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SHORT COMMUNICATION

Does caffeine supplementation improve physical performance of elite ice hockey players? A randomized, double-blind, placebo-controlled, counterbalanced, cross-over trial

La supplémentation en caféine améliore-t-elle la performance physique chez des joueurs élites de hockey ? Résultats d'une étude randomisée, en double aveugle, contrôlée par placebo, contrebalancée et croisée

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Ice-hockey ;
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Summary
Objectives. — Although the positive effects of caffeine supplementation on individual and team-sports have been widely described, the literature evaluating the effect of caffeine supplementation on athletic performance in ice hockey players is almost non-existent. Therefore, the aim of the present study was to evaluate the effect of acute caffeine ingestion (3 mg/kg body mass).

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Equipment and methods. — Thirteen elite adult ice hockey male players participated in this double-blind, randomized, counterbalanced, placebo-controlled crossover trial. A 35-m sprint, an agility test (Weave agility-slalom with puck), and a reaction test were performed twice in two separate days. On both occasions players ingested 330 ml of water with lemon isotonic drink (86 kcal/19 g of carbohydrates). On one of the days the drink included 3 mg/kg body mass of anhydrous caffeine. The randomization was performed by a researcher who was not involved in the register of main outcomes.
Results. — No differences were found between the placebo and the caffeine condition for the 35-m sprint (4.223 vs. 4.188 s respectively, $P = 0.516$), Weave agility test (22.492 vs. 22.341 s respectively, $P = 0.534$) and reaction test (4.869 vs. 4.837 s respectively, $P = 0.570$). When analyzing individual results, three players showed improvements in the 35-m sprint while two showed decreases in performance after ingesting caffeine. Caffeine consumption did not improve athletic performance in ice hockey players.
Trial registration. — Clinicaltrial.gov (NCT05170139).

MOTS CLÉS
Hockey sur glace ;
Ergogénique ;
Ergolytique ;
Supplémentation ;
Performance athlétique

Résumé
Objectifs. — Bien que les effets positifs de la supplémentation en caféine sur les sports individuels et collectifs aient été largement étudiés, la littérature évaluant l'effet de la supplémentation en caféine sur les performances sportives de joueurs de hockey sur glace est pratiquement inexistante. Par conséquent, l'objectif de cette étude était d'évaluer l'effet de l'ingestion aiguë de caféine (3 mg/kg de masse corporelle).
Matériel et méthodes. — Treize joueurs de hockey sur glace masculins, de niveau élite, ont participé à cette étude, croisée en double aveugle, randomisée, contrebalancée et contrôlée par placebo. Ont été effectués un sprint de 35 m, un test d'agilité (Weave agility-slalom avec un disque) et un test de réaction, sur deux jours différents. Dans les deux cas, les joueurs ont ingéré 330 ml d'eau avec une boisson isotonique (86 kcal/19 g de glucides). Au cours de l'une des deux sessions, la boisson comprenait 3 mg/kg de masse corporelle de caféine anhydre. La randomisation a été effectuée par un chercheur qui n'était pas impliqué dans le recueil des principales variables.
Résultats. — Aucune différence significative n'a été observée entre la condition placebo et la condition avec caféine pour le sprint de 35 m (respectivement 4,223 contre 4,188 s, $p = 0{,}516$), le test d'agilité Weave (respectivement 22,492 contre 22,341 s, $p = 0{,}534$) et le test de réaction (respectivement 4,869 vs. 4,837 s, $p = 0{,}570$). Lors de l'analyse des résultats individuels, trois joueurs ont montré des améliorations dans le sprint de 35 m tandis que deux ont montré des baisses de performance après avoir ingéré de la caféine. Dans les conditions expérimentales de cette étude, la consommation de caféine ne parait pas améliorer les performances sportives des joueurs de hockey sur glace.

1. Introduction

Ice hockey is a sport characterized by intermittent, high intensity bouts of skating that involve both the aerobic and anaerobic energy systems [1]. During a match, players perform explosive accelerations and decelerations with continuous changes of direction and speed [2]. Ice-hockey players are usually on the ice during short periods lasting between 30 and 80 seconds combined with 4—5 minute rest periods [3].

Physical fitness will therefore be critical to performance with skating acceleration and maximal skating velocity among the most important physical determinants of ice hockey performance [4]. Strength and power will also be determinant to performance [3], and consequently trainers will try to improve these parameters in their players in order to increase their overall physical performance and the odds of winning a game.

