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Chess and eSports Nutrition: Dietary Habits, Lifestyles and Hydration Status

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Nutrição no Xadrez e eSports: Hábitos Dietéticos, Estilos de Vida e Estado de Hidratação

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Os seguintes manuscritos fazem parte desta tese:

I. [Full Article] Ribeiro, Fernando J., et al. The Emergence of eSports Nutrition: A Review. (2021). Cent. Eur. J. Sport Sci. Med. Vol. 33, No. 1/2021: 81–95; https://doi.org/10.18276/cej.2021.1-08

II. [Full Article] Ribeiro, Fernando J., and Rui Poínhos. Nootropic Supplements for esports: A Scoping Review. (2023). Int. J. Vitam. Nutr. Res. https://doi.org/10.1024/0300-9831/a000790

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IV. [Full Article] Ribeiro, Fernando J., and Rui Poínhos. Sociodemographics, playing Habits, adherence to the Mediterranean dietary pattern, dietary supplements intake, physical activity level, and degree of Internet gaming disorder of Portuguese chess players (2024). Rev. Esp. Nutr. Hum. Diet. https://doi.org/10.14306/renhyd.28.2.2075

V. [Full Article] Ribeiro, F.J.; Teixeira, R.; Poínhos, R. Dietary Habits and Gaming Behaviors of Portuguese and Brazilian Esports Players (2023). Nutrients. https://doi.org/10.3390/nu15194200

VI. [Full Article] Hydration Status of Portuguese Esports Players in a Live Competition (Accepted for publication in *Science & Sports* - Elsevier)

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List of Abbreviations

FCNAUP - Faculty of Nutrition and Food Sciences of the University of Porto (Faculdade de Ciências da Nutrição e Alimentação da Universidade do Porto, in Portuguese)

BMI - Body Mass Index

DM - Dieta Mediterrânica

DP - Desvio Padrão

DS - Dietary Supplements

FPS - First-person shooter

IGD - Internet Gaming Disorder

IMC - Índice de Massa Corporal

IOC - International Olympic Committee

MD - Mediterranean Diet

PREDIMED - Prevención con Dieta Mediterránea

SD - Standard Deviation

Declarations

Declaro solenemente que, com o apoio e supervisão da minha equipa de orientação, sou o autor principal de todos os artigos que constituem esta tese. Fui o responsável pela conceção deste projeto, pelo desenvolvimento e aplicação da metodologia, pela recolha, tratamento, organização e análise de dados, bem como pela escrita, preparação e submissão dos manuscritos para publicação em revistas científicas.

Para os devidos efeitos, informa-se que a equipa de orientação inicialmente associada a este projeto de doutoramento incluía o Prof. Doutor Vítor Hugo da Costa Gomes Moreira Teixeira da FCNAUP como orientador, e o Prof. Doutor Víctor Manuel da Conceição Viana, e Prof. Doutor Nuno Pedro Garcia Fernandes Bento Borges, também da FCNAUP, como coorientadores. Estes professores figuram como coautores do artigo “The Emergence of eSports Nutrition: A Review”. Mais tarde, e por comum acordo, a equipa de orientação passou a ser constituída em exclusivo pelo Prof. Doutor Rui Manuel Almeida Poínhos, da FCNAUP, com a participação do qual foram desenvolvidos os 5 restantes artigos incluídos nesta tese.

Declaração de conflito de interesses: O autor e o seu orientador declaram que são os responsáveis pelo conteúdo e redação dos trabalhos aqui apresentados, e que não receberam financiamento, nem têm conflitos de interesse a declarar.

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"*What we know is a drop, what we don't know is an ocean*"

Isaac Newton

Abstract

The popularity of esports has grown dramatically in recent years and is expected to rise more in the future. At the same time, there has been an increase in the number of dietary supplement (DS) companies, as well as others associated with the fast food, alcoholic beverages, and energy drinks industry, which sponsor esports events, teams, and competitors and, in this way, they promote inadequate dietary habits in this population and in the audience that attends eGaming events. Young adults can be considered a nutritionally vulnerable population as they display a significant degree of dietary inadequacy. Furthermore, esports players may fail to prepare for competitions in a professional manner, neglecting many aspects of their lifestyle relating to health and cognitive performance. These include adhering to a healthy dietary pattern and DS regimen conducive to optimal health and maintenance of high cognitive performance during training and competition.

Traditionally, sports nutrition research has focused on the more physically demanding sports. However, other sports and competitive activities, highly reliant on cognitive abilities, such as chess and esports, have received less attention. Because of the notorious absence of published research in this area regarding nutrition sciences, there was a need to characterize the dietary habits of esports competitors, including the possible use of DS and their nutritional status. Simultaneously, we attempted to determine whether competitive video game practice is significantly related to these parameters. Until the beginning of this doctorate, no work of this kind had been conducted in Portugal, and this research added scientific knowledge to an area that is rapidly expanding as a growing number of individuals get involved in the world of esports.

Initially, a literature review was conducted on the existing nutritional strategies that could improve health and cognitive performance, decrease reaction time, and minimize fatigue in young adults (Paper I). This work yielded the following general recommendations: a) Maintain an appropriate weight for height; b) Follow a high-quality, low-glycemic index, nutritious, antioxidant-rich diet; c) Limit the intake of fat, especially saturated fatty acids and avoid the intake of trans fat; d) Avoid and correct possible vitamin and mineral deficits; e) Maintain an adequate state of hydration, especially before competitions; f) Maintain a regular eating pattern and do not omit breakfast; g) Have a light meal at lunch to minimize the negative effects of the post-lunch dip on cognition; h) Avoid the consumption of alcoholic beverages; i) Consider the sensible coffee intake.

Subsequently, a scoping review was conducted to identify studies that have tested the effects of DS in video game players (Paper II). Sixteen studies were outlined. Of ten studies that included caffeine (40 to 200 mg), four reported positive effects on cognition (attention, processing speed, and working memory), two on FPS performance (reaction time, accuracy of hit, time to hit 60 targets), and one about the score of the Tetris game. All three studies that included arginine silicate (1500 mg) reported improvements in one or more aspects of cognition (reaction time, attention, visual representation, and spatial planning). Neither of the two studies that tested sucrose (21 and 26.8 g) reported significant improvements, while one study that tested the administration of 26.1 g of glucose described positive effects on processing speed and sustained attention. It was concluded that the literature published so far has focused on the effects of caffeine, which can have both positive and negative effects on esports players.

An additional scoping review concerning the dietary habits of esports players was performed (Paper III). A systematic search was carried out in the main bibliographic databases. Seventeen relevant publications were identified, which surveyed a total of 8,760 esports players. Nine studies assessed caffeinated drinks intake, eight characterized alcohol consumption, six described fruit and vegetables, and four evaluated the consumption of dietary supplements. It was concluded that the quality of the diet of esports players may be inadequate and may ingest fewer servings of fruits and vegetables than non-gamers. Furthermore, caffeine consumption appears vulgarized in this population.

Subsequently, and through the application of an online survey, the consumption of DS, the level of adherence to the Mediterranean diet (MD), and the predictors of adherence to this diet style in chess players were characterized, including demographic data, game characteristics, degree of internet gaming disorder (IGD) and physical activity level (Paper IV). From the responses of 192 participants (93.8% men), the majority had completed higher education (mean = 15.1 years, SD = 1.7), averaged 41 years (SD = 14), a body mass index (BMI) of 26.2 kg/m² (SD = 4.3) and 20.8% (n = 40) had a low level of physical activity. 24.5% (n = 47) showed low adherence and 58.9% (n = 113) moderate adherence to the MD pattern. 30.2% ingested one or more DS in the last 12 months. Multivitamin-mineral complexes were the most consumed (41.4%), followed by whey protein (31.0%). The main reasons for using DS were to increase energy/decrease fatigue and for health reasons (44.8% each). In this paper, we theorized that the more dedicated chess players may be less concerned about maintaining a balanced diet as higher Elo scores were associated with higher consumption of red/processed meat, lower adherence to the MD, lower consumption of fish/shellfish, and a higher volume of chess playing was associated with higher consumption of confectionery and sweets.

Another online survey was applied to Portuguese and Brazilian esports players to characterize their dietary habits, including the level of adherence to the MD, consumption of DS, and the degree of IGD, as well as determining the possible existence of associations between the level of adherence to the MD and other lifestyle-related variables (Paper V). The 588 participants included were predominantly male (91.4%), with a mean age of 26.1 (SD = 7.0) years, BMI of 26.0 (SD = 6.8) kg/m^2, 13.6 (SD = 2.3) years of schooling, 4.4 (SD = 3.2) hours of video gaming per day, a total IGD score of 18.9 (SD = 6.8), consumption of 178.7 (SD = 208.5) mg of caffeine and 2.5 (SD = 1.9) servings of fruits and vegetables/day. Most reported poor (53.7%) or moderate to regular (42.7%) adherence to the MD on the PREDIMED scale. 23.0% stated they never eat breakfast. 32.3% consumed DS, mainly whey protein (59.4%), creatine (47.1%), caffeine (33.2%), and multivitamins/minerals (30.5%), mainly to improve sports performance (84.5%), preventing/treating injuries or diseases (58.8%), and optimizing cognitive performance (56.7%). Our sample presented a low adhesion to the MD, low compliance to the WHO recommended amount of vegetables and fruit, and high consumption of fast food, red and processed meats, soft drinks, and DS, including caffeine. Consumption of DS correlated with higher adherence to the MD and a higher degree of professionalization and IGD were associated with lower adherence. It was inferred that Portuguese and Brazilian esports players follow a lower-quality dietary pattern than the reference populations.

Given the importance of hydration to health and cognitive performance, the hydration status of esports players on competition day was assessed through the specific gravity of urine (g/cm^3) and by comparison with the Armstrong urine color scale, as well as the possibility of associations between hydration status and lifestyle-related variables was studied (Paper VI). Ninety-eight esports players participated in this study. The mean value of urine specific gravity, assessed by refractometry was 1.020 (SD = 0.007). 10.2% classified as euhydrated, 25.5% with minimal hypohydration, 60.2% with significant hypohydration, and 4.1% with severe hypohydration. The mean value for the 8-color scale method was 5.5 (SD = 1.1). 4.1% were classified as well hydrated, 77.6% as slightly dehydrated, and 18.4% as dehydrated. There were no significant associations between hydration status and lifestyle-related variables. This study revealed that about two-thirds of esports players were dehydrated on competition days, which is significantly higher than what was recorded in a reference population. It was concluded that, in collaboration with esports organizations, strategies should be developed to inform esports players about the importance of fluid balance for optimal health and cognitive performance. Given the lack of significant associations between lifestyle-related characteristics and hydration status, these awareness campaigns ought to be directed towards all esports players, rather than just one specific subset.

The scientific data produced in the context of this doctorate project represent scientific evidence on which nutritionists and other health professionals involved in esports can base their professional practice. It may also support the development of health promotion strategies to optimize dietary habits and DS protocols and consequently, the health and cognitive performance of players.

Keywords: video games, esports, chess, nutritional status, nutrition, Mediterranean diet, dietary supplements, nootropics, caffeine, hydration, cognitive performance, PREDIMED, internet gaming disorder, IGDS9, IPAQ.

Resumo

A popularidade dos jogos de vídeo tem vindo a crescer de forma exponencial ao longo dos últimos anos e espera-se que a sua popularidade continue a aumentar no futuro. Ao mesmo tempo, tem-se observado um aumento do número de empresas de suplementos alimentares, bem como de outras, associadas à indústria alimentar de *fast-food*, das bebidas alcoólicas e bebidas energéticas, que patrocinam eventos, equipas e competidores de *esports* e, deste modo, promovem hábitos alimentares e de nutrição inadequados nesta população e no público que assiste aos eventos de eGaming. De referir que os jovens adultos podem ser considerados uma população nutricionalmente vulnerável por apresentarem um grau significativo de inadequação alimentar. Para além disso, e apesar do elevado nível competitivo a que se sujeitam, os jogadores de *esports* poderão falhar em preparar-se para as competições de uma forma profissional, negligenciando diversos aspetos do estilo de vida relacionados com a saúde e o desempenho cognitivo. Este incluem a adesão a um padrão alimentar e regime de suplementação saudáveis, conducentes a um estado de saúde ótimo e à manutenção de um elevado desempenho cognitivo no decorrer de treinos e competições.

Tradicionalmente, a investigação na área da nutrição no desporto tem-se focado nos desportos mais intensos a nível físico, tal como o futebol, atletismo, etc. Entretanto, outros desportos e atividades competitivas, mais dependentes de capacidades cognitivas, tais como o xadrez e os *esports*, têm recebido menos atenção.

