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The prevalence and practices of caffeine use as an ergogenic aid in English professional soccer

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ABSTRACT: The ergogenic properties of caffeine are well established, with evidence supporting beneficial effects for physical and technical elements of performance required for successful soccer match play. Despite this, recommended caffeine practices for professional soccer have not been established. Therefore, the present study aimed to evaluate the use and behaviours surrounding caffeine use in elite English soccer clubs. Representatives of 36 clubs from the top four tiers of English professional football (40%) completed an online survey that sought to determine if, when, how and why caffeine was prescribed to players as a means of improving sports performance. Of the clubs sampled, 97% indicated that caffeine is provided to players as a means of improving performance. Caffeine is most commonly administered prior to (> 94%) and during a game (> 48%), with frequency uninfluenced by time of matches. There was a broad range and lack of consistency in the timing, dose and mode of caffeine administration, but doses were typically low. Evidence from the present study indicate a translational gap between science and practice, highlighting a need for future work to better understand how caffeine consumption can be optimised with respect to the specific demands and constraints in professional soccer.

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INTRODUCTION

The performance enhancing effect of caffeine for intermittent, endurance and resistance exercise has been firmly established [1], and there is a growing body of evidence inferring that caffeine ingestion may provide benefits for team sports performance [2, 3]. More specifically, data suggest that caffeine improves the physical and technical elements of performance required for successful soccer match play. The ingestion of 2–6 mg·kg body mass^{-1} of caffeine has been reported to increase repeated sprint and jump performance [4], reactive agility [5], jump height [6] and passing accuracy [7] during intermittent exercise protocols, replicating the physical demands of soccer. The mechanism by which caffeine provides an ergogenic effect is likely to be multifactorial, with central factors such as adenosine antagonism being the most probable [8], but with reductions in perceived exertion and pain perception [9], and improved reaction time, cognition, and mood [10] also having an influence on performance. Currently, little is known about the caffeine ingestion habits of elite soccer players making it difficult to establish whether best practice for caffeine ingestion is taking place and to what extent current practices are safe and evidence based.

Data obtained from urine samples used to detect doping, revealed that three out of four elite athletes use caffeine before or during competition [11], although the authors are unaware of any information relating to the prevalence of caffeine ingestion specific to soccer. The traditional form of caffeine administration in research and athletic settings has been to ingest tablets or capsules with liquid. However, currently there is a growing interest in investigating different vehicles of caffeine administration, such as coffee, aerosols, mouth rinses, and commercially available products such as chewing gums, bars, gels and energy drinks [12]. The popularity of these products in elite soccer is currently unknown and the evidence base outlining the effectiveness of alternative forms of caffeine is far from established. There are few studies that determine the effect of caffeine on complex and ecological soccer-specific tests [13], which may influence the translation of previous evidence into applied practice. Athletes seem to rely on inadequate sources of information such as coaches, family, and friends or teammates, rather than sports nutritionists or scientists, when acquiring and using supplements, with a considerable proportion of athletes engaging in self-prescription and purchase without consulting an accredited professional [14].

This may lead to soccer players using excessive and / or inappropriate dosing strategies of caffeine. For example, larger caffeine doses (≥ 9 mg·kg body mass^{-1}) do not appear to increase the performance benefit [15] and are more likely to increase the risk of negative side effects, including nausea, anxiety, insomnia and restlessness [16]. Whilst evidence pertaining to the performance enhancing effects of caffeine is clear, the translation of research to practice is yet to be reported where perception and knowledge of caffeine's effect and practical constraints within elite soccer likely influence how caffeine is used. Therefore, the aim of the present study was to evaluate the use and behaviours surrounding caffeine use in elite English soccer clubs as a needed first step to provide evidence-based and pragmatic guidance for safe and effective caffeine supplementation.

MATERIALS AND METHODS

Following ethics approval from the host institute (P89788), a cross-sectional, observational study was conducted using a self-administered online survey. Participants were asked to provide informed consent as part of the online survey, before accessing and completing the questions.