Several nutritional supplements have been suggested to improve physical performance, with caffeine being classified into the group of ''Strong evidence to support efficacy and apparently safe'' supplements for performance enhancement by the International Society of Sports Nutrition [5]. A recent position stand evaluating the effects of caffeine suggested that it could improve physical performance in both trained and untrained individuals when consumed in doses of 3—6 mg/kg of body mass [6]. Moreover, recent meta-analyses have suggested that caffeine supplementation is an effective technique to improve team sport performance [7,8].

To the best of our knowledge only one study has evaluated the effects of caffeine supplementation on ice hockey performance finding a limited impact on sport-specific skills performance [9]. Results that contradict previous studies in different sports with similar physical demands such as basketball [10] or soccer [11] that found positive effects of

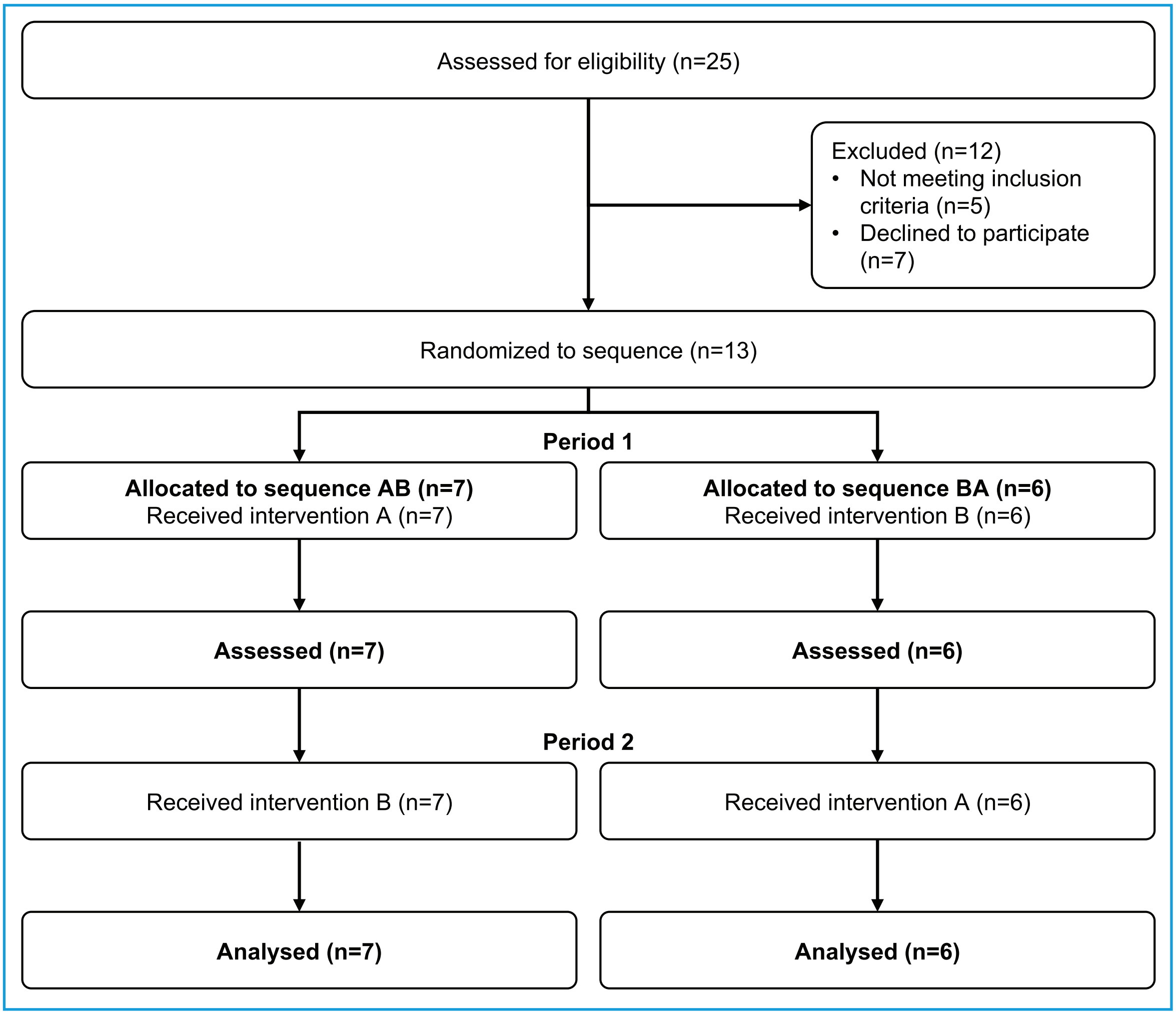

Figure 1 CONSORT flow diagram of ice hockey players who participated in this study.

caffeine on athletic performance. Thus, more evidence is needed in ice-hockey players to determine the possible ergogenic effects of caffeine supplementation in this athletic population.