Sendo evidente a escassez de trabalhos científicos relacionados com as ciências da nutrição nesta área, entre outros aspetos prioritários, constatou-se a necessidade de caracterizar os hábitos alimentares e a ingestão nutricional de praticantes de *esports*, inclusive o possível uso de suplementos alimentares e também caracterizar o seu estado nutricional. Ao mesmo tempo procurou-se compreender se a prática competitiva de jogos de vídeo exerce uma influência significativa nesses parâmetros.

Até ao início deste doutoramento ainda não havia sido realizado nenhum trabalho do género, em Portugal, e este trabalho de investigação acrescentou conhecimento científico a uma área em rápida expansão, à medida que um número crescente de indivíduos se envolve no mundo dos *esports*.

Inicialmente, conduziu-se uma revisão da literatura científica relativa a estratégias nutricionais que pudessem melhorar a saúde, o desempenho cognitivo, diminuir o tempo de reação e

minimizar a fadiga em jovens adultos (Manuscrito I). Desse trabalho resultou um conjunto de recomendações gerais: a) Manter um peso adequado para a altura; b) Seguir uma dieta de alta qualidade, de baixo índice glicémico, nutritiva e rica em antioxidantes; c) Limitar a ingestão de gordura, sobretudo de ácidos gordos saturados e evitar a ingestão de gordura trans; d) Evitar e corrigir possíveis défices vitamínicos e minerais; e) Manter um estado de hidratação adequado, sobretudo antes das competições; f) Manter um padrão alimentar regular e não omitir o pequeno-almoço; g) Fazer uma refeição leve ao almoço para minimizar os efeitos negativos da sonolência pós-prandial na cognição; h) Evitar o consumo de bebidas alcoólicas; i) Considerar a ingestão adequada de café.

Seguidamente, conduziu-se uma revisão de escopo com o propósito de identificar e reunir a informação relativa a suplementos alimentares cujos efeitos tivessem sido testados em jogadores de jogos de vídeo (Manuscrito II. Foram encontrados dezasseis estudos. De dez estudos que incluíram a cafeína (40 a 200 mg), quatro reportaram efeitos positivos na cognição (atenção, velocidade de processamento, e memória de trabalho), dois no desempenho de jogos de tiro na primeira pessoa (tempo de reação, precisão de tiro, tempo para acertar em 60 alvos) e um sobre a pontuação no jogo Tetris. Os três estudos que incluíram silicato de arginina (1500 mg) relataram melhorias em um ou mais aspetos da cognição (tempo de reação, atenção, representação visual e planeamento espacial). Nenhum dos dois estudos que testaram hidratos de carbono (21 e 26,8 g) reportaram melhorias significativas, enquanto um estudo que testou a administração de 26,1 g de glicose registou efeitos positivos na velocidade de processamento e atenção sustentada. Concluiu-se que a literatura publicada até ao momento focou-se nos efeitos da cafeína, que pode exercer efeitos positivos em jogadores de *esports*, sobretudo os do género “jogos de tiro”, mas também poderá ter efeitos negativos.

Subsequentemente, foi desenvolvida uma revisão de escopo dedicada à caracterização dos hábitos alimentares de jogadores de *esports* (Manuscrito III). Foi conduzida uma pesquisa sistemática nas principais bases de dados bibliográficas. Foram encontradas dezassete publicações relevantes, as quais incluíram um total de 8760 jogadores de *esports*. Nove estudos avaliaram a ingestão de bebidas com cafeína, oito caracterizaram o consumo de álcool, seis descreveram o consumo de frutas e vegetais e quatro avaliaram o consumo de suplementos alimentares. Verificou-se que a qualidade da dieta dos jogadores de *esports* pode ser inadequada, registando-se em vários casos um menor consumo de frutas e vegetais do que os não jogadores. Além disso, o consumo de cafeína parece proeminente nesta população.

Posteriormente, e através da aplicação de um inquérito *online*, caracterizou-se o consumo de suplementos alimentares, o nível de adesão à dieta mediterrânica (DM) e os preditores de adesão a este tipo de regime alimentar em jogadores de xadrez, incluindo dados demográficos, características de jogo, grau de transtorno de jogo pela internet e nível de atividade física (Manuscrito IV). Neste trabalho verificou-se que dos 192 participantes (93,8% homens), a maioria havia concluído o ensino superior (média = 15,1 anos, DP = 1,7), tinha uma idade média de 41 anos (DP = 14), um índice de massa corporal (IMC) médio de 26,2 kg/m² (DP = 4,3) e 20,8% (n = 40) apresentavam baixo nível de atividade física. 24,5% (n = 47) apresentaram uma adesão baixa e 58,9% (n = 113) uma adesão moderada ao padrão alimentar mediterrânico. 30,2% admitiram o uso de um ou mais suplementos alimentares nos últimos 12 meses. Os complexos multivitamínico-minerais foram os mais consumidos (41,4%), seguido pela proteína whey (31,0%). Os principais motivos reportados para o uso de suplementos alimentares foram: aumentar a energia/diminuir a fadiga e, por razões relacionadas com a saúde (44,8% cada). Neste artigo, teorizamos que os jogadores mais dedicados poderão estar menos preocupados em manter uma dieta equilibrada, uma vez que *scores* Elo mais elevados foram associados a um maior consumo de carne vermelha/processada, a uma menor adesão à DM, a um consumo mais baixo de peixe/marisco, e um maior volume de jogo de xadrez associou-se a um maior consumo de produtos de confeitaria e doces.

Em seguida, foi também aplicado um inquérito *online* a jogadores de *esports* portugueses e brasileiros com o propósito de caracterizar os seus hábitos alimentares, incluindo o nível de adesão à DM, o consumo de suplementos alimentares e o grau de transtorno de jogo pela internet, bem como determinar a possível existência de associações entre o nível de adesão à DM e as restantes variáveis (Manuscrito V). Os 588 participantes incluídos eram predominantemente do sexo masculino (91,4%), com uma média de 26,1 (DP = 7,0) anos, IMC de 25,9 (DP = 5,5) kg/m^2, 13,6 (DP = 2,3) anos de estudo, 4,4 (DP = 3,2) horas de jogo de vídeo por dia, uma pontuação total de transtorno de jogo pela internet de 18,9 (DP = 6,8), consumo de 178,7 (DP = 208,5) mg de cafeína e 2,5 (DP = 1,9) porções de frutas e vegetais/dia. A maioria apresentou um nível de adesão fraca (53,7%), ou moderada a regular (42,7%) à DM na escala PREDIMED. 23,0% referiram nunca tomar o pequeno-almoço. 32,3% reportaram o consumo de suplementos alimentares, principalmente proteína de soro do leite (59,4%), creatina (47,1%), cafeína (33,2%) e de complexos multivitamínicos/minerais (30,5%), sobretudo com o objetivo de melhorar o rendimento desportivo (84,5%), prevenir/tratar lesões ou doenças (58,8%), e otimizar o desempenho cognitivo (56,7%). Em comparação com uma população de referência, esta amostra de jogadores de *esports* apresentou uma menor adesão ao padrão alimentar mediterrânico, menor consumo de frutas e vegetais e maior consumo de *fast food*, carnes vermelhas e processadas, refrigerantes e também de suplementos alimentares, incluindo cafeína. O consumo de suplementos dietéticos correlacionou-se com uma maior adesão à DM, e um maior grau de profissionalização e de transtorno de jogo pela internet associaram-se a uma menor adesão. Inferiu-se que os jogadores de *esports* portugueses e brasileiros seguem um padrão alimentar de qualidade inferior ao das populações de referência.

Atendendo à influência que o estado de hidratação tem na saúde e no desempenho cognitivo, avaliou-se também o estado de hidratação de jogadores de *esports* em dia de competição através da gravidade específica da urina (g/cm^3) e por comparação com a escala de cores da urina de Armstrong, bem como a possível existência de associações entre o estado de hidratação e variáveis relacionadas com o estilo de vida (Manuscrito VI). Neste estudo participaram 98 jogadores de *esports*. O valor médio de gravidade específica da urina, avaliado por refratometria foi de 1,020 (DP = 0,007). 10,2% dos participantes foram classificados como euidratados, 25,5% apresentaram hipoidratação mínima, 60,2% hipoidratação significativa e 4,1% hipoidratação grave. O valor médio para o método da escala de oito cores foi de 5,5 (DP = 1,1). 4,1% foram classificados como bem hidratados, 77,6% como levemente desidratados e 18,4% como desidratados. Não se encontraram associações significativas entre o estado de hidratação e variáveis relacionadas com o estilo de vida. Este estudo revelou que cerca de dois terços dos jogadores de *esports* se encontravam desidratados em dia de competição. Um valor bastante superior ao registado numa população de referência. Concluiu-se que, em colaboração com organizações de *esports*, deveriam ser desenvolvidas estratégias para informar os jogadores de *esports* acerca da importância da manutenção de hábitos alimentares adequados para uma saúde e desempenho cognitivo ótimos.

Os dados científicos produzidos no contexto deste projeto de doutoramento representam uma base de evidência científica na qual os nutricionistas e outros profissionais de saúde envolvidos nos *esports* poderão basear a sua atuação profissional. Poderá ainda servir como suporte para o desenvolvimento de estratégias de promoção da saúde para otimizar os hábitos alimentares, os protocolos de suplementação dietética e, consequentemente, a saúde e o desempenho cognitivo dos jogadores de *esports*. Dada a ausência de associações significativas entre características relacionadas com o estilo de vida e o estado de hidratação, essas estratégias de sensibilização devem ser direcionadas para todos os jogadores de *esports*, e não apenas para um subconjunto específico.

Palavras-chave: jogos de vídeo, *esports*, xadrez, estado nutricional, nutrição, dieta mediterrânica, suplementos alimentares, nootrópicos, cafeína, hidratação, desempenho cognitivo, PREDIMED, internet gaming disorder, IGDS9, IPAQ.

1. Introduction

The human brain's greater relative weight compared to other large mammals, the higher number of cortical neurons, as well as structural and functional specializations in the prefrontal cortex, seem to have contributed to the higher information processing capacity and exceptional intelligence of humans compared to other mammals.[1] For thousands of years, humans have exercised their cognitive abilities in competitions with others and created a variety of "intelligence games" or "mental sports" that rely on cognitive ability. Examples include the game Go, invented in China over 2500 years ago,[2] and chess, which appeared about 1500 years ago, and has survived to the present day.[3]

More recently, in the 1970s, a variety of games began to be developed in digital form (video games), together with the emergence, development, and popularization of arcade cabinets, personal computers, and eventually, beginning in the 1980s, video game consoles.[4,5] The first organized competition of video games of significant dimension was the “Atari’s Space Invaders Championship” which took place in 1980 and had the participation of more than 10,000 players.[6] From 1990 on, there was a rapid expansion of the internet and the development of hardware and software systems that, by offering support for competitions over long distances and the participation of players from almost all over the world, supported the birth and the growing popularization of multiplayer video game competitions,[7] including chess simulators.[3] The first recorded esports event was the "Red Annihilation" tournament in 1997, where 2,000 players competed in "Quake", a first-person shooter (FPS) video game.[5]

Worldwide, it is estimated that by 2023 around 3 billion individuals were playing video games in some format.[8] The video game industry has been growing rapidly and currently generates more revenue than the film and music industries combined.[4] In 2018, gamers spent an estimated $139 billion across all video game platforms.[4]

In this context, esports have also been developing and gaining popularity. esports, described as “organized competitive video gaming”,[9] share many characteristics of traditional sports, namely their competitive nature, teams that include several players, fans who follow and empathize with the players, matches included in competitive tournaments, and the frequent use of stadiums or arenas for esports competitions, which allows spectators to enjoy a similar experience to that of a typical sporting context.[10] While there is a wide variety of esports titles, some of the most popular include League of Legends, Defense of the Ancients 2, and StarCraft II, three real-time strategy games; Counter-Strike: Global Offensive, an FPS; and the FIFA series, a football simulator.[11]

This market is estimated to generate 3 billion dollars yearly and had 300 million viewers worldwide in 2022.[10] The 2022 League of Legends World Championship smashed audience records in the same year, drawing 5.1 million spectators to a single game.[12] In parallel, the number of esports players has also been increasing. In 2024, the United States of America currently had the highest number of competitors (3525), followed by China (2019) and Brazil (1352).[8]

Live competition broadcasts, mostly via Twitch.tv platform but also through YouTube, have been one of the most significant reasons contributing to the quick growth of esports.[4] The periods of confinement imposed in the context of the COVID-19 pandemic, the growing support from investors and global brands, the development of social networks, and the audience made up mainly of teenagers and young adults, more interested in video games, contributed to accelerated growth of esports popularity.[4,10]

Some traditional athletes are also participating in simulator competitions of their sport. NASCAR and Formula 1 drivers were among the first to join in esports competitions, where they competed against esports professionals.[13,14] Traditional sports federations, such as F1 and football, have been organizing esports competitions that simulate these sports.[4,15] Several “classic” sports clubs have also added esports teams to their structure.[16,17] esports has also infiltrated and expanded into the academic world. To date, over 175 colleges and universities have joined this phenomenon and created associated programs, organized competitions, or formed an esports team.[10]