Participants

All 91 teams in the top four English professional soccer divisions were contacted electronically, on at least two occasions, to participate in the study. Data were obtained from a final sample of 36 professional clubs (Premier League™; N = 6, English Football League (EFL) Championship; N = 13, EFL One; N = 10, EFL Two; N = 7) resulting

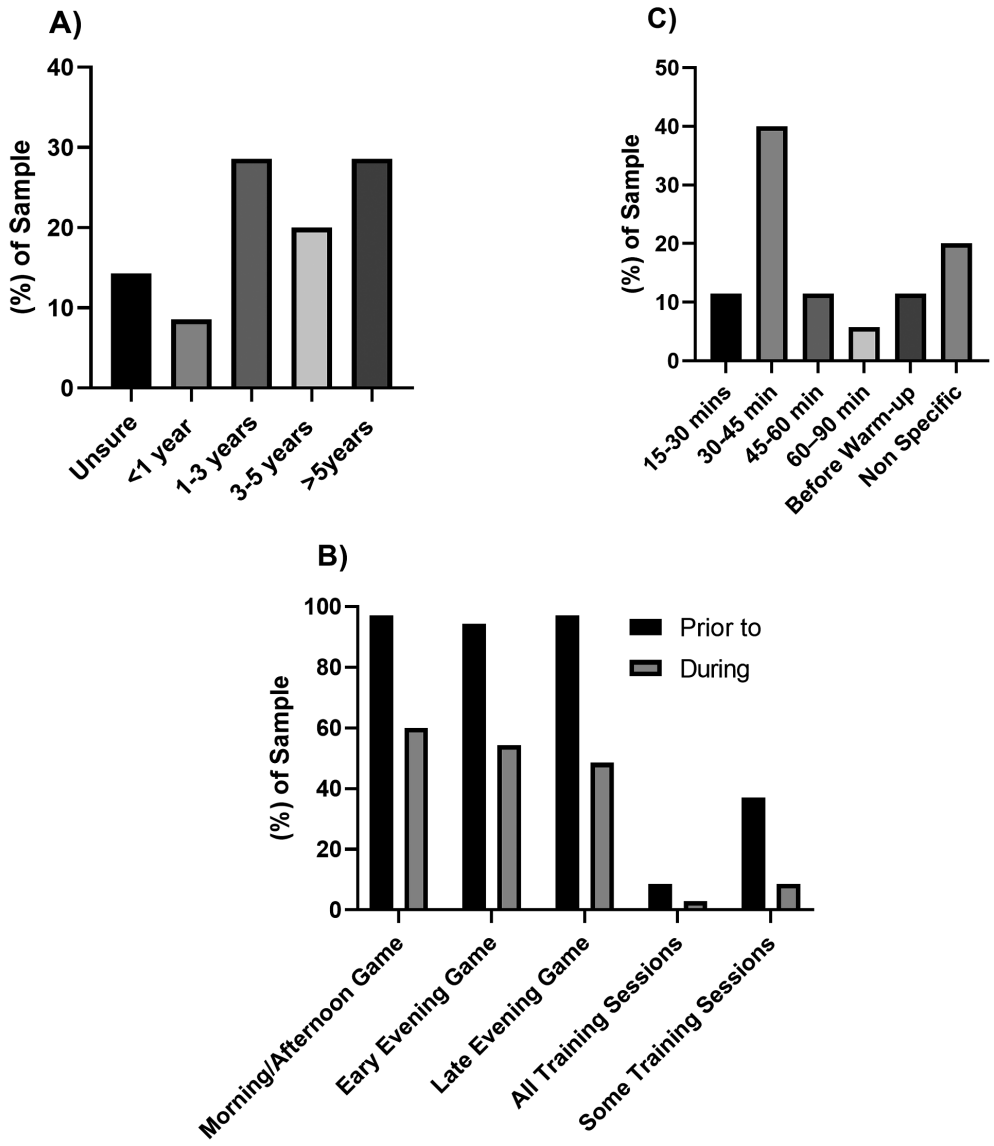

FIG. 1. Duration and timing of caffeine consumption. A) Duration caffeine has been used as a supplement; B) When caffeine is prescribed; C) Time caffeine consumed prior to a game [Data represented as frequency of reported responses; N = 35].

in a response rate of 40% of the total possible sample. The survey was typically completed by either the club sport scientist (N = 13), coach (N = 7) nutritionist (N = 6), or head of performance (N = 6), representing either the first team (N = 30) or under 23's squad (N = 7).