Therefore, the aim of the present study was to evaluate the effect of 3 mg/kg dose of caffeine supplementation on physical performance in elite ice hockey players. We hypothesized that caffeine supplementation would increase ice hockey playerś physical performance.

2. Materials and methods

2.1. Participants

Before participating in the study, all players were fully informed of the study protocol, its benefits and risks, and completed and signed a written informed consent to participate. The study protocol followed the Declaration of Helsinki 1961 (revision of Fortaleza 2013) and was registered in clinicaltrials.gov (NCT05170139) and approved (PI21/225) by the Ethics Committee of Clinical Research from the Government of Aragón (CEICA, Spain). The CONSORT 2010 statement was used as a guideline for reporting randomized cross-over trials [12] and the corresponding checklist is presented as Supplementary Data.

A convenience sampling was used for the present study. Thirteen ice hockey players were recruited from a team of the LNHH (''Liga Nacional de Hockey Hielo''/''National ice hockey league''), the best ice hockey division in Spain (Fig. 1). In order to participate in the study participants had to be over 18 years, male and had to play at least 3 matches in the LNHH. The exclusion criteria were as follows: participants taking drugs containing ephedrine or antibiotics, or having suffered a musculoskeletal injury in the 3 months prior to the tests. Measurements were performed on an indoor ice arena located in Jaca (Huesca, Spain). Habitual caffeine consumption was not registered during the study but all participants confirmed that they were currently not ingesting and had not ingested caffeine supplements during the previous month.

2.2. Experimental design

A double-blind, randomized, counterbalanced, placebo-controlled crossover experimental design was used. The two trials were performed a week apart at the same arena and time (8 p.m.). On the first trial day, half of the participants were randomly allocated to ingest 3 mg of anhydrous caffeine (HSN®) per kg of body mass mixed with 330 ml of water that included one tablet of lemon powertabs isostar® (86 kcal/19 g of carbohydrates), while the rest of participants ingested the same drink without caffeine. On the second trial day those who had consumed the caffeinated drink ingested the placebo and vice versa. The drinks were provided in opaque bottles and ingested 60 minutes before the onset of the experimental tests to allow complete caffeine absorption [6]. Participants were asked to avoid caffeine ingestion, and strenuous exercise 24 hours prior to testing. Moreover, participants were instructed to consume their habitual pre-competition meal and replicate it in both trial days.

Participants were randomly assigned to one or two sequences: caffeine supplementation and placebo, or placebo and caffeine supplementation. Research randomizer webpage were used to do randomization. The randomization and the drink preparation were performed by a researcher who was not involved in the register of performance variables (main outcome of the present study). Caffeine was measured in laboratory conditions with an analytical balance (Kern ALS 220-4; with a precision of 0.1 mg). The exchange of bottles between players was not allowed and researchers made sure that all players drank the entire bottle content.

2.3. Performance tests

The performed tests were ice hockey tests described by Novák et al. [13].

Before testing, participants had 15 minutes to warm up in the ice ring. This warm-up was guided by the captain and consisted of a usual pre-match warm up including progressive forward and backward sprints, change of directions with increasing intensity and with the last part including exercises with a puck. After the warm-up participants were grouped into small groups (7 players), and the four tests were explained. All players performed two submaximal familiarization attempts of all tests on both days.