Meanwhile, at least 11 countries recognized esports as a sport, including South Korea, China, Nepal, the United States of America, Finland, Denmark, Germany, South Africa, Russia, Ukraine, and Italy.[18] In 2017 the International Olympic Committee (IOC) declared that “competitive esports could be considered as a sporting activity, and the players involved prepare and train with an intensity which may be comparable to athletes in traditional sports.”[19] Meanwhile, the IOC also launched the “Virtual Olympic Series” esports tournament ahead of the Tokyo 2020 Olympic Games, which included 5 genres of esports simulators.[20] The 2023 version of this event now includes 10 sports simulators: Archery (Tic Tac Bow), baseball (WBSC eBASEBALL™: POWER PROS), cycling (Zwift), dancing (JustDance), sailing (Virtual

Regatta), taekwondo (Virtual Taekwondo), tennis (Tennis Clash), shooting (Fortnite), motorsport (Gran Turismo) and chess (Chess.com).[21,22]

Accompanying this popularity increase, companies that commercialize low-quality hyper-processed foods (junk food) and beverages (alcohol and energy drinks) have increasingly advertised their products at events related to esports,[23] promoting inadequate health and dietary habits in this population and the public attending esports events. This issue concerns health authorities, as playing video games is associated with sedentarism, weight gain, and low-quality food intake,[24] including lower consumption of fruits and vegetables and a higher intake of soft drinks, snack food, salty snacks, and total energy.[25] Insufficient fruit and vegetable intake is associated with a higher prevalence of chronic diseases and a decrease in healthy life years,[26] and sugary drinks, including energy and sports drinks, are linked to weight gain[27] and the deterioration of oral health.[28] Alcohol consumption and diets based on hyper-processed or hyperenergetic foods also appear to impair cognitive performance through increased body fat and neuroinflammation.[29]

However, video games can benefit attention, memory, cognitive plasticity, spatial reasoning, and problem-solving skills.[30] In certain contexts, they can also reduce school absenteeism, improve student grades, and promote social interaction.[31] As they usually play in teams consisting of 5 members, esports may enhance soft skills that colleges and employers value, like teamwork, communication, and problem-solving under pressure.[31]

Video games can also be used to promote healthy habits.[32] Active videogame systems (exergames), a category of video games that simulates physical activities, have been successfully used to increase energy expenditure and physical activity levels. Examples of exergame genres include dance simulation, aerobic fitness, interactive cycling, and isometric resistance games. These can be played on video game systems such as Nintendo Wii, Sony EyeToy, Sony PlayStation Move, and Xbox Kinect.[33]

Nonetheless, the excessive or compulsive practice of sedentary video gaming is associated with decreased gray matter in various brain regions, especially in the frontal lobe, and a greater tendency towards aggressiveness, hostility, antisocial behavior, and lower social self-esteem,[34] Many esports players do not seem to understand the level of demand they are subjecting themselves to and may fail to adopt an adequate diet, not preparing for competitions in a professional way.[35] Novice players may be able to execute under 100 and highly skilled players up to 400 actions per minute[36] and regularly train for five to ten hours per day.[37] These individuals frequently experience eyestrain, neck, lower back, hand, and wrist pain.[38] This highly competitive and challenging environment frequently leads to "burnout"[39] and translates into remarkably short careers, where only about 20% of professional esports players complete two years of career.[5]

Traditionally, research in sports nutrition has focused on the more physically intense sports, such as soccer and athletics.[40,41] However, other sports and competitive activities, highly dependent on cognitive abilities, also require attention. These include chess and esports,[42-44] which rely primarily on fluid intelligence, crystallized intelligence, processing speed, fine motor skills, short-term memory, and resistance to mental fatigue.[45-47] In most esports titles, and especially in shooters and fighting games, the ability to react quickly is a decisive factor, as a difference in reaction time of just a few milliseconds can mean the difference between victory and defeat.[48]

However, human cognitive capacity implies a high energy cost. The brain is the most active and expensive organ in metabolic terms. Under normal conditions, it accounts for about 20% of total resting energy expenditure[49] and requires a minimum of 130 g of glucose per day.[50] On the other hand, exposure to cognitively demanding activities raises brain glucose expenditure by up to 12% and significantly decreases blood glucose levels.[51] Proper brain function requires several other nutrients, including fatty acids, amino acids, vitamins, and minerals.[52] Additionally, hydration status,[53] diet quality,[54] meal patterns, and some dietary supplements (DS) may affect cognitive performance. Despite the dearth of scientific evidence, some nutritional strategies may optimize health, and performance, minimize injury risk, and possibly, lengthen the competitive careers of esports players.[55,56]

Although there have been prior reviews on the dietary habits of video gamers, none specifically addressed esports players.[57] Its competitive and organized nature,[9] the recognition by the IOC as a sport,[19] and the existence of individuals who dedicate themselves part or full-time to esports, and who may practice for up to 10 hours a day,[37] distinguish esports from the recreational practice of video games.

Furthermore, the spectacular rise in esports popularity,[7,10] the need to include nutritionists in esports teams to optimize the health and performance of these players,[58] the fact that several esports teams staff include nutritionists[59-61] and that some esports players seek the support of nutritionists,[62] reinforces the need to investigate the health of esports players, including the nutritional aspects and to generate scientific evidence on which nutritionists and other health professionals can base their activity when working with esports players.[37]

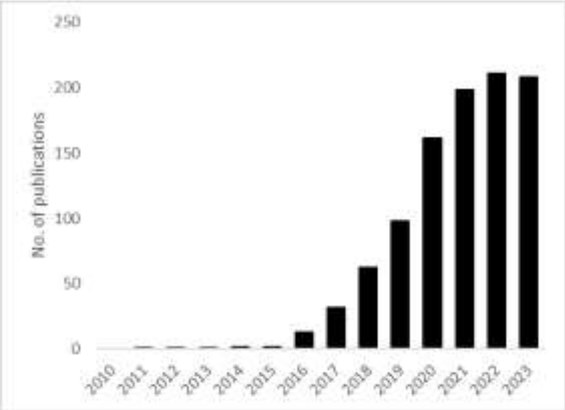

Figure 1. Number of publications returned when searching for the keyword "esports" on Web of Science.

As can be seen in Figure 1, the number of scholarly articles on esports increased significantly between 2015 and 2023. Although the number of academic publications has also increased globally over the years,[63] the increase in publications related to esports appears to be higher. This indicates a growing interest in this topic among academics, which, combined with esports' growing popularity, validates the conduct of this thesis and underscores the need for additional research in this field.

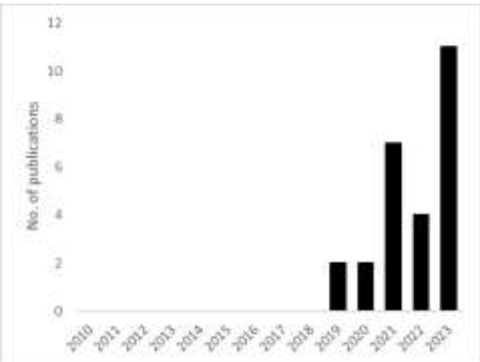

Figure 2. Number of publications related to the keywords "esports" AND "nutrition" OR "diet*" OR "supplement*" on Web of Science.

As far as the author of this doctorate thesis is aware, until the date of his enrollment in the Food Consumption and Nutrition Sciences doctorate course, in 2019, no study related to electronic sports (esports) and nutrition, or DS had yet been published. However, some articles published from 2019 to 2023 include nutrition-related content (Figure 2), and although their number is still quite small, the relevant information contained in these articles has been included in two scope reviews, which form part of this doctorate thesis.

2. Objectives

2.1. General Objectives

This doctoral project encompassed two main objectives:

1) To summarize the existing scientific literature on dietary habits and nutritional status that could influence the cognitive performance of healthy young adults.
2) To characterize the dietary habits of esports players.

2.2. Specific Objectives

1) To conduct a review that summarizes how nutritional status and dietary strategies can influence health, cognitive performance, reaction time, and mental fatigue in healthy adolescents and young adults [Paper I];
2) To undertake a scoping review to outline studies that tested the effects of DS on video gaming, summarize their findings, highlight knowledge gaps, and recommend future research [Paper II];
3) To conduct a scoping review to identify studies that included information on esports players' dietary habits, summarize their findings, highlight knowledge gaps, and recommend future research [Paper III];
4) To characterize chess and esports players' lifestyles, including playing traits, adhesion to the MD and other dietary habits, DS consumption, physical activity level, and degree of IGD and, additionally, to look for any potential links between the evaluated variables and MD adhesion [Papers IV and V];
5) To assess esports players' hydration status during a live competition and possible associations between urine-specific gravity outcomes and the video game genre, hours of video game play per day, physical activity level, and professional status [Paper VI].

3. Methods

The applied methodology is included and described in the "Methods" section in each of the six articles.

4. Results

Paper I: The Emergence of eSports Nutrition: A Review

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THE EMERGENCE OF ESPORTS NUTRITION: A REVIEW

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Abstract Peak cognitive performance is of paramount importance for the sports and competitive activities that depend on a high level of cognitive performance, such as eSports. The popularity of eSports has increased rapidly in recent years and will probably continue to rise in the forthcoming years. Above all, eSports practitioners require higher levels of cognitive abilities and motor skills for optimal performance and may benefit from adequate body composition and proper nutrition, as happens with more traditional athletes. However, there is a noticeable shortage of scientific knowledge in this area, including in nutritional-related aspects. Therefore, the objective of this non-systematic review is to summarize the nutritional strategies that may enhance health, cognitive performance, decrease reaction time and minimize fatigue. This information may be relevant for eSports competitors and set a base for further investigations, which could ultimately lead to the establishment of nutritional recommendations specific for this competitive population.

Key words eSports, nutrition, eSports nutrition, video games, cognitive performance

Introduction

Traditionally, sports nutrition has focused on promoting an optimum level of physical fitness particularly for athletes of more physically intense sports, such as the marathon, football, weightlifting, etc. (Kerksick et al., 2018). However, sport is not limited to these modalities. There are other sports and competitive activities that depend mainly on another type of skills, like a high level of cognitive capacity, high-speed response, accuracy and resistance to mental fatigue, such as billiards, darts, motorsports, drone racing, chess, and eSports (Campbell, Toth, Moran, Kowal, Exton, 2018).

eSports involve video game competitions with other players. Some examples of eSports games include League of Legends, Dota 2, Starcraft II, Counter-Strike: Global Offensive, and the FIFA series (Hamari, Sjöblom, 2017).

While it is debatable if eSports are considered a true sport or not, its popularity has been growing tremendously, and it is estimated that by the end of the year 2018, it may have reached a total of 380 million fans and $906 million in incomes (Hallmann, Giel, 2018).

The practice of eSports may provide benefits in various cognitive domains, including refined attention, memory, plasticity, spatial reasoning and problem-solving, among others (Taylor, Elam, 2018). It may also motivate students to reduce school absenteeism and improve their grades, and, as it is practiced in teams, it could also improve soft skills that are desired by universities and employers, such as teamwork, communication skills and problem-solving in high-pressure contexts (Rothwell, Shaffer, 2019).

The average age of eSports professional players maybe around 21–25 years (ESPN, 2017, acessed: 22.01.2020) and their careers are usually very brief, lasting until their mid-twenties, an age from which their speed of responsive action starts decreasing and younger competitors may be in advantage (Hallmann, Giel, 2018). The scientific literature mentions various cognitive domains that seem to be of the utmost importance in the competitive practice of video games, namely: fine cognitive motor skills, including aiming and manual dexterity (Reeves, Brown, Laurier, 2009), cognitive motor speed, including reaction time, speed of action and actions per-minute (Huang, Yan, Cheung, Nagappan, Zimmermann, 2017; Reeves et al., 2009), fluid intelligence, memory (Kokkinakis, Cowling, Drachen, Wade, 2017), visuospatial attention (Han, Lyoo, Renshaw, 2012), concentration (Cottrell, McMillen, Harris, 2019), resistance to mental fatigue (Thomas, Rothschild, Earnest, Blaisdell, 2019), multitasking, management and organization (Huang et al., 2017).

Nonetheless, it seems that most competitors do not recognize the cognitive and physiological demands of competitive eSports, and fail to adhere to healthy dietary patterns, not preparing themselves for competition in a professional manner (Schütz, 2016). As in most sports, and as the level of demand rises, a progressive increase in demand for strategies to improve performance is expected, and there are already companies dedicated to providing personalized programs, including nutritional plans (Himmelstein, Liu, Shapiro, 2017). However, there is a noticeable shortage of scientific knowledge in this area, including in the field of nutritional science.