Survey Design

The survey required participants to outline the typical caffeine practices of the club. The survey was designed, distributed and managed using Jisc (https://www.onlinesurveys.ac.uk) and sought to determine if, when, how and why caffeine was prescribed to players as a means of improving sports performance by using a combination of multiple-choice, selection list, grid and free text questions. Two distinct survey pathways were designed in order to distinguish between clubs that did prescribe caffeine to players and clubs that did not. A list of questions and a survey map can be found in the appendices (Appendix 1. & 2. r). Questions pertaining to reported adverse effects of caffeine and the perception of caffeine as an ergogenic aid were based on previous evidence indicating that caffeine may elicit a response on each included parameter [7, 17–19].

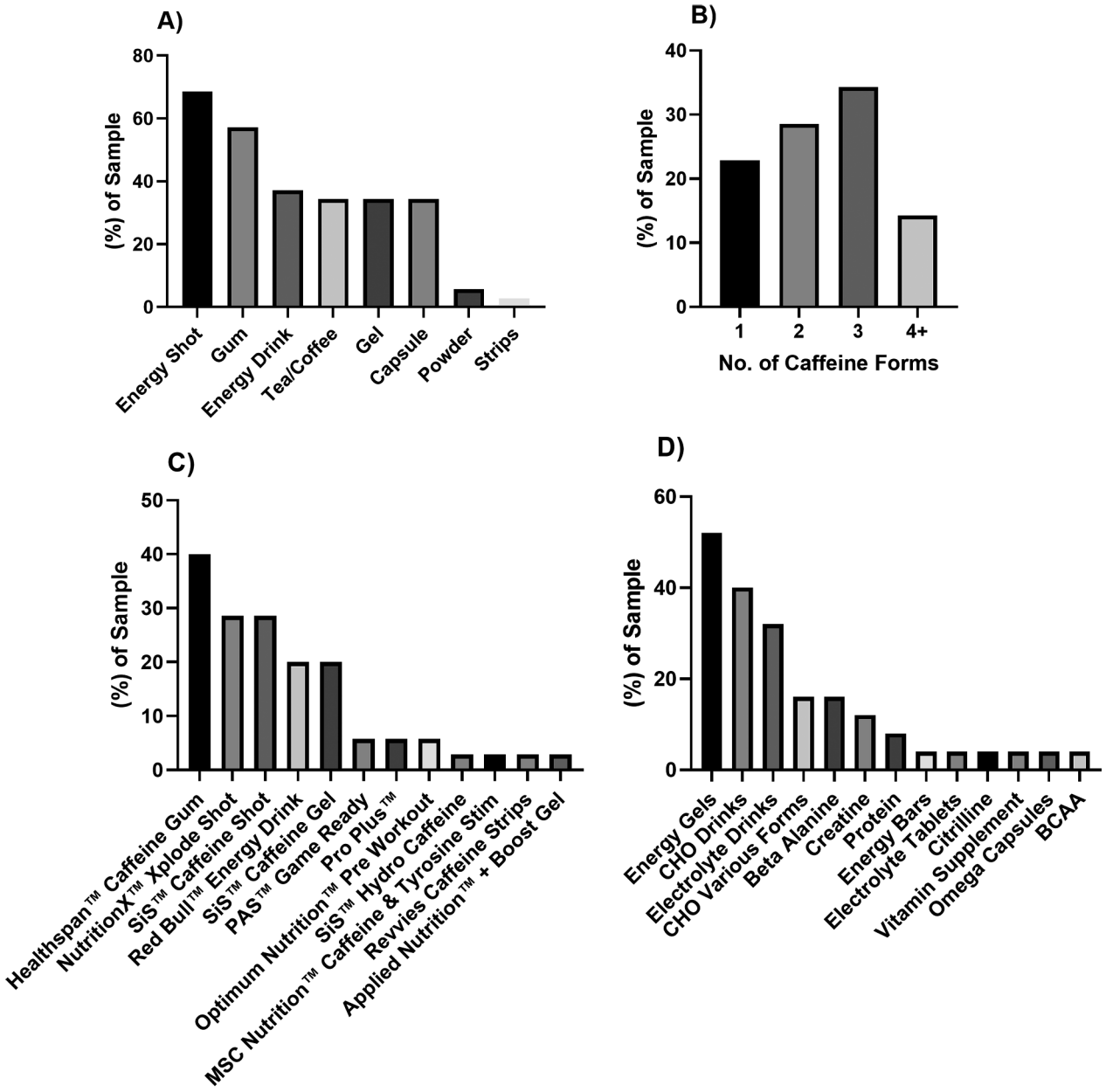

FIG. 2. A) Forms of caffeine consumption; B) Number of caffeine forms used; C) Caffeine products; D) Other supplements consumed with caffeine [Data represented as frequency of reported responses; A-B) N = 35; C) N = 25].