After the familiarization the players performed two maximal attempts and the best one was selected for further analyses. Players had 3-minute rests between attempts. All tests were registered with photoelectric cells (Witty Gate Wireless Training Timer Photocells, Microgate, Italy, with a precision of 0.001 seconds). Following the protocol of previous studies in ice hockey players [14], players started 15 cm behind the timing gates in order to assure that the timing was initiated as the participant took his first stride. The starts were self-determined. Reliability results for each test were obtained from the two attempts performed during the placebo condition. The tests were performed in the following order in both trial days (placebo and caffeine conditions):

- 35-m sprint test: Players were asked to perform an all-out straight 35-m sprint. This test has shown a very high reliability. The coefficient of variation (CV) of this test for the present sample was of 2.0%, similar to the CV obtained in a previous study (CV = 1%) [15];
- Weave agility - slalom with puck (Fig. 2a): The start and finish lines were combined, and therefore, only one timing gate was used. Players were asked to perform a slalom as specified in Fig. 2a. driving the puck at maximal speed going (black line) and returning (gray) through the same path. This test was designed by MacCormack [16] showing a Pearson product-moment correlation coefficient of 0.83 (reliability test used by the authors). The CV of this test for the present sample was 2.9%;
- Reaction test (Fig. 2b): For this test, the start and finish lines were combined and therefore, only one timing gate was used. The players followed the right or left track direction according to stick movements performed by a simulated defender. In Fig. 2a, the defender who was placed at a distance of 3 m moved his stick to his left side and therefore the player had to go towards the left cone (opposite cone of that indicated by the defender) in first place to then go the other cone and return to the start/finish line. This path is represented with a black curved arrow in Fig. 2b. The CV of this test for the present sample was 4.1%

2.4. Statistical analyses

The normality of the distribution was checked with the Kolmogorov-Smirnov test; with all tests showing a normal distribution. Paired t-tests were performed to analyze the differences in the 35-m sprint, weave agility, and reaction tests between the two conditions (caffeine vs. placebo). All tests were performed with Statistical Package for the Social Sciences (SPSS) version 24.0 for MacOS (SPSS Inc., Chicago, IL, USA). The results are presented as mean ± SD, and the significance level was set at $P < 0.05$. Effect size statistics using Cohen's d was calculated for paired *t*-tests. The effect size for Cohen's d can be small (0.2—0.5), medium (0.5—0.8) or large (0.8) [17]. CV was calculated to evaluate the variability of the tests and was determined as the standard deviation of the within player performance (two attempts performed in the placebo condition of each test) divided by the mean of the same two attempts multiplied by 100.

For individual responses, the smallest important change and test-retest typical error were required to include in the simple-change spreadsheet of the workbook for monitoring an individual [18]. The smallest important change was estimated via standardization by multiplying the between-player deviation of the best attempt in the placebo condition by 0.2. To estimate the typical error, the SD of the differences between attempt one and two in the placebo condition was first divided by $\sqrt{2}$; this value (the typical error of a single measurement) was then multiplied by 0.83, which simulations with a spreadsheet showed was the factor reduction in the typical error of a single measurement for the better of two measurements (W.G. Hopkins, unpublished observations; cf. the factor for the error in the mean of two measurements, $1/\sqrt{2} = 0.71$). Finally, the better of the two attempts in both the placebo and caffeine conditions for each player were inserted in the simple-change spreadsheet. An individual change was deemed unclear, when the true change could be substantial positive and negative (probabilities of substantial positive and negative both < 0.10);

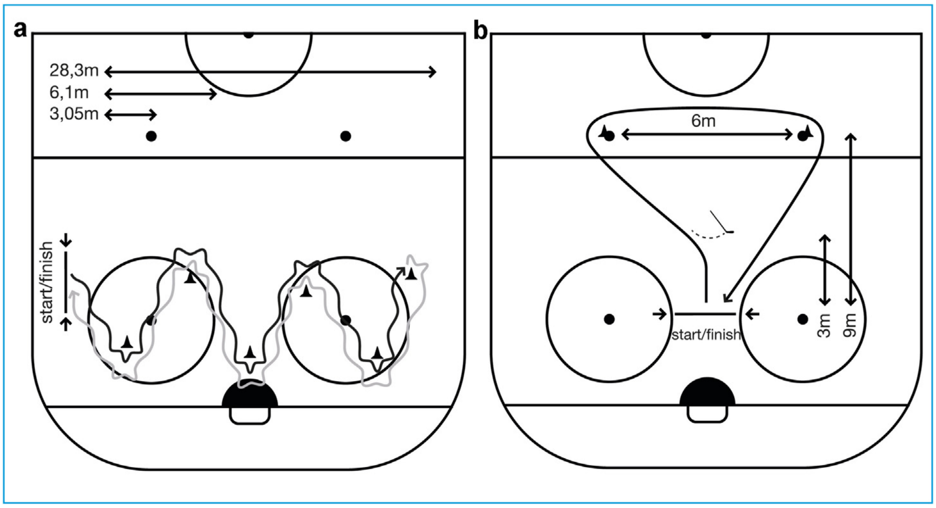

Figure 2 Weave agility test (2a) and reaction test (2b). Figure adapted from Dominik et al., 2019. JSSM.