The objective of this review is to summarize how nutritional status and dietary strategies can influence health, cognitive performance, decrease reaction time and minimize fatigue. While the information here summarized may be relevant for eSports competitors, it may have a higher favorable influence for typical adolescents and young adults, as high-level eSports players may already be operating close to the limit of human cognitive ability, leaving little room for performance improvement (Bernard, Louise, Louise, 2018).

Methods

This article is a non-systematic review and the information here resumed was collected through research on Google Scholar, PubMed, and Web of Science. The searches included the following keywords: “esports”, “cognition”, “nutrition”, “diet”, “breakfast”, “lunch”, “snack”, “evening meal”, “protein”. “carbohydrates”, “glucose”, “fat”, “saturated fats”, “polyunsaturated fats”, “vitamins”, “minerals”, “hydration”, “alcohol”, “coffee”, “caffeine”, “BMI”, “overweight”, “obesity”, and “weight loss”. The information considered relevant was included in this review. In addition, published books on nutrition and cognition were also consulted for retrieval of additional information and references.

Diet-related aspects influence on cognition

Diet quality

Diet quality may impact cognitive capacities, including learning and memory of the immature and adult brain (Reichelt, Westbrook, Morris, 2017). Poor eating habits are associated with decreased performance in various cognitive domains (Wright, Gerassimakis, Bygrave, Waldstein, 2017), which may be partially explained by ethanol neurotoxicity (Brust, 2010), increased brain inflammation promoted by high fat (Pistell et al., 2010) and high sugar diets (Yeomans, 2017). The western pattern diet, which is typically high in refined sugars and cereals, sodium, saturated fats and alcohol (Statovci, Aguilera, MacSharry, Melgar, 2017), may predispose to obesity, is linked to an overall decrease in cognitive function, and may have a negative influence in the hippocampus, which is implicated in memorization and learning (Morris, Beilharz, Maniam, Reichelt, Westbrook, 2015).

On the other hand, a healthier diet correlates with optimum mental performance (Kim, Kang, 2017). The Mediterranean diet, which is composed mainly by significant amounts of whole grains, legumes, vegetables, fruit and a modest amount of fish, dairy and olive oil, may decrease the risk of cognitive impairments (Radd-Vagenas Duffy, Naismith, Brew, Flood, Fiatarone Singh, 2018).

Meal patterns

Meal timing, size, and composition also have the potential to affect cognitive performance (Dye, Lluch, Blundell, 2000; Leigh Gibson, Green, 2002; Prasad, Lieberman, Kanarek, 2005).

Moreover, the ingestion of a meal with a nutritional composition different to the one that is usually eaten seems to worsen the mood and energy ratings (Cunliffe, Obeid, Powell-Tuck, 1997).

The frequent omission of meals, especially breakfast, in young adults, is correlated with inferior diet quality, reduced intake of micronutrients, greater BMI and risk of abdominal adiposity, increased insulin resistance (Pendergast, Livingstone, Worsley, McNaughton, 2016), poorer sleep (Tanaka et al., 2002), fatigue, decreased attention, and inferior academic performance (Ackuaku-Dogbe, Abaidoo, 2014).

Breakfast intake enhances cognitive aspects linked to attention, executive function, memory (Adolphus, Lawton, Champ, Dye, 2016), test scores (Rampersaud, Pereira, Girard, Adams, Metzl, 2005), and improves the capacity to cope with cognitive workload (Sihvola et al., 2013).

There is some evidence that lunch is a major contributor for the post-prandial dip in performance, and leads to a decline in some aspects of cognitive performance, including in discrimination efficiency, sustained attention (Smith,Miles, 1986), and increased response time (Lloyd, Green, Rogers, 1994). These detrimental effects may be modulated by personality type (Craig, Baer, Diekmann, 1981) and meal size, with biggest decrements being observed after the ingestion of a big (922–1,380 Kcal) versus a light lunch (260–305 Kcal) (Craig, Richardson, 1989; Reyner, Wells, Mortlock, Horne, 2012). The ingestion of a lunch containing high amounts of fat or carbohydrates decreases alertness and cognitive efficiency (Lloyd et al., 1994).

In a study involving university students as volunteers, those who had an evening meal felt more energetic, more attentive, more competent and achieved a better performance in a logical reasoning test than those who didn't (Smith, Maben, Brockman, 1994). On the other hand, the ingestion of a big supper (30% of daily total energy intake) at late night increased sleepiness (Gupta et al., 2019), decreased driving performance and vigilant attention

(Gupta et al., 2019; Gupta et al., 2017), while the ingestion of a light meal (10% of 24 h energy intake) led to improved performance in those parameters (Gupta et al., 2019).

Hydration

It is estimated that 54.5% of the USA children and adolescents (Kenney, Long, Cradock, Gortmaker, 2015) and 15,8% of the adults (20–29 years) are dehydrated and 40% have borderline blood plasma hypertonicity (295 to 300 mmol/L) (Stookey, 2005).

Water accounts for 75% of brain mass (Zhang, Du, Zhang, Ma, 2019) and hydration status may be one of the main variables that affect the performance of eSports practitioners since there is reasonably consistent evidence that a dehydration level greater than 2% of body mass decreases cognitive performance (Adan, 2012; Riebl, Davy, 2013) decreases alertness, mood and increases fatigue (Benton, Young, 2015). Seemingly, a greater level of dehydration correlates with greater decreases in cognitive performance and mood (Pross et al., 2013), while water consumption can improve these parameters (Masento, Golightly, Field, Butler, van Reekum, 2014).

Moreover, some studies suggest that a dehydration level of 1–2% is enough to diminish cognitive performance (Riebl, Davy, 2013), and a more recent study found that a dehydration level of only 0.22% had a negative influence on memory and attention (Benton, Jenkins, Watkins, Young, 2016).

Indeed, the mere sensation of thirst may negatively affect memory and attention (Benton et al., 2016; Benton, Young, 2015) possibly by diverting some attention from cognitive performance (Benton, Young, 2015), and it was observed that the consumption of water favors mental performance in thirsty young adults, although it impaired it in those who were not thirsty (Rogers, Kainth, Smit, 2001).

Even if a moderate level of dehydration doesn't decrease cognitive test performance in adolescents and healthy adults, it may require more brainwork to reach a similar cognitive output as in a hydrated condition (Barulli, Stern, 2013; Kempton et al., 2011; Stern, 2017), and these individuals also exhibit lower mental clarity, well-being and greater fatigue (Kempton et al., 2011).

The daily amount of water necessary to maintain euhydration varies between individuals and must be adjusted to environmental conditions. The European Food Safety Agency (EFSA) has set an adequate total water intake value of 2,5L/day for males and 2,0L/day for females (EFSA, 2017).

Nutrients

Glucose. Notwithstanding constituting just ~2% of an adult individual's body mass, the energy expenditure of the brain represents ~20% of the body total expenditure (Herculano-Houzel, 2011). Because its energy reserves are limited, brain depends on continued delivery of glucose, its main fuel substrate (Murray, Rosenbloom, 2018) except during long periods of fasting, in which it oxidizes ketone bodies (Morris, 2005). In fasting and resting conditions, approximately 60% of blood glucose is metabolized by the brain (Wasserman, 2009), totalizing around 130 g about glucose/day (Lupton, Brooks, Butte, Caballero, Flatt, Fried, 2005).

In cognitively demanding scenarios, brain glucose consumption can increase by up to 12% (Madsen et al., 1995), and blood glucose levels may drop by as much as 10% (Fairclough, Houston, 2004; Gailliot et al., 2007; Scholey, Harper, Kennedy, 2001; Scholey, Laing, Kennedy, 2006). It has been shown that playing Tetris consumes a significant quantity of glucose (Haier, Siegel, Tang, Abel, Buchsbaum, 1992) and decreases blood glucose levels (Lange, Seer, Rapior, Rose, Eggert, 2014). In this context, the consumption of glucose may increase the availability of this nutrient and support the brain areas involved in the heightened workload and ultimately increase cognitive performance (Smith, Riby, Eekelen, Foster, 2011).

The potential mechanisms behind glucose cognitive enhancement effects through a) increased acetylcholine production, whose synthesis depends upon glucose (Messier, 2004); b) raised insulin levels, which may promote hippocampus glucose utilization (Craft, Murphy, Wemstrom, 1994); c) rewarding pathways upon activation of glucose-sensitive receptors present in the mouth (Hagger, Chatzisarantis, 2013); d) interplay with dopamine, serotonin, and opiates (Riby, 2004).

The positive effects of glucose administration on cognitive performance have been supported by the results of a meta-analysis (Riby, 2004), with larger effects on episodic memory, and possible benefits on sustained attention and vigilance (Bernard et al., 2018). The cognitive enhancements may be visible up to 20 min after its ingestion (Jones, Sunram-Lea, Wesnes, 2012) and glucose blood levels may start to decline after around 30 min, dropping to basal levels in approximately 2 hours (Benton, Parker, Donohoe, 1996). The nootropics effects of glucose seem more noticeable on prolonged and cognitively demanding tasks and in fasting conditions (Riby, 2004). This may explain why most interventions were performed at breakfast time (Hoyland, Lawton, Dye, 2008). These nootropic effects may be short-lived, as impairments in working memory have been detected 60 min after the administration of 25 g of glucose, possible due to a subsequent decrease in plasma glucose levels, secondary to increased insulin levels (Jones et al., 2012).

It may not be necessary to ingest carbohydrates through a pure glucose solution to potentiate cognition. The ingestion of a dietary source of carbohydrates (breakfast cereals) at early morning also improves spatial memory (Smith, Clark, Gallagher, 1999). Moreover, the regular ingestion of sugary drinks, including energy drinks and sports drinks, should be discouraged due to its association with increased inflammation, weight gain and oral health problems (Aeberli et al., 2011; Malik, Pan, Willett, Hu, 2013; Hardy, Bell, Bauman, Mihrshahi, 2018).

It should be noted that practicing eSports for many hours a day and during various months may lower or block the cognitive benefits associated with glucose intake. Playing Tetris daily for 4–8 weeks result in a decrease in cerebral glucose expenditure, despite a concomitant >7-fold increase in performance (Haier et al., 1992).

Lipids. Lipids account for 50–60% of adult brain's dry weight (Sastry, 1985) and it was found that alterations in the lipid constituents of neurons membrane may affect neurotransmission by modulating the activity of ion channels, receptors, enzymes and ion channels wrapped or involved with the membrane phospholipids (Prasad et al., 2005). In humans, high-fat diets have been documented to modify the brain metabolism of glucose, causing the electroconvulsive threshold to rise (Appleton, DeVivo, 1974), and the consumption of fatty foods has been robustly correlated with an increase in reaction time (Phillimore, 1988).

The type of fat may also influence cognition. The ingestion of higher amounts of unsaturated fatty acids has been correlated with optimized cognitive health in comparison with saturated fatty acids (Cao et al., 2019), while the ingestion of trans fatty acids is strongly linked with the worsening of word recall ability (Golomb, Bui, 2015). Trans fatty acids, which are produced in industrial installations (Stender, Astrup, Dyerberg, 2008), are associated to increased oxidative stress (Tomey et al., 2007), negative repercussions on blood lipids, metabolic processes, decreased glucose tolerance, general body inflammation, disrupted endothelial function, visceral adiposity, increased BMI, worsening of cardiac and general health (Mozaffarian, Aro, Willett, 2009), which may impair cognition (Atzmon et al., 2002; Eggermont et al., 2012; Geroldi et al., 2005; Isaac et al., 2011; Messerotti, Benvenuti, Zanatta, Valfre, Polesel, Palomba, 2012; van Exel et al., 2003).

Additionally, dietary trans fats decrease the availability of the long chain omega-3 fatty acids EPA and DHA, which are anti-inflammatory (Kaur, Chugh, Gupta, 2014), important to brain health and have been associated with a more favorable cognitive function (Lim, Gammack, Van Niekerk, Dangour, 2006; Robinson, Ijioma, Harris, 2010).

According to EFSA, for adults, the ingestion of total fat should represent 20–35% of total energy intake, the adequate intake of EPA + DHA is 250 mg/day, and the intake of saturated fat and trans fats should be as low as possible (EFSA, 2017).

Unlike glucose, the effects of acute consumption of pure fat and protein on cognition have been scarcely studied, with contradictory results. These inconsistencies may have been due to different methodologies applied in these studies. Additional investigations must be conducted before any conclusions can be drawn (Bachlechner et al., 2017; Jones et al., 2012).