Prior to distribution, the survey was piloted by a group that were not involved with the study and the survey refined based on the responses and the feedback provided. The final survey was only available in English and was administered between May and November 2019. Those that opted to participate accessed the survey via a secure link sent in the recruitment email.

Data analysis

Descriptive data is reported and presented as response frequency. Key themes were distinguished from free-text questions, and the frequency of each theme displayed in the results.

RESULTS

Caffeine Use in Professional Soccer

Of the clubs sampled, 97% (N = 35) reported that they provide caffeine to players as a means of improving performance, with approximately half (N = 17) of clubs administering caffeine to players for a period greater than 3 years (Fig.1A). The decisions about providing caffeine are often based on current/previous colleagues using caffeine (N = 19; 54%), personal experience of using caffeine (i.e. with athletes or individually) (N = 16; 46%), research/scientific literature (N = 13; 37%) or online resources/forum (N = 12; 34%).

The data indicate that caffeine is most commonly administered prior to (> 94% of responses; Fig.1B) and during a game (> 48% of responses; Fig.1B), with the frequency largely uninfluenced by the time of day in which these events occur. Caffeine is less commonly supplemented to support training, but 37% of the clubs sampled (N = 13; Fig.1B) outlined that caffeine was used on some occasions prior to training. Timing of caffeine consumption before a game ranged between 15–90 minutes, with 30–45 minutes prior to kick-off being the most frequently used timing strategy (N = 14; 40%; Fig.1C).

Caffeine is administered via several forms with energy shots (N = 24, 68%) and caffeinated gum (N = 20, 57%) being the most popular (Fig.2A). Twenty-seven clubs (77%) indicated that they use more than one caffeine form, with 17 (49%) using more than three caffeine forms (Fig.2B). Caffeine is administered via 12 commercially available caffeine products, with Healthspan™ Elite Kick-Start Caffeine Gum (N = 14; 40%), NutritionX™ Xplode Shot (N = 10; 29%) and SiS™ Caffeine Shot (N = 10; 19%) being the most popular (Fig.2B.) Only 8 (23%) clubs monitored caffeine consumption beyond that prescribed. Thirty-one clubs (89%) indicated that not all players follow the same caffeine consumption strategy, and 11 clubs (31%) specified that the caffeine dose administered was not consistent across all time points. Eight clubs specifically outlined that caffeine consumption is optional and not compulsory. Three clubs (9%) indicated that players were educated/advised on the quantity of caffeine in the supplements provided.

There was a lack of consistency in the reported caffeine dose administered. Of the clubs that administered caffeine to players, 23 (66%) provided absolute doses, eight (23%) targeted a dose relative to body mass, and four clubs (11%) stated that the dose was unknown. The range of relative doses provided was between