Table 1 Descriptive characteristics of the male ice hockey players.

	Mean ± SD n = 13
Age (y)	22.9 ± 5.0
Weight (kg)	81.9 ± 6.5
Heigh (m)	1.8 ± 0.1
BMI (Kg/m^2)	25.5 ± 1.6
Played years	17.3 ± 5.3
Trained years	16.2 ± 4.8

BMI: Body mass index; kg: kilograms; m: meters; SD: Standard deviation.

otherwise, the change was deemed either possibly trivial and possibly substantial (probabilities of trivial and substantial positive or negative both > 0.10) or likely substantial (probability of substantial positive or negative > 0.90).

3. Results

3.1.1. Descriptive characteristics

Descriptive characteristics are presented in Table 1.

3.2. Physical performance parameters

Physical performance results are presented in Table 2. No differences were found between placebo and caffeine conditions (d ranged from 0.17 to 0.22; P > 0.05).

Fig. 3 presents the individual effects of caffeine on the physical performance tests. Participants 2, 6 and 7 showed a decisive increase in their sprint performance (they reduced their times after caffeine ingestion) while individuals 11 and 13 showed a decisive decrease (they increased their times after caffeine ingestion). All the other individual changes were classified as unclear.

3.3. Blinding effectiveness

Players were asked to indicate which substance they thought they had ingested (caffeine or placebo). From a total of 26 responses (13 players in two different trial days), only 10 responses were correct (38.5%), which could indicate that the blinding worked.

4. Discussion

The main finding of the present study is that caffeine did not show a positive effect on improving physical performance in an ice hockey team. We therefore reject our hypothesis that caffeine intake would have an ergogenic effect on ice-hockey players. Nonetheless, when analyzing at an individual level we did find variability in individual responses in the 35-m sprint test, with some players showing positive ergogenic effects.

The lack of effect at a ''group level'' is in line with the only previous existing study that evaluated the effect of caffeine supplementation on ice hockey players finding that performance times were not different between intervention conditions during performance trials performed in non-competitive conditions similar to ours [9]. Nevertheless, in the aforementioned study, researchers also evaluated peak head accelerations and rating of perceived exertion during a scrimmage finding that both were higher in the caffeine condition which would suggest an increase in physicality during the caffeine condition which could entail a positive effect for the team. This is in line with results from other sports as showed in recent meta-analyses that found that body impacts [8] and running speeds [7] are increased in match situations after caffeine ingestion.

This lack of effect should not be interpreted as a general lack of effect of caffeine on ice-hockey players, as it is possible that if higher doses would have been ingested and different tests (with higher reliability values) had been used we could have found positive effects. Moreover, some studies have found a lack of effect on laboratory conditions but an increased activity during match conditions [9] which

Table 2 Physical Performance results of ice hockey players in both placebo and caffeine conditions.

	Caffeine		Placebo			
	Mean	SD	Mean	SD	*P*	*d*
35-m sprint (s)	4.188	0.147	4.223	0.173	0.516	0.22
Weave agility (s)	22.341	0.839	22.492	0.943	0.534	0.17
Reaction test (s)	4.837	0.127	4.869	0.200	0.570	0.19

s: seconds; SD: Standard deviation; d: Cohen's d effect size. Cohen's d can be small (0.2—0.5), medium (0.5—0.8) or large (0.8).