Protein. The ingestion of adequate amounts of protein is also necessary for optimum brain development and functioning. With a protein content of approximately 10% (Banay-Schwartz, Kenessey, DeGuzman, Lajtha, Palkovits, 1992), the brain has a daily turnover rate of 3–4%, superior to that of skeletal muscle mass (1–2%) (Smeets et al., 2018). The central nervous systems also uses amino acids as neurotransmitters or as substrates for the synthesis of neurotransmitters and neuromodulators (Chertoff, 2015). The production of the neurotransmitters serotonin and catecholamines requires tryptophan and tyrosine as substrates, respectively, and its synthesis rate is influenced by the blood availability of these amino acids and, consequently, by the ingestion of protein (Fernstrom, Fernstrom, 2007).

It has been observed that the ingestion of a larger proportion of carbohydrates relative to protein raises tryptophan levels by elevating insulin levels, which promotes the uptake of the large neutral amino acids (LNAA) valine, leucine, and isoleucine by muscle tissues, thus dropping their blood levels, while tryptophan levels remain relatively unaltered. As tryptophan competes with these branched chain amino acids for the same transporter through the blood-brain barrier (BBB), the rate of transport of tryptophan through the BBB increases, as well as the brain availability of this amino acid, thus increasing serotonin production, a neurotransmitter that exerts sedating effects and consequently slows motor performance (Lieberman, 1999; van de Rest, van der Zwaluw, de Groot, 2013).

In general, dietary protein sources contains higher proportions of tyrosine in comparison with tryptophan. Being a LNAA, tyrosine competes for transport through the BBB with tryptophan and other LNAAs. As the proportion of protein to carbohydrates of a given meal increases, greater decreases in tryptophan levels are observed and, consequently, the brain synthesis of serotonin also decreases (Lieberman, 1999; van de Rest et al., 2013).

Acute high-stress conditions may decrease brain tyrosine levels due to heightened catecholamines synthesis triggered by an increased fire rate of central catecholaminergic neurons. In these cases, the ingestion of a protein-rich food increases blood tyrosine levels, favors its transport through the BBB, and boosts brain catecholamines synthesis, which may increase alertness and enhance cognition (Lieberman, 1999; van de Rest et al., 2013). Arguably, the lifestyle of eSports professional players may be considered stressful, especially in periods congested with important competitions (Pereira, Brito, Figueiredo, Verhagen, 2019).

In 2010 Jakobsen et al. applied a high protein diet (3.0 g kg/body weight) to a group of healthy young male college students (19–31 years), for 3 weeks, while another group followed a usual protein diet (1.5 g kg). These authors observed a significantly reduction in the reaction time in the high protein group, in comparison with the usual protein diet group, and attributed these effects mainly to increased levels of tyrosine, but also to raised phenylalanine and BCAA concentration in the high protein group (Jakobsen, Kondrup, Zellner, Tetens, Roth, 2011). However, there is clearly a need for further investigations on this topic. Moreover, the amount ingested by the high protein diet largely surpassed the population reference intake value of 0.83 g/kg proposed by EFSA (EFSA, 2017).

Micronutrients. The brain energy metabolism is also dependent on an adequate supply of vitamins and minerals (Kennedy et al., 2016). Low brain magnesium levels appear to decrease serotonin levels and promote depressive states (Eby, Eby, 2010), which may decrease performance in cognitive tasks, possibly due to a reduced capacity to allocate cognitive resources to challenging tasks (Jones, Siegle, Muelly, Haggerty, Ghinassi, 2010). Due to its key role in myoglobin, cytochromes, and many other cellular proteins and enzymes (DeLoughery, 2017), iron deficiency has been strongly associated with fatigue (Brunner, Wuillemin, 2010) and decreased mental performance in children (Lozoff, Beard, Connor, Barbara, Georgieff, Schallert, 2006) and young adults (Scott,Murray-Kolb, 2016). Iodine is necessary for the endogenous production of two hormones in the thyroid (triiodothyronine and thyroxine), which influence human development and growth, including the central nervous system (Zimmermann, 2009). Iodine deficiency may cause a number of negative health consequences, including impaired cognition capacity (Zimmermann, 2009). Zinc plays a key role in controlling the expression of genes and in normal synaptic signaling processes (Trumbo, Yates, Schlicker, Poos, 2001). Vitamin D deficiency might have negatives effects on the brain because it also has vitamin D receptors (Garcion, Wion-Barbot, Montero-Menei, Berger, Wion, 2002) and some studies suggest that hypovitaminosis D is associated with a lower cognition performance in adults (Goodwill, Szoeke, 2017).

Caffeine. Caffeine is considered the main constituent of coffee that provides cognitive facilitation effects (Haskell-Ramsay, Jackson, Forster, Dodd, Bowerbank, Kennedy, 2018). A dosage of 100 ml of coffee, extracted by the drip method, contains 60–100 mg of caffeine, an amount found sufficient to improve reaction time, alertness, vigilance, and attention (0,5 to 4 mg/kg) (McLellan, Caldwell, Lieberman, 2016). This value is below the EFSA established safe upper limit for acute caffeine ingestion (3 mg/kg) (EFSA Panel on Dietetic Products & Allergies, 2015). Nonetheless, coffee contains other components, such as chlorogenic acids, that may also exert positive mood and cognitive effects (Camfield et al., 2013). One study found that the ingestion of decaffeinated coffee improved alertness in young healthy adults (Haskell-Ramsay et al., 2018). In another investigation, the mere act of smelling coffee improved performance on an analytical reasoning task, an effect that may be attributed to the placebo effect (Madzharov, Ye, Morrin, Block, 2018).

Alcohol. Binge and heavy alcohol drinking during adolescence, a time when the brain is still maturing, is associated with significant negative brain and behavioral changes, inferior academic performance, retardation of white matter maturation, and volume reductions of specific brain areas, such as the cerebellar region and the frontal lobe (Cservenka, Brumback, 2017).

Cognition and weight status

Obesity may induce insulin resistance, promote inflammation, increase oxidative stress, and lead to endothelial dysfunction (Montero, Walther, Perez-Martin, Roche, Vinet, 2012), which can be harmful to the brain, and correlates with cortical thinning of specific brain regions, diminished integrity of white matter and reduced nerve conduction velocity in adolescents (Medic et al., 2016; Sweat, Yates, Migliaccio, Convit, 2017; Yau, Kang, Javier, Convit, 2014) and adults (Majumdar, Chaudhuri, Ghar, Rahaman, Hai, 2017; Stanek et al., 2011; Xu, Li, Lin, Sinha, Potenza, 2013). Compared with their lean counterparts, obese adolescents perform worst in various domains of cognition, such as arithmetic, working memory, spelling, mental flexibility, attention, executive functioning, cognitive processing speed, visuospatial performance, and motor skills (Liang, Matheson, Kaye, Boutelle, 2014; Sweat et al., 2017; Yau et al., 2014).

A significant percentage of esports practitioners may be overweight. In a survey conducted in Germany, involving 1,066 esports players from 18 to 38 years old, the average BMI was 24.6 (±4.8) and that only 51.9% of the sample had a normal weight, while the mean value for the population of Germany with the same age is 59.9–72.3%. Moreover, time spent playing video games was positively associated to BMI and self-reported health status (Rudolf, Bickmann, Froböse, Tholl, Wechsler, Grieben, 2020).

If obesity is linked to decreased cognitive performance, it is reasonable to theorize that weight loss could improve cognitive performance in obese. Indeed, intentional weight loss seems to enhance several aspects of cognition in overweight and obese adults, such as executive function, attention, memory, and language (Veronese et al., 2017), although some works only found cognitive benefits in obese and not in overweight individuals (Siervo et al., 2011).

Weight loss requires a negative energy balance, which has been associated with functional cognitive deficits in self-reported dieters (Green, Rogers, 1995, 1998; Kemps, Tiggemann, 2005; Kemps, Tiggemann, Marshall, 2005; Vreugdenburg, Bryan, Kemps, 2003), that seems to be more concerned with esthetics (Green, Elliman, Rogers, 1997; Green Rogers, 1998; Kemps Tiggemann, 2005; Kemps et al., 2005; Shaw,Tiggemann, 2004; Vreugdenburg et al., 2003). Such concerns can deviate cognitive resources for trivial cognitive tasks, thus diminishing the total cognitive resources available to other mental tasks (Green et al., 1997; Green, Rogers, Elliman, Gatenby, 1994; Sebastian, Williamson, Blouin, 1996). However, such association is missing or minimized when weight loss is reported or energy restriction is applied through clinical intervention (Bryan, Tiggemann, 2001; Green, Elliman, Rogers, 1995; Kretsch, Green, Fong, Elliman, Johnson, 1997; Landers, Arent, Lutz, 2001; Martin et al., 2007).

On the other hand, a too low BMI (i.e. *anorexia nervosa*) may impair cognitive flexibility and working memory. Weight recovery seems to restore these cognitive domains (Olivo, Gaudio, Schiöth, 2019). Chronic malnutrition undoubtedly hinders cognitive development and performance (Dauncey Bicknell, 1999; Kretchmer, Beard, Carlson, 1996).

Conclusions

To our knowledge, to date, no studies have evaluated the effects of dietary strategies on the cognitive performance of eSports competitors. However, there is a relatively great amount of evidence regarding nutritional strategies that may simultaneously benefit health and cognition, which may also be useful to eSports players:

1. Maintain an adequate weight for height.
2. Follow a low GI, high quality, and nutritious diet.
3. Limit the intake of fat to (20–25 total energy) an avoid saturated and trans fat.
4. Avoid and correct possible vitamin and mineral deficits.
5. Maintain a regular dietary pattern and do not skip breakfast.
6. A light meal at lunch may minimize the detrimental effects of post-lunch dip on cognition.
7. Avoid drinking alcoholic beverages.
8. Maintain an adequate hydration state, especially before competitions.
9. Consider the sensible ingestion of coffee before competitions.

Considering the currently available literature, it is not yet possible to establish specific recommendations for eSports competitors, but the information here presented may help to set a basis and identify the most viable topics which warrant further investigation. As this new world of eSports involves an increasing number of individuals over time, it is urgent to carry out further research in this area, which may ultimately lead to the establishment of nutritional and supplementation recommendations that may promote health and optimize cognitive performance.

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Paper II: Nootropic Supplements for esports: A Scoping Review

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Review

Nootropic supplements for esports

A scoping review

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Abstract: *Background:* esports, or organized video game competitions, have been expanding quickly. The use of dietary supplements by esports players appears vulgarized but lacks supporting evidence. *Objectives:* To outline studies that tested the effects of dietary supplements on video gaming, summarize their findings, highlight knowledge gaps, and recommend future research. *Eligibility criteria:* Clinical trials published in English between 1990 and 2023 that assessed the effects of dietary supplements on the cognitive performance of video gamers. *Sources of evidence:* The Web of Science, PubMed, Scopus, and Google Scholar databases. *Charting methods:* PRISMA's (2020) flow diagram was used to create the data chart. *Results:* Sixteen studies were outlined. Thirteen were randomized, thirteen applied acute interventions, ten applied a crossover design and only three weren't placebo-controlled. Of the 10 studies that included caffeine (40–200 mg), four reported significant positive effects on cognition (attention, processing speed, working memory), two on first-person shooter video gaming performance (reaction time, hit accuracy, time to hit 60 targets), and one on Tetris game score. All 3 studies that included arginine silicate (1500 mg) reported significant improvements in one or more aspects of cognition (reaction time, attention, visual representation, and spatial planning). Two studies that tested sucrose (21 and 26.8 g) didn't report significant improvements, while one study that tested 26.1 g of glucose registered significant positive effects on processing speed and sustained attention. *Conclusions:* The published literature has focused on the effects of caffeine, which may exert both positive and negative effects on esports players. Additional, high-quality research is needed.

Keywords: esports, video games, dietary supplements, nootropics, cognitive enhancement

Introduction

esports emerged in the early 1990s, powered by the birth of the world wide web (www) and the development of software and hardware with network and multiplayer playing capabilities [1]. Since then, esports, or video game competitions, have been gaining relevance and accumulating an audience and currently represent a market worth millions of dollars [2].

The use of cognitive performance-enhancing drugs seems ubiquitous in esports [3], mainly prescription stimulants such as pharmaceutical amphetamines, methylphenidate, and modafinil [4]. The Ip, Urbano et al. (2021) survey revealed that 6.1% of online video game players use prescription medications to enhance their video gaming performance [5]. The highly competitive environment, the desire to win no matter the cost, the monetary prizes, the typically short professional careers, the long duration of tournament matches, and the almost complete absence of anti-doping testing, may explain why esports competitors resort to illegitimate use of controlled substances in an attempt to enhance their performance [3, 6], which threatens esports fair play [7] and increases the risk of health complications [8, 9, 10].

Health professionals should be able to advise esports competitors on these issues based on the current level of evidence, namely on alternatives, such as nootropic supplements that are not forbidden and do not harm health. Nootropics are compounds that improve one or more aspects of cognitive performance, including reaction time, alertness, memory, attention, and mood [11]. These and other elements of cognition are especially relevant to esports players, including fluid intelligence, executive function, fine motor skills, and resistance to mental fatigue [2]. In the United States, about 32% of young adults use dietary supplements (DS) regularly [12]. Various companies have been formulating and launching supplements targeted at esports players and actively promoting them as aids to improve performance in training and competitions [13, 14, 15].