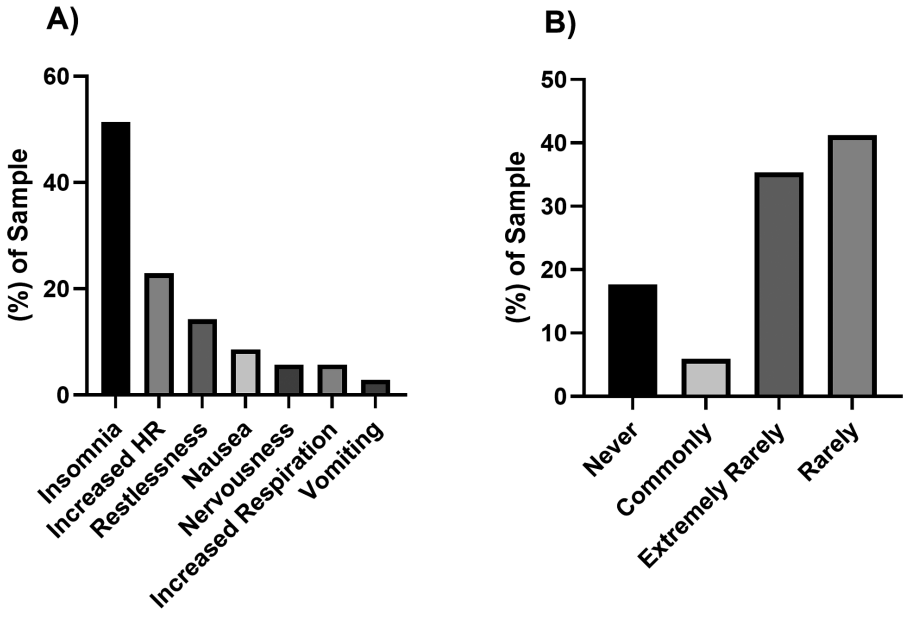

FIG. 3. A) Reported adverse effects of caffeine consumption; B) Frequency of reported adverse effects. [Data represented as frequency of reported responses; A) N = 35; B) N = 34].

2 mg.kg^{-1} and 6 mg.kg^{-1}, with 3 mg.kg^{-1} being the most common. The range of absolute doses provided was between 50 mg and 500 mg. Some clubs (N = 13; 39%) indicated that more than one absolute dose was provided, resulting in a sample of 38 data points. When data for all of the relative doses provided was considered, the most commonly administered absolute caffeine doses were 100 mg, 200 mg and 300 mg (N = 8; 21% in each case). Furthermore, 25 clubs (71%) stated that caffeine may be administered at the same time as other nutritional supplements, with 13 different supplement identified. Energy gels (N = 13; 52%), carbohydrate drinks (N = 10; 40%) and electrolyte drinks (N = 8; 32%) were the most frequently used supplements in conjunction with caffeine (Fig.2D).

Adverse Effects of Caffeine Consumption

Twenty-five clubs (71%) stated that players had reported adverse effects of caffeine consumption, with insomnia (N = 18; 53%) and an increased heart rate (N = 8; 24%) being most frequently cited (Fig.3A). However, reported side effects occurred rarely or extremely rarely (N = 25; 76%; Fig.3B).

Perception of Caffeine as a Performance Enhancer

Caffeine was perceived to be most beneficial for improving decision making, reaction time and reducing physical and mental fatigue, with over 70% of the sample (N > 25) indicating a moderate effect or greater for these facets of performance (Table 1). More than 50% of the sample perceived caffeine to have a moderate effect or greater on muscular power, endurance and sleep (Table 1). Twenty-two percent of the sample (N = 8), indicated that mental fatigue and sleep is extremely affected by caffeine ingestion (Table 1), the highest of all of the facets analysed. Eighty percent of the sample (N = 29) perceived caffeine to have a moderate effect or greater on vigour, whilst 44% (N = 16) perceived moderate effects or greater for confidence (Table 1).

DISCUSSION

The present study is the first to determine the prevalence, practices and perceptions of caffeine use as an acute performance enhancing nutritional supplement in professional soccer. Given the vast evidence exploring the performance enhancing benefit of caffeine, the study provides important information regarding the translation of research evidence into practice. These data indicate that caffeine use is widespread across the English professional soccer leagues with 35 of the 36 clubs sampled indicating that caffeine was administered as a method to improve soccer performance. Whilst caffeine is commonly administered prior to a match, 21 clubs provided caffeine to players during a game, and 13 clubs provided caffeine prior to some training sessions. Time of day (i.e. kick-off time) had only a limited influence on caffeine consumption strategy. There was little commonality regarding caffeine dose, mode of administration, and timing of consumption, with what would appear to be in most cases an individual self-prescribed strategy preferred. These results do not necessarily infer a lack of application of the published evidence, but potentially a lack of research that specifically considers the demands and constraints of using caffeine as a nutritional supplement in soccer.

The prevalence of caffeine use in soccer is not particularly surprising, given its well documented performance enhancing effects [1].

