 0-30 m (s)	4.09 ± 0.18
Skating sprint 0-10 m (s)	1.68 ± 0.10
Skating sprint 10-20 m (s)	1.27 ± 0.04
Skating sprint 20-30 m (s)	1.14 ± 0.05

IMTP: isometric mid-thigh pull; RSS: resisted sled sprint; CMJ: countermovement jump; RSImod: reactive strength index modified

A repeated measures ANOVA yielded a significant difference in mean RSImod between groups (n = 12) at baseline, 24h-PRE intervention (24h-INT), and 24h-PRE control (24h-CON) ($F_{1,2}$ = 4.14, p = 0.03, η^2 = 0.27). However, post hoc tests identified a non-significant difference between baseline and 24h-INT (p = 0.06), baseline and 24h-CON (p = 0.09), and between 24h-INT and 24h-CON (p = 1.00). There was a significant difference in mean RSImod between groups (n = 14) at baseline, 1h-PRE intervention (1h-INT), and 1h-PRE control (1h-CON) ($F_{1,2}$ = 5.59, p = 0.01, η^2 = 0.30). Post hoc tests revealed a significant difference only between baseline and 1h-INT (p = 0.01) with a large ES of neuromuscular fatigue in 1h-INT (g = 0.89, 95% CI = 0.27-1.49). No other significant differences were found. The means and 95% CI for RSImod and skating sprint times in the different groups are presented in Figures 4 and 5.

The comparison of subjective ratings showed no significant difference in RTP between 24h-INT (3.08 ± 0.49) and 24h-CON (2.69 ± 0.63) (mean difference [MD] = 0.38 ± 0.77, 95% CI = -0.08-0.85; t(12) = 1.81, p = 0.10), and between 1h-INT (2.57 ± 0.76) and 1h-CON (2.21 ± 0.80) (MD = 0.36 ± 0.84, 95% CI = -0.13-0.84; t(13) = 1.59, p = 0.14). Similarly, no significant difference was found between RPP of 24h-INT (2.46 ± 0.52) and 24h-CON (2.62 ± 0.51) (MD = -0.15 ± 0.38, 95% CI = -0.38-0.07; t(12) = -1.48, p = 0.17), and between RPP of 1h-INT (2.36 ± 0.84) and 1h-CON (2.36 ± 0.74) (MD = 0.00 ± 0.96, 95% CI = -0.55-0.55; t(13) = 0.00, p = 1.00).

DISCUSSION

The primary aim of this study was to assess the objective and perceived priming effect of RSS performed 24 and 1 h before a 30 m skating sprint. A second purpose was to determine whether pre-priming exercise neuromuscular status impacts the priming effect of RSS. Without considering neuromuscular status, the results indicate that the RSS protocol used in this study did not enhance