DS recommendations should be sport-specific and accordingly to the subject's characteristics [16], including sports expertise (untrained versus highly trained) [17]. Mastery of video games is associated with brain adaptations that may decrease DS efficacy, including a decrease in cerebral glucose expenditure, even when accompanied by a sevenfold increase in gaming performance [18]. Furthermore, Melentev et al. (2020) demonstrated that highly competitive esports players present distinct electroencephalogram (EEG) activity compared to casual video gamers [19].

This warrants the conduction of investigations that assesses the efficacy of DS on video gamers. This scoping

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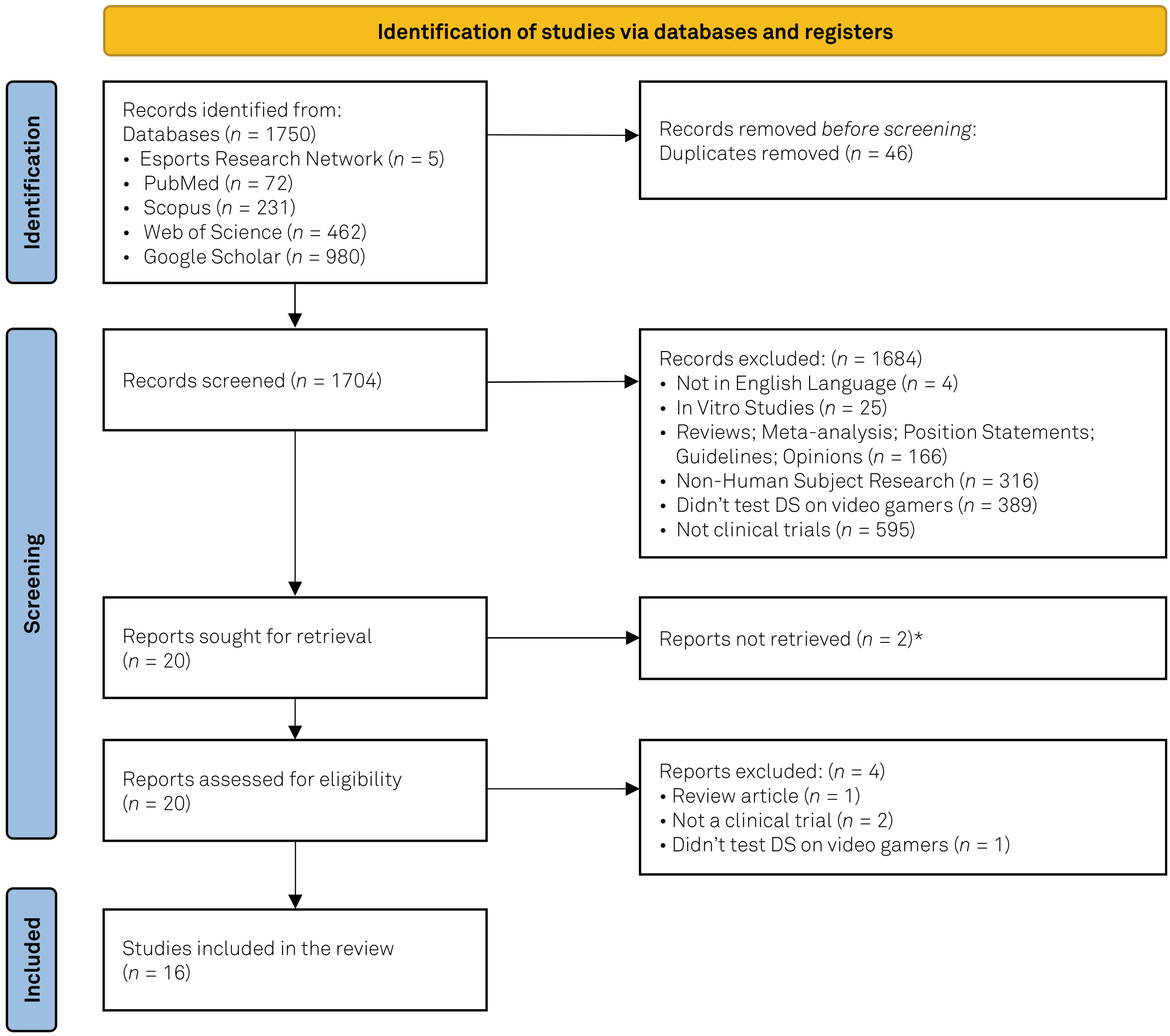

Figure 1. PRISMA 2020 flow diagram. *Although the full article of the studies authored by Emerson et al. (2022), and Kriter (2020) could not be retrieved because these authors only published an abstract, the authors of this scoping review chose to include these studies as their content fit the scope of this review.

review will outline the studies that tested the effects of DS on video gaming, summarize their findings, highlight potential knowledge gaps, and recommend a future research agenda.

Methods

This scoping review adopted the methodology described in the PRISMA Extension for Scoping Reviews [20]. A review protocol has been registered on the Open Science Framework website and can be found at https://osf.io/k32w4/.

The application of the methodology, the database searches, and the selection of articles to be assessed for inclusion in this review were carried out by the first author. All authors assessed the titles and abstracts independently and came to an agreement on the final articles to be included. The initial search strategy was devised, tested, and refined by the lead author (Fernando J. Ribeiro), who received academic training in researching bibliographic databases. To identify pertinent papers, the lead author searched the Web of Science, PubMed, Scopus, and Google Scholar databases applying keywords related to esports, nutrition, and DS. The entire Esports Research Network database was also manually screened for relevant articles by reading the items' titles.

The eligibility criteria included studies that tested the effects of DS on video gaming, published in English, between 1990 (the beginning of esports history) [1] and 2023. Studies that did not investigate the effects of DS on video gaming performance were excluded, as well as animal trials, recommendations, and letters to the editor.

On PubMed, on Advanced Search, the following keywords and boolean operators were inserted in the "Query Preview" field: ("esport*" OR "e-sport*" OR "e-gamer*" OR "egamer*" OR "video gamer*" OR "cognitive enhancement") AND ("nutrition" OR "nutrient*" OR "supplement*" OR "nootropic*" OR "caffeine"). The search was limited to clinical trials; Language: English; Species: Humans; Publication date – custom range: 1990-01-01 to 2023-05-25.

Following the search in each database, conducted in May 2023, the returned references were exported to Endnote X9. The duplicates were then removed, as well as the references written in other languages than English. The titles and abstracts of the remaining articles were screened and those that didn't fit the eligibility criteria were removed. The full text of the remaining articles was obtained and read for identification of potentially relevant publications. The final decision for the inclusion of the retrieved articles was made by consensus and discussion between the authors of this review. The authors divided the studies into groups based on the categories of DS tested and assessed their content to present their findings, identify potential gaps in knowledge, and recommend future research.

The lead author applied the PRISMA (2020) flow diagram as a basis for creating the data chart [21]. The database search strategy is available as electronic supplementary material (ESM) 1. In a continual procedure, the data has been plotted separately, then the findings were presented and discussed between the authors (Table 1). A form has been created and tested by the author's team to extract and present key information regarding the studies described in this review, including the reported year of publication, country of origin, aims/purpose, study population, subjects age, sample size, study design, methodology/methods, intervention type/duration, substances tested, comparator, outcome measures, and key findings (Table 1).

As clinical studies may be affected by methodological errors that can influence the outcomes of studies that tested the effects of a treatment, a critical appraisal of the included articles was conducted through the Jadad, Moore et al. (1996) scale (Table 2), which assesses the methodological quality of clinical trials, including randomization, double-blinding, and description of withdrawals and dropouts [22]. JADAD has high validity evidence, has been evaluated for reliability in various scenarios, and is one of the most referenced scales to assess the methodological quality of randomized controlled trials [23]. Its scale score ranges from 0 (very poor quality) to 5 (rigorous). Clinical trial articles with a score of 0–2 are considered poor quality, while those with a value of 3–5 points are deemed top quality [22, 24].

Results

Search results

The searches yielded a total of 1750 references, which were exported to EndNote X9. A total of 46 duplicates were removed. Of the remaining 1704 articles, 4 were written in another language than English, 166 were reviews, meta-analyses, position statements, guidelines or opinion articles, 133 were books, magazine articles, website articles, patents, supplementary material or multimedia content, 595 weren't clinical trials, 316 didn't involve human subjects, 25 were in vitro studies, and 445 didn't test the effects of DS on video gaming and thus were removed.

The full articles of the remaining 20 references were sought for retrieval, and 18 were obtained. Although the full article of the studies authored by Emerson et al. (2022), and Kriter (2020) could not be retrieved because these authors only published an abstract, the authors of this scoping review chose to include these studies as their content fit the scope of this review.

The full articles of the 18 references were assessed for eligibility, and 4 reports of clinical trials were excluded as they didn't evaluate the effects of DS on video gaming. Finally, a total of 16 studies remained and were included in this review [13, 14, 15, 25, 26, 27, 28, 29, 30, 31, 32, 33].

Quality of evidence

The mean score of the sixteen trials included in this review on the JADAD scale was 2.2 (ranging from 0 to 5). According to this scale, the trials conducted by La Monica et al. (2021) [15], Rhoden et al. (2021) [27], Tartar et al. (2021) [29], Furukado et al. (2022) [34], Emerson et al. (2022) [35], Lange et al. (2014) [32], Kriter (2020) [31], and Molesworth et al. (2008) [36] are low-quality studies (0–2 points), while the remaining eight studies classify as high quality (3–5 points) [13, 14, 25, 26, 28, 30, 33, 37]. Of note, only the articles authored by Franke et al. (2017) [28], and Bloomer et al. (2022) [37] reported withdrawals and dropouts. To our knowledge, none of the included articles has been retracted.

Included studies

This subsection presents a brief description of the characteristics and findings of the sixteen studies included in this review, ordered according to the main active substance tested in each study.

Table 1. Data items

Authors (year)	Country of origin	Aims/ purpose	Study population	Age¹	Sample size	Study design	Methodology	Intervention type	Comparator	Outcome measures	Key findings
Sowinki et al. (2021)	USA	Examine the acute effects of a combination of arginine, silicate, and inositol on cognitive performance.	Experienced esports players	23 (5) y	*n*=26 (18♂, 8♀)	Randomized, double-blind, placebo-controlled, crossover, prospective.	In 2 trials, 7–14 days apart, after 8–12 hours of fasting, volunteers underwent cognitive tests before receiving a supplement or placebo. They repeated the tests 15 min after ingestion, then played a video game for 60 min before repeating the tests.	1500 mg (~21.1 mg/kg) arginine silicate+100 mg inositol; Acute ingestion.	Placebo	Berg-Wisconsin Card Sorting Task test; Go/No-Go test; Sternberg Task test; Psychomotor Vigilance Task test; Cambridge Brain Sciences Reasoning and Concentration tests; Light Tracking Reaction test; Video game performance.	Video game performance (n) Berg-Wisconsin Card Sorting Task test (n) Go/No-Go test (n) Psychomotor Vigilance Task Test (n) Cambridge Brain Sciences tests (n) Light Tracking Reaction Test (n) ↓ Reaction time (Sternberg Task Test) ☺
Tartar et al. (2019)	USA	Examine the effects of a combination of arginine, silicate, and inositol on cognitive performance.	Experienced esports players	28.6 (5.4) y	*n*=60 (50♂, 10♀)	Randomized, double-blind, placebo-controlled, parallel-group, prospective.	Volunteers ingested a supplement or placebo for 7 days. On days 1 and 7, before and 15 min after dosing, subjects completed a battery of cognitive tests, played a video game for 60 min, and repeated the cognitive tests.	1500 mg (~17.4 mg/kg) arginine silicate +100 mg inositol; Ingested daily for 7 days.	Placebo	Trail Making Test (TMT) A and B; Stroop Test; Video game performance.	Video game performance (n) Stroop test (n) TMT A completion time (n) TMT B completion time (n) ↓ TMT B errors ☺
Emerson et al. (2022)	USA	Examine the effects of a combination of arginine, silicate, and inositol on cognitive performance.	Experienced esports players	[18–32 y]	*n*=9 (♂,♀)²	Open-label, parallel-group, prospective.	Volunteers ingested a supplement daily for 7 days. On days 1 and 7, subjects completed a set of cognitive tests.	600 mg arginine +105 mg silicon +385 mg inositol +60 mg potassium; Ingested daily for 7 days.	Pre-suppl-ementation regime cognitive test scores	6 Cambridge Brain Sciences tasks: – Feature Match (Visual perception); – Double Trouble (Stroop test for attention); – Mental Rotations (Visual representation); – Polygons (Object relationship); – Odd One Out (Deductive reasoning); – Spatial Planning (Forethought/ sequencing).	↑ Attention/concentration ☺ ↑ Visual representation ☺ ↑ Spatial planning ☺ Visual perception (n) Visuospatial processing (n) Deductive reasoning (n)