TABLE 1. Perception of caffeine effects on performance facets important for soccer match play and mood

	Unsure (N =)	Not at all (N =)	A little (N =)	Moderately (N =)	Quite a bit (N =)	Extremely (N =)
Muscular Power	2 (5.6%)	6 (16.7%)	10 (27.8%)	6 (16.7%)	12 (33.3%)	0 (0%)
Endurance	1 (2.8%)	1 (2.8%)	9 (25.0%)	4 (11.1%)	16 (44.4%)	5 (13.9%)
Decision Making	0 (0%)	3 (8.3%)	7 (19.4%)	11 (30.6%)	13 (36.1%)	2 (5.6%)
Reaction Time	0 (0%)	0 (0%)	7 (19.4%)	8 (22.2%)	14 (38.9%)	7 (19.4%)
Physical Fatigue	1 (2.8%)	3 (8.3%)	4 (11.1%)	10 (27.8%)	11 (30.6%)	7 (19.4%)
Soccer Specific Skills	3 (8.3%)	12 (33.4%)	10 (27.8%)	4 (11.1%)	7 (19.4%)	0 (0%)
Recovery	5 (13.9%)	18 (50.0%)	7 (19.4%)	1 (2.8%)	3 (8.3%)	2 (5.6%)
Mental Fatigue	0 (0%)	1 (2.8%)	7 (19.4%)	9 (25.0%)	11 (30.6%)	8 (22.2%)
Sleep	0 (0%)	11 (30.6%)	4 (11.1%)	2 (5.6%)	11 (30.6%)	8 (22.2%)
Tension	6 (16.7%)	17 (47.2%)	7 (19.4%)	4 (11.1%)	1 (2.8%)	1 (2.8%)
Anger	7 (19.4%)	16 (44.4%)	6 (16.7%)	5 (13.9%)	1 (2.8%)	1 (2.8%)
Confidence	6 (16.7%)	9 (25.0%)	5 (13.9%)	10 (27.8%)	5 (13.9%)	1 (2.8%)
Vigour	0 (0%)	1 (2.8%)	6 (16.7%)	7 (19.4%)	14 (38.9%)	8 (22.2%)

[Data represented as frequency of reported responses; N = 36]

Previous work has indicated that up to 73.8% of national and international athletes consume caffeine prior to competition [11], with consumption typically influenced by sport and level of competition [20]. Del Coso et al. [11] demonstrated a mean post event urine caffeine concentration of ~1.40 μg.ml^{-1} in a sample of 2691 soccer players, indicative of low dose caffeine consumption. However, data from the present study is the first to document prevalence and practices around caffeine use in soccer. Despite evidence suggesting that caffeine may be beneficial for team sports [2, 3], there are few studies that determine the effect of caffeine on complex and ecological soccer-specific tests [13] resulting in limited knowledge in optimal caffeine consumption strategies. This is particularly evident by the varied approaches to caffeine consumption outlined in the results of the present study.

The data provided highlight an important gap in the literature with respect to not only the timing of caffeine consumption for relatively long duration intermittent intensity sports, but also the value of a multiple dosing strategy. The time of caffeine consumption prior to a match ranged between 15–90 minutes, and was most commonly consumed 30–45 minutes prior to kick-off. Evidence indicates that peak blood plasma concentration typically occurs 60 minutes post ingestion [21], so the administration times outlined in the present study would appear to be appropriate for achieving peak blood plasma concentration at some point during a match. However, if the magnitude of the ergogenic effect varies with respect to peak blood plasma concentration, time of ingestion could potentially influence where within a game the maximal benefit occurs. Despite high individual variability in caffeine half-life, typically between 2.5–10 hours [22], there is limited evidence outlining the duration that caffeine elicits a beneficial effect. Negaresh et al [23] demonstrated that 10 mg.kg^{-1} caffeine improved performance on the Pittsburgh Wrestling Performance Test 45 minutes post ingestion, but no effects were seen when re-assessed at 90, 135, 180 and 360 minutes post ingestion. Interestingly, there was evidence to suggest that dividing the dose over the course of the event may provide greater benefit over the time course of the protocol. Whilst this variation in response may, in-part, be attributed to adverse effects of high dose single bolus caffeine consumption, it is not possible to rule out the potential for superior effects of a divided dose. As such, these results infer a need to optimise consumption timing and possibly, a need for repeat dosing. Furthermore, alternative forms of caffeine administration, such as caffeinated gum, have been demonstrated to evoke an increase in performance 5–10 minutes after consumption [24, 25], thus use of gum 30–45 minutes prior to game may result in the peak benefit occurring prior to the start of competition. Whilst in the context of team sports such as soccer, it may be more appropriate to provide a standardised caffeine consumption timing strategy, recent evidence indicates that effective caffeine dosing strategies are likely to be susceptible to large individual variability attributed, in part, to genetic predisposition to be either a fast or slow caffeine metaboliser [26]. Nearly half of the clubs sampled outlined that caffeine was administered at half-time, which may prove beneficial for enhancing performance in the latter stage of a match. Another substantial gap in the caffeine literature pertains to the understanding of multiple/divided doses of caffeine on exercise performance [27]. As such, there is no empirical evidence to support that multiple caffeine doses will be effective for soccer.