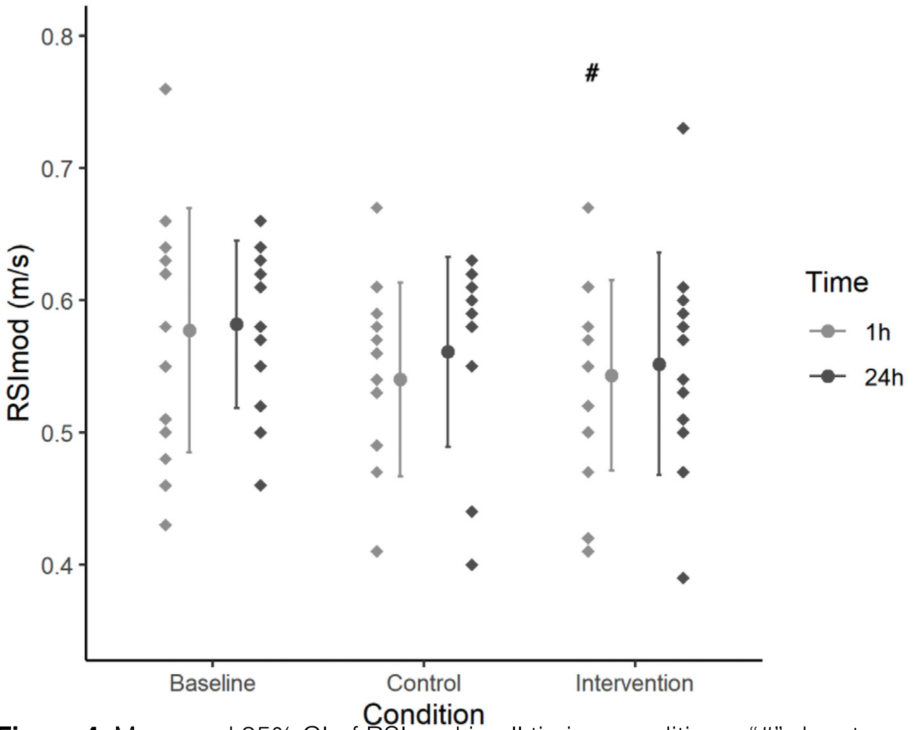

Figure 4. Mean and 95% CI of RSImod in all timing conditions. “#” denotes a significant difference with 1-h baseline. Significance level $p \leq 0.05$.

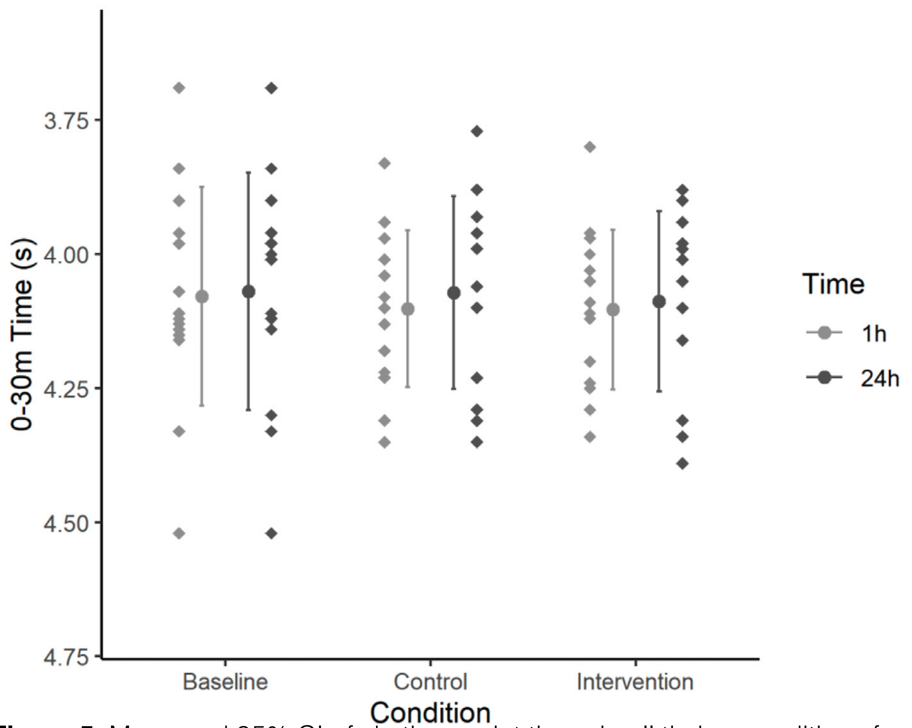

Figure 5. Mean and 95% CI of skating sprint times in all timing conditions for 0-30 m.

skating sprint performance and subjective ratings of perceived performance of elite U20 ice hockey players when performed 24 or 1 h before a 30 m skating sprint. Interestingly however, a skating sprint performance similar to baseline and the control group was measured 1 h after the RSS priming intervention, despite participants having a fatigued neuromuscular status prior to the priming intervention.