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Table 1. Data items (Continued)

Authors (year)	Country of origin	Aims/ purpose	Study population	Age¹	Sample size	Study design	Methodology	Intervention type	Comparator	Outcome measures	Key findings
Lange et al. (2014)	Germany	Assess the influence of glucose on cognitive and gaming performance.	University students; Tetris players	21.8 (2.6) y	n=70 (62♀, 8♂)	Randomized, blinded, placebo-controlled, parallel-group.	Volunteers ingested either 250 mL of caffeine-free soda sweetened with sugar or an artificial sweetener ≥10-15 min before playing Tetris for 10 min.	26.8 g of sugar; Acute ingestion.	Placebo	Video game performance (Tetris): % of single-line clears; – % of four-line clears; – Total number of lines; – Number of restarts; – Total score.	n
Rhoden et al. (2021)	USA	Assess the link between blood glucose levels and performance in esports.	Experienced esports players	22 (3.0) y	n=10 (9♂, 1♀)	Randomized, crossover.	In 2 trials, 24 hours apart, 8-hour fasting volunteers had a nutritious bar and continued fasting before having their performance assessed during 1 hour of video gaming.	Cliff bar containing 44 g of carbohydrates (21 g sugar); Acute ingestion.	Fasting	Video game performance (osu!; Aim Hero).	n
Furukado et al. (2022)	Japan	Assess the influence of glucose on cognitive and gaming performance.	University students	20.3 (1.2) y	n=20 (♂)	Randomized, double-blind, placebo-controlled, crossover.	In 2 trials, 2 weeks apart, volunteers received a placebo or a candy containing glucose and completed cognitive tests and EEG assessments before and after playing a racing game.	Glucose (26.1 g); Acute ingestion.	Placebo	Trail-making tests (TMT-A and TMT-B); Racing game performance (Gran Turismo Sport); Electroencephalogram (EEG) power.	↑ Processing speed ☺ ↑ Sustained attention ☺ ↑ Alpha and sensorimotor rhythm waves (EEG) at 25 min ☺
Molesworth et al. (2008)	Australia	Determine the acute effects of caffeine on video game performance	Aircraft pilots	20.6 (2.2) y	n=42 (♂)	Randomized, placebo-controlled, single-blind, between-subjects.	Volunteers played a game (baseline) before ingesting a placebo (0 mg), 3 mg, or 5 mg/kg of caffeine. 30 min later they played another game (final test).	Caffeine (5 mg/kg); Acute ingestion.	Caffeine: 3 mg/kg; Placebo.	Video game Space Fortress total score (Control, Speed, and Accuracy).	n

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Table 1. Data items (Continued)

Authors (year)	Country of origin	Aims/ purpose	Study population	Age[1]	Sample size	Study design	Methodology	Intervention type	Comparator	Outcome measures	Key findings
Sainz et al. (2020)	Spain	Determine the acute effects of caffeine on reaction time and video game performance.	Professional esports players: 7 FN and 8 CS: GO players	22 (3) y	*n*=15 (♂)	Randomized double-blind, placebo-controlled, cross-over.	In 3 trials, 3 days apart, 8-hour fasting participants ingested a placebo or caffeine. 45 min later, they completed a reaction time test and played an FPS game.	Caffeine (3 mg/kg/ bodyweight); Acute ingestion.	Placebo	Simple Visual Reaction test; FPS video game performance (3D Aim Trainer).	↑ Hit accuracy ☺ ↓ Reaction time ☺ ↓ Time to hit 60 targets ☺
Franke et al. (2017)	Germany	Assess the acute effects of methyl-phenidate, modafinil, and caffeine on cognitive and chess performance.	Elite chess players	37.3 (12.5) y	*n*=39 (♂)	Randomized, double-blind, placebo-controlled, cross-over.	On 4 trials, 7 days apart, the volunteers took breakfast, completed a set of cognitive tests, ingested caffeine, methylphenidate, modafinil, or a placebo, then played 10 chess games against a computer program, followed by another round of tests. The procedure was repeated in the afternoon, after lunch.	Caffeine (200 mg, ~2.5 mg/kg); Ingested twice a day with a 4 h interval; Acute ingestion.	Placebo	Stroop task; Psycho-Motor-Vigilance-Test; Trail-Making-Test; Wisconsin-Card-Sorting-Test; Balloon Analogue Risk Task; Tower of Hanoi.	Interference inhibition (n) Selective attention (n) Alertness (n) Psychomotor speed (n) Risk-taking (n) Behavior control (n) Cognitive control (n) Planning capacity (n) Problem-solving capacity (n) Chess game score (n) ↑ Time of reflection per game ☹
La Monica et al. (2021)	USA	Assess the acute effects of a combination of caffeine, methylliberine, and theacrine, on video game performance.	Recreational video gamers	23.4 (5.7) y	*n*=9 (♂)	Repeated measures, double-blind, crossover, placebo-controlled.	In 3 trials, 8-hour fasting participants ingested either a placebo, caffeine, or a combination of caffeine, methylliberine, and theacrine and then completed four 20-min gaming sessions designed to assess performance at 0, 60, 120, and 180 min.	125 mg (~1.5 mg/ kg) caffeine+75 mg methylliberine +50 mg theacrine (CMT); Acute ingestion.	Caffeine (125 mg); Placebo	FPS video game performance (Aimlab).	CMT: ↑ Visuospatial working memory vs. PL and Caffeine ☺ CMT: ↓ Median kill time vs. PL ☺ Caffeine: ↑ Time on target tracking vs. PL and CMT ☺ Caffeine: ↓ Reaction time for false alarms vs. PL and CMT ☹

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Table 1. Data items (Continued)

Authors (year)	Country of origin	Aims/ purpose	Study population	Age¹	Sample size	Study design	Methodology	Intervention type	Comparator	Outcome measures	Key findings
Tartar et al. (2021)	USA	Assess the acute effects of caffeine, methylliberine, and theacrine on cognitive performance.	Experienced esports players (FPS)	20.5 (2.0) y	*n*=50 (♂)	Randomized, repeated measures, double-blind, crossover, placebo-controlled.	In 3 trials, 1 week apart, volunteers received either a placebo, caffeine, or a combination of caffeine, methylliberine, and theacrine and then completed a set of cognitive tests.	125 mg (~1.5 mg/kg) caffeine+75 mg methylliberine +50 mg theacrine (CDT); Acute ingestion.	Caffeine (125 mg); Placebo	Flanker Test of Inhibitory Control; Psychomotor Vigilance Task; Pattern Comparison Processing Speed Test; Dimensional Change Card Sort Test; Electroencephalogram (EEG) power.	CDT & Caffeine: ↑ Attention, inhibitory control (Flanker test) vs. PL ☺ CDT: ↓ Reaction time (Psychomotor vigilance test) pre to post ☺ Caffeine: ↓ Delta power (EEG) ☹ CDT: ↑ Delta & theta bands (EEG) ☺ Pattern Comparison Processing Speed Test (n) Dimensional Change Card Sort Test (executive function) (n)
Bloomer et al. (2022)	USA	Assess the acute effects of caffeine and polyphenols on cognitive and video game performance.	Experienced esports players (FN)	22 (3.0) y	*n*=49 (47♂, 2♀)	Randomized, double-blind, placebo-controlled, crossover.	In 3 trials, 7 days apart, on a 3-hour fast, volunteers received either a placebo, caffeine, or a combination of caffeine and polyphenol antioxidants, and then completed cognitive tests.	Combination of 270 mg (~3.3 mg/kg) caffeine and polyphenols; Acute ingestion.	Caffeine (270 mg); Placebo	Reaction Time (Go/No-Go); Digit Symbol Substitution Test; AX-Continuous Performance Test; Third-person shooter video game performance (FN).	n
Leonard et al. (2023)	USA	Assess the acute and 30-day effects of a combination of microalgae (Phaeodactylum tricornutum) and guarana on cognitive and video game performance.	Experienced esports players (FPS, LOL, Super Smash Bros, Rocket League)	21.7 (4.1) y	*n*=61 (51♂, 10♀)	Randomized, double-blind, placebo-controlled, parallel-group, prospective.	Volunteers ingested a supplement daily for 30 days. On days 1 and 30, subjects completed a set of cognitive tests and played video games for 60 min.	Low dose: 4.4 mg of fucoxanthin +40-44 mg (~0.5–0.6 mg/kg) of caffeine, OR; High dose: 8.8 mg of fucoxanthin +40–44 mg of caffeine.	Placebo	Berg-Wisconsin Card Sorting Task; Go/No-Go Task; Sternberg Task; Psychomotor Vigilance Task; Light Tracking Reaction Test; Video game performance (FPS, LOL, Super Smash Bros, Rocket League).	n
Thomas et al. (2019)	USA	Examine the acute effects of a sugar-free energy drink on cognition and video game performance.	Professional esports players (LOL)	21 (2) y	*n*=9 (♂)	Randomized, double-blind, placebo-controlled, cross-over.	Volunteers completed cognitive tests before consuming an energy drink or a placebo, then repeated the tests after playing each of the 3 competitive LOL games.	Sugar-free energy drink (Reload™) containing 150 mg (~1.9 mg/kg) caffeine; Acute ingestion.	Placebo	Eriksen Flanker test; Go/No-go test; N-back test; Hand grip strength.	Attention (n) Reaction time (n) Response inhibition (n) Fatigue (n) ↑ Working memory ☺

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Table 1. Data items (Continued)

Authors (year)	Country of origin	Aims/ purpose	Study population	Age¹	Sample size	Study design	Methodology	Intervention type	Comparator	Outcome measures	Key findings
Schwager et al. (2023)	USA	Examine the acute effects of a sugar-free energy drink on cognition and video game performance.	Video gamers	25.2 (5.8) y	*N*=45 (37♂, 8♀)	Randomized, double-blind, placebo-controlled, cross-over.	40 min after ingesting the supplement, the volunteers were subjected to a battery of cognitive tests and played 5 different video games.	Sugar-free energy drink (C4 Smart Energy) containing 200 mg caffeine and tyrosine; Acute ingestion.	Placebo	10 CNS Vital Signs tests: – Verbal Memory Test; – Visual Memory Test; – Finger Tapping Test; – Symbol Digit Coding; – Stroop Test; Shifting Attention Test; – Continuous Performance Test; – Perception of Emotions Test; – Non-Verbal Reasoning Test; – Four Parts Continuous Performance Test.Video game performance (Tetris, Four-in-a-Row, Rayman Legend, FIFA-14, Call of Duty: Advanced Warfare).	Visual memory (n) Verbal memory (n) Composite memory (n) Reaction time (n) Simple attention (n) Complex attention (n) Processing speed (n) Social acuity (n) Reasoning (n) ↑ Cognitive flexibility ☺ ↑ Executive function ☺ ↑ Sustained attention ☺ ↑ Motor speed ☺ ↑ Psychomotor speed ☺ ↑ Working memory ☺ ↑ Tetris game scores ☺ Four-in-a-Row (n) Rayman Legend (n) FIFA-14 (n) Call of Duty: Advanced Warfare (n)
Kriter (2020)	USA	Examine the acute effects of a sugar-containing energy drink on recognition and reaction.	Not reported	Not reported	*n*=5	Not reported	The volunteers played 5 rounds of Tetris before ingesting the supplement, then practiced for 15 min and played 5 additional rounds of Tetris.	Energy drink (Red Bull) containing 80 mg of caffeine, 21.5 g of sucrose, 5.3 g of glucose, and 1000 mg of taurine; Acute ingestion.	Tetris score before ingesting the energy drink.	Tetris game scores.	n

Abbreviations: FPS: First-person shooter; CS: GO: Counter-Strike: Global Offensive; FN: Fortnite; LOL: League of Legends; EEG: Electroencephalogram; TMT: Trail Making Test; CDT: Combination of 125 mg caffeine+75 mg methylliberine+50 mg theacrine; CMT: Combination of 125mg caffeine+75 mg methylliberine+50 mg theacrine; PL: Placebo; ↑: Increase; ↓: decrease; n: No statistically significant differences; ☺: improved cognitive/gaming performance; ☹: worsening cognitive/gaming performance; ¹Age: Mean (SD); [2]Did not report the sample size for each sex.