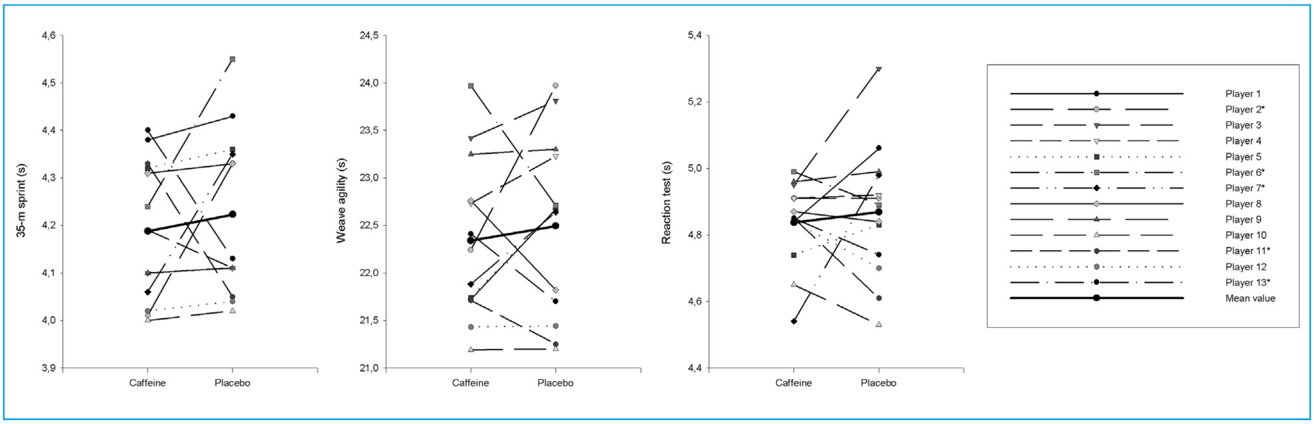

Figure 3 Individual changes for the three different performed tests. *: Participants 2, 6 and 7 showed a decisive increase.

would suggest that caffeine could be effective to improve performance in real match conditions.

When applying statistics for individual cases the only test that showed significant differences between the placebo and the caffeine condition was the 35-m sprint test, which was improved in three of 13 players (23%) and impaired in two players (15%), showing unclear results in the other players. For the agility and reaction tests, all participants had unclear effects. It should be noted that the Weave agility and Reaction tests had higher CV and typical errors than the 35-m sprint test (CV = 2.9 and 4.1%; typical error = 1.042 and 0.322 vs. CV = 2.0%; typical error = 0.082, respectively). These elevated CV and typical error values in agility and reaction tests could explain the lack of individual changes. In fact, these individual changes were classified as ''uncertain'' since these changes could be due to the intrinsic variability of the tests and not to the changes of performance in our athletes. Thus, we would recommend other tests in this population when individual changes are being evaluated.

It is worth noting that two participants (11 and 13), showed a decrease in performance after caffeine intake. These inter-individual responses have been discussed in previous research [19] with some studies finding negative responders for at least some of the measured variables like us [20,21].

These interindividual differences could partially be explained by the variations in genes such as the CYP1A2 associated with caffeine metabolism, sensitivity and response [6]. In a large study performed by Guest et al. [22] participants were classified according to the CYP1A2 gene, grouping into three genotypes: AA (fast), AC (heterozygous slow), and CC (homozygous slow). Researchers found that caffeine had an ergogenic effect only in those with the AA genotype, while it had no effect in the AC genotype and a negative effect in the CC genotype. In the Guest et al. study 8 out of 101 participants were genotyped as CC which is an 8% of participants, while in our study there was two out of 13 participants (a 15%) who showed a negative response. Therefore, it is possible that the negative response of those participants might be due to a CC genotype, although we cannot confirm this hypothesis as we did not collect samples to genotype our participants.

From our findings and the aforementioned genetic studies, it is clear those athletes who are willing to try dietary supplements should follow guidelines from official institutions (e.g. International Society of Sports Nutrition [5]) but also try the supplements with their coaches in order to see if they actually have a positive effect on them.

The present study is not exempt of limitations with the main ones being: (1) we did not register usual caffeine intake. Nonetheless, recent studies have suggested that usual caffeine intake does not moderate the ergogenic effects of acute caffeine supplementation if it does not reach certain doses (3 mg/kg body mass) and is not consumed regularly and on a long-term basis [23]. (2) We did not perform a specific familiarization day so that participants could get used to the performed tests. (3) We did not perform real match tests or simulated games that would have a higher ecological validity, and (4) we did not perform a sample size calculation which may have caused a low statistical power producing a type II error. Nonetheless, it should be noted that the number of participants was similar or even higher than previous studies evaluating the effects of caffeine on athletic performance in elite team sports measuring 10 [10,24], 12 [25] or like us 13 [26] athletes. Additionally caffeine ingestion was controlled and all the tests were performed at the same ice arena and time of day.

In conclusion, this study demonstrated that caffeine supplementation was not be effective to improve physical performance of male elite ice hockey players. It was also observed that the individual response of caffeine presents a high variability, consequently future research evaluating individual changes should be performed.

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Disclosure of interest

The authors declare that they have no competing interest.

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