Contrary to the initial hypotheses, the RSS protocol used in the study did not provide a performance enhancing objective or subjective priming effect in either timing condition. Previous research has highlighted the positive effect of loaded kinematic specificity in priming exercise interventions to improve subsequent performance (29). The specificity factor has been suggested to possibly help athletes experience a more positive subjective response to priming exercise (19,29,38). The current study attempted to elaborate on these statements, whilst including elements that have not been researched before. PAPE is the result of a balance between fatigue and post-activation potentiation (PAP) resulting from a conditioning activity and its benefits are typically seen within 20 min of the conditioning activity with a peak after 7-10 min (19,21,39,43,49). The same principles apply to priming exercise (19). Given the longer recovery time following priming protocols, slightly greater volumes of neuromuscular activity may need to be used in priming interventions compared to PAP protocols, which may result in greater acute fatigue. Metabolic or neural fatigue due to excessive volume or resistance could therefore explain the lack of priming effect of this RSS protocol in both timing conditions, but more specifically in 1h-PRE, which would limit the expression of delayed potentiation.

Neuromuscular fatigue 24 h after the current 4x15 m RSS protocol may be excluded as a factor. In a study by Monahan et al. (31), team sport athletes completed 12x20 m RSS with a resistance determined as 23% Vdec. After 24 h, performance in the 20 m sprint and the CMJ had returned to baseline level. 24 h after an 8x20 m RSS protocol with 20-40-60-80% BM, performance tests showed a return to baseline results in a 10 and 20 m sprint and a CMJ (1). Furthermore, RPP showed no difference between intervention and control groups. Metabolic and neuromuscular fatigue can therefore be excluded as factors limiting the priming effect of the current RSS protocol.

As seen in PAPE research, the intensity of RSS protocols influences the response by the athletes. After unsuccessfully targeting PAPE by using 3x20 m RSS with 45% BM with varsity sprinters, Thompson et al. (42) suggested that stronger athletes may need to perform RSS with heavier loads to achieve PAPE. In fact, 75% BM has been used successfully in athletic populations (40,50). The resistance used in the current study corresponds to this load and to the intensity required to optimize maximal horizontal power. Compared with unresisted sprinting, which has shown to elicit a priming effect, RSS is characterized by greater propulsive mean force and impulse (2), and by an increase in rate of force development with greater loads (28). However, better adaptations are obtained when RSS is combined with unresisted sprint training (47). Similarly, PAPE is generally greater when plyometric activity is included in the conditioning activity (39). RSS combined with unresisted sprints might therefore provide a priming effect that RSS alone does not provide.

Limited research exists on the effect of priming exercise on sprint performance. It has been suggested that sprint-based priming interventions would be more effective for subsequent sprint performance. However, semi-professional rugby union players had a better priming effect on 40 m sprint performance 5 h after 3x3 back squat at 80-90-100% 1RM than after 5x40 m sprints (8). Given the key requirement in skating sprints to produce high amounts of horizontal force and power (35) and the greater force output in lower-body resistance priming exercises such as the squat, the jump squat and the CMJ (34) compared to RSS, ice hockey players may respond better to high force resistance priming interventions, particularly with a 24 h time window before competition, when aiming to provide a priming effect on skating sprint performance.

Based on the second hypothesis, the results of the current study show that neuromuscular status may influence the priming effect experienced by athletes. In 1h-INT, there was no decrease in skating sprint performance in all splits despite a lower initial neuromuscular status, indicating a potential priming effect of a 4x15 m RSS protocol when athletes experience neuromuscular fatigue. This could be considered as an improvement in skating sprint performance relative to predicted performance. Two principal mechanisms have been proposed to induce PAP: an increased recruitment of higher order motor neurons, and the phosphorylation of myosin regulatory light chains, which increases calcium sensitivity of actin and myosin (21,43). Both these effects increase human potential for strength and speed performance. How PAP impacts PAPE in human motor performance requires further understanding, but it has been suggested that lower muscle activation may be required to increase muscle torque in fatigued skeletal muscles following phosphorylation of myosin phosphorylatable light chains (22), which could explain a better priming response in fatigued athletes. However, the current study does not provide enough evidence for such a statement and future research is needed to understand the difference in response to PAPE and delayed potentiation between fatigued and fresh athletes.