Thirty-one clubs (89%) indicated that not all players follow the same caffeine consumption strategy, with responses to open ended questions indicating an individual approach based on players preference and tolerance. As a result, there was large variation in the caffeine doses consumed. Only 7 clubs (21%) targeted a dose relative to body mass of typically 3 mg.kg^{-1} (range 2–6 mg.kg^{-1}), whilst players from 22 (67%) clubs consumed absolute doses of typically 100 mg, 200 mg and 300 mg (range 50–500 mg). It is widely considered that 3 mg.kg^{-1} represents a minimum dose to elicit effects on physical performance [28], and is typically the minimum dose demonstrated to elicit an effect on soccer specific exercises [13]. More recently, a small number of studies have suggested that doses lower than 3 mg.kg^{-1} may be beneficial for acutely improving components of physical fitness [29–31], though this is not always the case [29, 32, 33]. Evidence examining the effects of low dose caffeine is lacking and is yet to be robustly considered specifically in soccer. As such, it is not yet clear if absolute doses < 200 mg provided by many clubs is beneficial for physical performance. However, there is a more robust body of evidence indicating that lower doses of caffeine may be beneficial for cognitive function [8], where caffeine has been demonstrated to provide benefits for attention, vigilance and reaction-time [8]. Only eight clubs monitored caffeine consumption beyond that prescribed, and four clubs indicated that dose of caffeine consumed by players was unknown, highlighting a need for closer monitoring given the adverse effects associated with high dose caffeine consumption [17, 34].

Data in the present study further indicate large variation in the mode of caffeine administration, with caffeine being consumed in several forms and clubs using a combination of multiple forms. Whilst the use of caffeine drinks and capsules was common, and are commonly used methods of consumption in published literature denoting positive caffeine effects [12, 33, 35], evidence for the effectiveness of caffeinated gum, gel and caffeine strips is far less well established [12], and rarely considered with respect to soccer specific exercise. Caffeine gum was the second most popular mode of consumption and only relatively recently has this been considered in the published literature [24, 25]. The mechanisms by which caffeine gum and strips elicit a performance enhancing response may differ to that of typical caffeine ingestion, with evidence demonstrating a faster rate of absorption through the highly vascularised buccal mucosa [12], resulting in a quicker biological response. There is limited evidence to indicate if alternative forms of caffeine consumption are equivalent, and no evidence inferring the potential benefits of combining modes of administration. In addition, the data indicate that caffeine is typically consumed with a broad range of other

nutritional supplements. The effect of caffeine in combination with other performance enhancing nutritional supplements is yet to be robustly considered.

Although less frequently than during matches, a number of clubs (37%) provided caffeine to players as a nutritional strategy to support training. Whilst acute caffeine consumption may evoke greater work in training, which may theoretically translate into an enhanced training response, there is a distinct dearth of evidence examining the effectiveness of chronic caffeine consumption to support training induced physiological adaptions. What may result from chronic caffeine use is habituation to caffeine's performance enhancing effects. Whilst this is a point of contention, there is evidence to suggest chronic caffeine consumption can result in tolerance and a subsequent reduction in any beneficial effects [36, 37]. Having evidence of these effects specifically in soccer would help to further develop guidelines to optimise caffeine consumption strategies.