In both timing conditions, skating sprint performance and perceived performance levels did not decrease following RSS priming. A training intervention that has a neutral or positive impact on performance when performed 24 or 1 h prior to competition could therefore be used as part of a micro-dosing strategy, where training frequency is increased, and volume of each training session is decreased to minimize short-term fatigue. Such strategies may be particularly useful for athletes who compete in team sports that have a long and congested season such as ice hockey players at professional and elite junior level. Cuthbert et al. (11) showed that resistance training frequency does not influence lower-body maximal strength adaptations in well-trained athletes after 6-12 weeks when total training volume is equated. Recent research suggests that RSS training may be a more effective method to improve short sprint performance when it is performed with heavy or very heavy loads, which define loads that cause >50% Vdec relative to an unloaded sprint and which correspond approximately to 70-100% BM (10,26,32,36). Volume of heavy RSS training should be limited in-season to avoid metabolic fatigue and muscle damage (1). Given the high metabolic cost of ice hockey games (45), further metabolic fatigue through S&C training should be limited, and training prescription should be adapted to the competition schedule. A micro-dosing strategy is therefore warranted for the training of neuromuscular qualities targeting strength and speed, and the 4x15 m RSS protocol may be used for this purpose 24 or 1 h before competition.

In summary, the 4x15 m RSS protocol used in the current study did not provide a performance enhancing effect 24 and 1 h after the priming intervention. Based on the analysis of past research, it is unlikely that metabolic and neural fatigue influenced this result. The neuromuscular or hormonal response to this RSS protocol were therefore insufficient to provide a priming effect in the two measured timing conditions. However, a possible priming effect was measured when athletes experienced neuromuscular fatigue prior to the 1h-PRE intervention. Finally, skating sprint performance did not decrease 24 and 1 h after the RSS intervention. The current RSS protocol could therefore be used as part of an in-season micro-dosing training strategy.

FUTURE RECOMMENDATIONS

The results of this study suggest that a 4x15 m RSS priming intervention is not effective at providing a skating sprint performance enhancement effect 24 and 1 h after the priming intervention in male elite U20 ice hockey players. Based on these results, despite kinematic similarity to sprinting, RSS does not provide a priming strategy superior to resistance priming, which has been shown to positively impact lower-body neuromuscular qualities and subsequent athletic performance. Subjective ratings of perceived performance did not increase either following RSS priming, excluding a subjective priming effect of this RSS protocol. However, a possible priming effect was observed after one hour when athletes experience neuromuscular fatigue before the priming intervention. Finally, skating sprint performance and ratings of perceived performance did not decrease 24 and 1 h after RSS priming. The current RSS protocol may therefore be used in both tested timing conditions as part of an in-season micro-dosing strategy of RSS and possibly to provide a priming effect 1 h before competition with fatigued athletes.

ACKNOWLEDGEMENTS

The authors would like to thank the players, staff, and management of Hockey Club Lugano for their availability and collaboration for this study.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

FUNDING

No external funding was obtained for this research.

ETHICAL APPROVAL

In accordance with the Declaration of Helsinki, ethical approval for the study was granted by the university ethics committee.

DATES OF REFERENCE

Submission - 11/11/2024
Acceptance - 02/01/2025
Publication - 17/04/2026

REFERENCES

1. Bachero-Mena, B, Sánchez-Moreno, M, Pareja-Blanco, F, Sañudo, B. Acute and short-term response to different loading conditions during resisted sprint training. Int J Sports Physiol Perform 15: 997–1004, 2020. https://doi.org/10.1123/ijspp.2019-0723
2. Bentley, I, Atkins, SJ, Edmundson, CJ, Metcalfe, J, Sinclair, JK. Impact of harness attachment point on kinetics and kinematics during sled towing. J Strength Cond Res 30: 768–776, 2016. https://doi.org/10.1519/JSC.0000000000001155
3. Bishop, D. Warm up II: Performance changes following active warm up and how to structure the warm up. Sports Med 33: 483–498, 2003. https://doi.org/10.2165/00007256-200333070-00002
4. Budarick, AR, Shell, JR, Robbins, SMK, et al. Ice hockey skating sprints: run to glide mechanics of high calibre male and female athletes. Sports Biomech 0: 1–17, 2018. https://doi.org/10.1080/14763141.2018.1503323
5. Cochrane, DJ, Monaghan, D. Using sprint velocity decrement to enhance acute sprint performance. J Strength Cond Res 35: 442–448, 2021. https://doi.org/10.1519/JSC.0000000000002707
6. Cohen, J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. Hillsdale, N.J: L. Erlbaum Associates, 1988.
7. Comfort, P, Dos'Santos, T, Beckham, GK, et al. Standardization and methodological considerations for the isometric midthigh pull. Strength Cond J 41: 57–79, 2019. https://doi.org/10.1519/SSC.0000000000000433
8. Cook, CJ, Kilduff, LP, Crewther, BT, Beaven, M, West, DJ. Morning based strength training improves afternoon physical performance in rugby union players. J Sci Med Sport 17: 317–321, 2014. https://doi.org/10.1016/j.jsams.2013.04.016
9. Cronin, J, Hansen, K, Kawamori, N, Mcnair, P. Effects of weighted vests and sled towing on sprint kinematics. Sports Biomech 7: 160–172, 2008. https://doi.org/10.1080/14763140701841381
10. Cross, MR, Brughelli, M, Samozino, P, Brown, SR, Morin, J-B. Optimal loading for maximizing power during sled-resisted sprinting. Int J Sports Physiol Perform 12: 1069–1077, 2017. https://doi.org/10.1123/ijspp.2016-0362
11. Cuthbert, M, Haff, GG, Arent, SM, et al. Effects of variations in resistance training frequency on strength development in well-trained populations and implications for in-season athlete training: A systematic review and meta-analysis. Sports Med 51: 1967–1982, 2021. https://doi.org/10.1007/s40279-021-01460-7
12. De Koning, JJ, Thomas, R, Berger, M, De Groot, G, Van Ingen Schenau, GJ. The start in speed skating: from running to gliding. Med Sci Sports Exerc 27: 1703–1708, 1995.
13. Donghi, F, Rampinini, E, Bosio, A, et al. Morning priming exercise strategy to enhance afternoon performance in young elite soccer players. Int J Sports Physiol Perform 16: 407–414, 2021. https://doi.org/10.1123/ijspp.2020-0094