Despite the well reported beneficial effects, a number of adverse effects of caffeine consumption have been established [17, 34]. Although reported to occur rarely in the current sample, twenty-five clubs (71%) indicated that players had reported adverse effects of caffeine consumption. It is likely that the subjective approach to caffeine dosing used by many clubs is an effective strategy in managing individual caffeine tolerance, given that adverse effects are associated with much higher doses (> 9 $mg.kg^{-1}$; 675 mg in a 75 kg player) than reported to be consumed in the present study [38, 39]. Despite this, it should be considered that adverse effects maybe underreported without the use of an explicit assessment strategy imposed by the club. Insomnia was the most frequently reported side effect (N = 18; 51%) and more than 50% of the sample perceived caffeine to have a moderate effect or greater on sleep. Despite this, there was little evidence of a change in caffeine consumption strategy prior to an evening game, with one respondent commenting "performance boosting" was the priority with respect to post-match sleep habits. The effects of caffeine on sleep have been well reported, with evidence suggesting an increase in sleep latency and a reduction in sleep duration when caffeine is consumed in the evening [40, 41]. Such effects may therefore present a trade-off between a caffeine induced improvement in exercise performance and acute changes in the duration and quality of sleep. This may present a problem for professional athletes given that both chronic and acute sleep loss are recognised as being detrimental to sports performance and exercise recovery [42, 43].

Given the distinct lack of published evidence on this topic, it is difficult to determine if/how effective current caffeine consumption habits in professional soccer are for eliciting a performance enhancing benefit. However, the power of individual choice around dose and mode may be effective in itself in inducing a performance enhancing effect. There is now a solid foundation of evidence indicating that caffeine expectancy (i.e. one's belief that the substance they consume will be ergogenic) alone can be effective in inducing a performance enhancing repose [44]. This has recently been evidenced for soccer where Shabir, Hooton [45] demonstrated that caffeine expectancy was beneficial for improving performance in a simulated soccer assessment.

Limitations & Future Direction

Although this study adds much needed insight in to the prevalence and practices of caffeine use in professional soccer, it is not without limitations. This study uses a sample of teams from the top four professional soccer divisions in England, and whilst this may provide a good insight into caffeine use in professional soccer globally and the challenges presented, further work is needed to understand if the trends in England correspond the global trends, where access to and restrictions around caffeine use may be different. One of the clubs sampled indicating that caffeine was not prescribed to players, however the survey did not account for self-prescribed caffeine in this instance. Whilst the data provides important insight with respect trends in caffeine use, reported adverse effects and the perceived benefits specific to the demands of soccer, obtaining this information directly from players would be useful to provide further insight with respect to caffeine consumption habits and beliefs at the individual level. It was not possible to obtain individual player data in this study.

The present study offers unique insight into the use of caffeine in professional soccer which also helps identify key future work in order to develop optimal strategies for caffeine use. Based on the results from the present study, the following are identified as areas of priority. Future work should consider:

- Investigating the effect of acute and chronic caffeine supplementation considering different caffeine forms and multiple dosing strategies using exercise modalities that better replicate the demands of soccer.
- Investigating the effectiveness of low dose caffeine (i.e. < 3 $mg.kg^{-1}$) on soccer specific performance.
- Investigating the use of caffeine as a chronic nutritional supplement to support training, the potential for habituation, and strategies for overcoming this.
- Understanding how time of day influences the ergogenic effect of caffeine on soccer performance and consideration of the interaction between caffeine effects on performance and subsequent sleep and recovery.
- Examining the synergistic effect of caffeine with other reported nutritional ergogenic aids.

CONCLUSIONS

The present study is the first to determine the prevalence and perceptions of caffeine use as an acute performance enhancing nutritional supplement in professional soccer, indicating its wide spread use in the professional English leagues and a broad range of practices with respect to caffeine administration. Despite the wealth of published evidence outlining the effect of caffeine on physical and cognitive function, the application of these findings to practice is poor. This is principally due to a lack of research studies explicitly considering the

demands of the game and the range of influencing factors that dictate caffeine administration. For the first time, this work provides some insight into these challenges and identifies important areas of future work needed to better understand how caffeine consumption can be optimised to elicit the greatest performance enhancing effects.

Disclosure statement

The authors report no conflict of interest.

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SUPPLEMENTARY ONLINE MATERIAL

Appendix 1. Survey Map

Appendix 2. Survey Questions [link]