14. Ebben, WP, Petushek, EJ. Using the reactive strength index modified to evaluate plyometric performance. J Strength Cond Res 24: 1983–1987, 2010. https://doi.org/10.1519/JSC.0b013e3181e72466
15. Fradkin, AJ, Zazryn, TR, Smoliga, JM. Effects of warming-up on physical performance: A systematic review with meta-analysis. J Strength Cond Res 24: 140–148, 2010. https://doi.org/10.1519/JSC.0b013e3181c643a0
16. Glaister, M, Howatson, G, Abraham, CS, et al. Caffeine supplementation and multiple sprint running performance. Med Sci Sports Exerc 40: 1835–1840, 2008. https://doi.org/10.1249/MSS.0b013e31817a8ad2
17. Hajek, F, Keller, M, Taube, W, et al. Testing-specific skating performance in ice hockey. J Strength Cond Res 35: S70–S75, 2021. https://doi.org/10.1519/JSC.0000000000003475
18. Harrison, PW, James, LP, Jenkins, DG, et al. Time course of neuromuscular, hormonal, and perceptual responses following moderate- and high-load resistance priming exercise. Int J Sports Physiol Perform 16: 1472–1482, 2021. https://doi.org/10.1123/ijspp.2020-0646
19. Harrison, PW, James, LP, McGuigan, MR, Jenkins, DG, Kelly, VG. Resistance priming to enhance neuromuscular performance in sport: Evidence, potential mechanisms and directions for future research. Sports Med 49: 1499–1514, 2019. https://doi.org/10.1007/s40279-019-01136-3
20. Harrison, PW, James, LP, McGuigan, MR, Jenkins, DG, Kelly, VG. Prevalence and application of priming exercise in high performance sport. J Sci Med Sport 23: 297–303, 2020. https://doi.org/10.1016/j.jsams.2019.09.010
21. Hodgson, M, Docherty, D, Robbins, D. Post-activation potentiation: Underlying physiology and implications for motor performance. Sports Med 35: 585–595, 2005. https://doi.org/10.2165/00007256-200535070-00004
22. Houston, ME, Grange, RW. Torque potentiation and myosin light-chain phosphorylation in human muscle following a fatiguing contraction. Can J Physiol Pharmacol 69: 269–273, 1991. https://doi.org/10.1139/y91-041
23. Jarvis, P, Turner, A, Chavda, S, Bishop, C. The acute effects of heavy sled towing on subsequent sprint acceleration performance. J Trainol 6: 18–25, 2017. https://doi.org/10.17338/trainology.6.1_18
24. Keogh, C, Collins, DJ, Warrington, G, Comyns, T. Intra-trial reliability and usefulness of isometric mid-thigh pull testing on portable force plates. J Hum Kinet 71: 33–45, 2020. https://doi.org/10.2478/hukin-2019-0094
25. Laakso, LA, Schuster, JG. Dynamic correspondence of the hang power clean to skating starts in men's ice hockey. Strength Cond J 43: 1–8, 2021. https://doi.org/10.1519/SSC.0000000000000618
26. Lahti, J, Huuhka, T, Romero, V, et al. Changes in sprint performance and sagittal plane kinematics after heavy resisted sprint training in professional soccer players. PeerJ 8: e10507, 2020. https://doi.org/10.7717/peerj.10507
27. Marrier, B, Durguerian, A, Robineau, J, et al. Preconditioning strategy in rugby-7s players: Beneficial or detrimental? Int J Sports Physiol Perform 14: 918–926, 2019. https://doi.org/10.1123/ijspp.2018-0505
28. Martínez-Valencia, MA, Romero-Arenas, S, Elvira, JLL, et al. Effects of sled towing on peak force, the rate of force development and sprint performance during the acceleration phase. J Hum Kinet 46: 139–148, 2015. https://doi.org/10.1515/hukin-2015-0042
29. Mason, B, McKune, A, Pumpa, K, Ball, N. The use of acute exercise interventions as game day priming strategies to improve physical performance and athlete readiness in team-sport athletes: A systematic review. Sports Med 50: 1943–1962, 2020. https://doi.org/10.1007/s40279-020-01329-1
30. McMahon, J, Lake, J, Comfort, P. Reliability of and relationship between flight time to contraction time ratio and reactive strength index modified. Sports 6: 81, 2018. https://doi.org/10.3390/sports6030081
31. Monahan, M, Petrakos, G, Egan, B. Physiological and perceptual responses to a single session of resisted sled sprint training at light or heavy sled loads. J Strength Cond Res doi: 10.1519/JSC.0000000000003973. Epub ahead of print. https://doi.org/10.1519/JSC.0000000000003973
32. Morin, J-B, Petrakos, G, Jiménez-Reyes, P, et al. Very-heavy sled training for improving horizontal-force output in soccer players. Int J Sports Physiol Perform 12: 840–844, 2017. https://doi.org/10.1123/ijspp.2016-0444
33. Neeld, K. Preparing for the demands of professional hockey. Strength Cond J 40: 1–16, 2018. https://doi.org/10.1519/SSC.0000000000000374
34. Okkonen, O, Häkkinen, K. Biomechanical comparison between sprint start, sled pulling, and selected squat-type exercises. J Strength Cond Res 27: 2662–2673, 2013. https://doi.org/10.1519/JSC.0b013e31829992b0
35. Perez, J, Guilhem, G, Hager, R, Brocherie, F. Mechanical determinants of forward skating sprint inferred from off- and on-ice force-velocity evaluations in elite female ice hockey players. Eur J Sport Sci 21: 192–203, 2021. https://doi.org/10.1080/17461391.2020.1751304
36. Petrakos, G, Morin, J-B, Egan, B. Resisted sled sprint training to improve sprint performance: A systematic review. Sports Med 46: 381–400, 2016. https://doi.org/10.1007/s40279-015-0422-8
37. Raastad, T, Hallén, J. Recovery of skeletal muscle contractility after high- and moderate-intensity strength exercise. Eur J Appl Physiol 82: 206–214, 2000. https://doi.org/10.1007/s004210050673
38. Russell, M, King, A, Bracken, RM, et al. A comparison of different modes of morning priming exercise on afternoon performance. Int J Sports Physiol Perform 11: 763–767, 2016. https://doi.org/10.1123/ijspp.2015-0508
39. Seitz, LB, Haff, GG. Factors modulating post-activation potentiation of jump, sprint, throw, and upper-body ballistic performances: A systematic review with meta-analysis. Sports Med 46: 231–240, 2016. https://doi.org/10.1007/s40279-015-0415-7
40. Seitz, LB, Mina, MA, Haff, GG. A sled push stimulus potentiates subsequent 20-m sprint performance. J Sci Med Sport 20: 781–785, 2017. https://doi.org/10.1016/j.jsams.2016.12.074
41. Stuart, GR, Hopkins, WG, Cook, C, Cairns, SP. Multiple effects of caffeine on simulated high-intensity team-sport performance. Med Sci Sports Exerc 37: 1998–2005, 2005. https://doi.org/10.1249/01.mss.0000177216.21847.8a
42. Thompson, KMA, Whinton, AK, Ferth, S, Spriet, LL, Burr, JF. Moderate load resisted sprints do not improve subsequent sprint performance in varsity-level sprinters. J Strength Cond Res 35: 72–77, 2021. https://doi.org/10.1519/JSC.0000000000002524
43. Tillin, NA, Bishop, D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. Sports Med 39: 147–166, 2009. https://doi.org/10.2165/00007256-200939020-00004
44. Tsoukos, A, Veligekas, P, Brown, LE, Terzis, G, Bogdanis, GC. Delayed effects of a low-volume, power-type resistance exercise session on explosive performance. J Strength Cond Res 32: 643–650, 2018. https://doi.org/10.1519/JSC.0000000000001812

45. Vigh-Larsen, JF, Ermidis, G, Rago, V, et al. Muscle metabolism and fatigue during simulated ice hockey match-play in elite players. Med Sci Sports Exerc 52: 2162–2171, 2020. https://doi.org/10.1249/mss.0000000000002370
46. Vigh-Larsen, JF, Haverinen, MT, Panduro, J, et al. On-ice and off-ice fitness profiles of elite and U20 male ice hockey players of two different national standards. J Strength Cond Res 34: 3369–3376, 2020. https://doi.org/10.1519/JSC.0000000000003836
47. West, DJ, Cunningham, DJ, Bracken, RM, et al. Effects of resisted sprint training on acceleration in professional rugby union players. J Strength Cond Res 27: 1014–1018, 2013. https://doi.org/10.1519/JSC.0b013e3182606cff
48. Whelan, N, O'Regan, C, Harrison, AJ. Resisted sprints do not acutely enhance sprinting performance. J Strength Cond Res 28: 1858–1866, 2014. https://doi.org/10.1519/JSC.0000000000000357
49. Wilson, JM, Duncan, NM, Marin, PJ, et al. Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training status. J Strength Cond Res 27: 854–859, 2013. https://doi.org/10.1519/jsc.0b013e31825c2bdb
50. Winwood, PW, Posthumus, LR, Cronin, JB, Keogh, JWL. The acute potentiating effects of heavy sled pulls on sprint performance. J Strength Cond Res 30: 1248–1254, 2016. https://doi.org/10.1519/JSC.0000000000001227