Table 2. JADAD evaluation scale

	Sowinski et al. (2021)	Tartar et al. (2019)	Tartar et al. (2021)	Thomas et al. (2019)	Sainz et al. (2020)	Franke et al. (2017)	La Monica et al. (2021)	Rhoden et al. (2021)	Bloomer et al. (2022)	Furukado et al. (2022)	Emerson et al. (2022)	Leonard et al (2023)	Schwager et al. (2023)	Lange et al. (2014)	Kriter (2020)	Molesworth et al. (2008)
Was the study described as randomized?	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	1
The method was described and appropriate? (+1)	–	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–
The method was described and inappropriate? (−1)	–	–	–	–	–	–	–	−1	–	–	–	–	–	–	–	–
Was the study described as double-blind?	1	1	1	1	1	1	1	0	1	1	0	1	1	0	0	0
The method was described and appropriate? (+1)	1	1	–	1	1	1	1	–	1	–	–	1	1	–	–	–
The method was described and inappropriate? (−1)	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Was there a description of withdrawals and dropouts?	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0
Total Score	**3**	**3**	**2**	**3**	**4**	**4**	**2**	**0**	**3**	**2**	**0**	**5**	**4**	**1**	**0**	**2**

Caffeine

In an experiment with a randomized, placebo-controlled, single-blind, between-subjects repeated measures design, Molesworth et al. (2008) [36] tested the effects of caffeine supplementation on video game performance (Space Fortress). Forty-two Australian pilots with a mean age of 20.6 (SD=2.2) and 135.7 (SD=76.8) hours of flight experience were recruited and randomly divided into three groups (0 mg, 3 mg, or 5 mg/kg of caffeine). After being briefed on the rules and mechanics of the video game Space Fortress, the volunteers played a game session to obtain baseline values. Then, they ingested a lemon-flavored drink containing either zero, three, or five mg of caffeine per kg of body weight, and 30 minutes later, they played one last game. Each game session lasted about 3 minutes. The Cognitive Psychophysiological Laboratory at the University of Illinois created Space Fortress, a freely accessible video game, to measure the ability to perform complicated interactive tasks. The authors registered the video game's total score, which comprised the sub-variables control, speed, and accuracy. Control assesses hand-eye coordination and dexterity while the player tries to maintain the ship's direction and position during the game. Speed assesses working memory capacity and reaction time as the player recognizes and responds to stimuli (enemy mines). Accuracy assesses psychomotor skill as the player successfully hits his target (fortress). The authors of this study did not detect any statistically significant differences between the three groups in any of the evaluated variables. No assessments or occurrences of side effects have been reported.

The effects of caffeine on the cognitive performance of professional esports players have been tested in a double-blind, placebo-controlled crossover study conducted by Sainz et al. (2020) in Spain [26]. The volunteers consisted of 7 Fortnite and 8 Counter-Strike: Global Offensive professional male players, with a mean age of 22 (SD=3) years, and which averaged 10 (SD=2) hours of esports training per day. On two occasions, separated by 3 days, they received 3 mg/kg of caffeine or a placebo, 45 to 60 min before performing 5 attempts in a simple visual reaction time and 3 attempts at a 2-min FPS game (3D Aim Trainer) in which each subject had to hit 60 fixed targets on each occasion and that included hit accuracy and average hit time variables. These investigators observed significant improvements of caffeine on the simple visual reaction time test [0.20 (SD=0.01) vs. 0.19 (SD=0.01) s, $p<0.01$], in the mean time entailed to hit 60 targets that showed in each try at the FPS computer game [0.92 (SD=0.07) vs. 0.88 (SD=0.07) s, $p<0.01$], and on the targets hit accuracy [98.8 (SD=0.92) vs. 99.8 (SD=0.35) of targets hit, $p<0.01$] compared to the placebo condition.

In a randomized placebo-controlled crossover study, Franke et al. (2017) [28] tested the effects of 200 mg

Table 3. Limitations of the included studies

	Molesworth et al. (2008)	Sainz et al. (2020)	Franke et al. (2017)	Thomas et al. (2019)	La Monica et al. (2021)	Bloomer et al. (2022)	Tartar et al. (2021)	Leonard et al. (2023)	Schwager et al. (2023)	Kriter (2020)	Tartar et al. (2019)	Sowinski et al. (2021)	Emerson et al. (2022)	Rhoden et al. (2021)	Furukado et al. (2022)	Lange et al. (2014)
Main DS tested	Caffeine										L-Arginine			Carbohydrates		
Excluded smokers	–	Yes	Yes	–	–	–	Yes	–	Yes	–	Yes	–	–	–	–	–
Excluded consumers of caffeine-containing beverages	–	Yes	Yes	–	Yes	–	Yes	Yes	–	–	–	Yes	–	–	–	–
Requested to stop caffeine intake before testing	Yes	Yes	–	Yes	Yes	Yes	–	Yes	Yes	–	Yes	–	–	–	–	–
Reported habitual caffeine consumption	–	–	–	–	–	Yes	–	–	Yes	–	–	–	–	Yes	–	–
Requested to stop alcohol intake before testing	No	Yes	–	–	No	Yes	–	–	Yes	–	Yes	–	–	–	–	–
Excluded DS users	No	Yes	–	–	Yes	–	–	Yes	–	–	–	Yes	–	–	–	–
Requested to cease DS intake before testing	–	–	–	–	Yes	–	–	Yes	–	–	Yes	Yes	–	–	–	–
Excluded medicine users	–	Yes	Yes	–	Yes	–	Yes	–	–	–	–	Yes	–	–	Yes	–
Assessed sleepiness or sleep duration/quality	Yes	Yes	–	–	–	–	–	Yes	Yes	–	–	–	–	–	–	–
Assessed physical exercise before testing	–	Yes	–	–	–	Yes	–	Yes	Yes	–	–	–	–	–	–	–
Requested to refrain from or moderate physical exercise	–	Yes	–	–	Yes	–	–	–	Yes	–	–	–	–	–	–	–
Assessed the volunteer's typical diet (e.g. food diary)	–	–	–	–	Yes	Yes	–	Yes	Yes	–	–	Yes	–	–	–	–
The DS was tested for purity and potency by a third-party laboratory	–	–	–	–	Yes	–	–	–	Yes	–	No	Yes	–	–	–	–
The DS manufacturer/source was stated	–	Yes	–	Yes	Yes	–	–	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
The DS dosage was adjusted to the volunteer's body weight (kg)	Yes	Yes	–	No	No	–	–	No	No	–	–	–	–	–	–	–
Reported if the DS was consumed in a fasted or fed state	Yes	–	Yes	–	Yes	Yes	–	Yes	Yes	–	–	Yes	–	Yes	–	Yes
Reported the specific hours of the day for DS and tests administration	Yes	Yes	Yes	Yes	–	Yes	–	–	–	–	–	–	–	–	–	–
Reported the number of hours of videogame play per day/week	Yes	Yes	–	Yes	–	Yes	–	–	–	–	–	–	Yes	Yes	–	–
Reported esports players expertise level (e.g. professional)	–	Yes	Yes	Yes	Yes	–	–	–	–	–	–	–	–	–	–	–

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Table 3. Limitations of the included studies (Continued)

	Molesworth et al. (2008)	Sainz et al. (2020)	Franke et al. (2017)	Thomas et al. (2019)	La Monica et al. (2021)	Bloomer et al. (2022)	Tartar et al. (2021)	Leonard et al. (2023)	Schwager et al. (2023)	Kriter (2020)	Tartar et al. (2019)	Sowinski et al. (2021)	Emerson et al. (2022)	Rhoden et al. (2021)	Furukado et al. (2022)	Lange et al. (2014)
Reported the specific video game genre the volunteers typically played	–	Yes	Yes	Yes	–	Yes	Yes	Yes	–	–	–	–	–	–	–	Yes
Assessed DS side effects	–	–	Yes	–	Yes	Yes	Yes	Yes	Yes	–	Yes	Yes	–	–	–	–
Performed sample size calculations	–	–	Yes	–	–	–	–	Yes	–	–	–	–	–	–	–	–
Enrolled a sufficient number of volunteers to detect effect sizes (n≥15)	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes
The study was funded by a food or DS company	–	–	No	Yes	Yes	Yes	Yes	Yes	Yes	–	Yes	Yes	Yes	–	Yes	–

Abbreviations: DS: dietary supplement.

(~2.5 mg/kg) of caffeine on 39 German male chess players [mean age: 37.3 (SD=12.5) y, body weight: 81.0 kg (SD=13.9), height: 179.7 (SD=6.9) cm, BMI 25.0 (SD=3.7) kg/m^2] in a battery of cognitive tests and a series of rapid chess games. These were highly skilled tournament players, with a mean ELO score of 1670.4 (SD=340.0) and an intelligence quotient (IQ) of 127.7 (SD=11.3). The set of cognitive tests included the Stroop task, Psycho-Motor-Vigilance-Test, Trail-Making-Test, Wisconsin-Card-Sorting-Test, Balloon Analogue Risk Task, and Tower of Hanoi. Each chess game had a time limit of 15 min, in which the participants played against a computer program. Although these investigators detected trends for an improved score in all games [from 0.510 (SD=0.028) to 0.543 (SD=0.023); p=0.164], caffeine significantly increased the average time of decisive reflection per chess game (from 436.8 (SD not stated) to 530.1 (SD not stated) s; p<0.001), which increased timeout game losses in comparison with the placebo condition (from 30 (SD not stated) to 70 (SD not stated) games; p=0.023). Short-term adverse effects were reported by 6 volunteers (8 events) treated with caffeine. The most common were headaches (3 subjects).

Thomas et al. (2019) [13] conducted a randomized, double-blind, placebo-controlled, crossover study in which they tested the effects of an energy drink (Reload^{TM}) containing 150 mg (~1.9 mg/kg) of caffeine on attention, reaction time, working memory, and fatigue on players of League of Legends, an action real-time strategy game. The 9 participants were members of a professional male team that trained in esports for an average of 10.3 (SD=2.1) hours a day and had a mean age of 21 (SD=2) y, body weight: 80.1 kg (SD=13.9), height: 177.0 (SD=7.0) cm, BMI 25.6 (SD=3.4) kg/m^2]). The cognitive tests applied included measures of attention (Erikson Flanker Test), reaction time and response inhibition (Go/No-Go visual test), working memory (n-back test), and fatigue (hand grip strength and finger tap speed). The mean reaction time significantly improved in the n-back test for the energy drink [−171 ms (95% CI, −327.91 to −14.09), p<0.004] versus the placebo condition [−92 ms (95% CI, −213.63 to 29.63)], indicating enhanced working memory. These investigators didn't observe any statistically significant effects in the remaining cognitive tests. Of note, the energy drink included 12 g of glycerol, 150 μg of cobalamin, 70 mg of magnesium, 40 mg of sodium, and a non-disclosed quantity of theanine, NADH, choline, phosphatidylserine, alpha-glycerylphosphorylcholine, and L-Carnitine. No health side effects were assessed nor described in this study.

In a repeated-measures, double-blind, crossover, placebo-controlled trial, La Monica et al. (2021) [15] tested the acute effects of 125 mg (~1.5 mg/kg) of caffeine, or a combination of 125 mg of caffeine with 50 mg of theacrine and 75 mg of methylliberine (CMT) on nine male amateur esports players [mean age: 23.4 (SD=5.7) y, body weight: 86.0 kg (SD=17.1), height: 178.9 (SD=5.8) cm, BMI: 26.7 (SD=4.0) kg/m^2], on a first-person shooter game (Aim Lab). Aim Lab included 4 tasks: 1) the Spidershot, in which the participant must shoot an orb three times to "kill" the target, which is presented on the screen at pseudo-random intervals. It assesses motor control, precision, accuracy, and reaction time; 2) the TriggerControl, a go/no-go style test, evaluates visual processing speed and accurateness, as well as the cognitive capacity to prevent premature responses, false alarms, and reaction time; 3) the Spheretrack, in which one must maintain the crosshair of a virtual weapon on a moving orb as long as possible, tests motor control and visuospatial processing of motion 4) the Capacity, in which the participant is required to recognize and shoot targets that have changed color, assesses visuospatial working memory. On the Spidershot task, CMT lowered reaction time from starting point compared with placebo (Effect Size as ξ=0.35; p=0.017), while the decrease with the caffeine alone wasn't statistical significance in comparison with the placebo condition (ξ=0.35; p=0.061). On the Spheretrack task, caffeine increased the proportion of time on target compared to CMT (ξ=0.50; p=0.047) and placebo (ξ=0.50; p=0.008). CMT improved the visual capacity threshold in the Capacity task compared with caffeine (ξ=0.48; p=0.007) and a placebo (ξ=0.48; p=0.030). However, caffeine provided a significant reduction in the time to kill in comparison with the placebo (ξ=0.37; p=0.018), while the reduction in the CMT condition didn't reach statistical significance compared to the placebo (ξ=0.37; p=0.065). Additionally, in TriggerControl, caffeine significantly decreased reaction time for false alarms (trigger happy) compared to both CMT (ξ=0.61; p=0.001) and placebo (ξ=0.61; p=0.002). Despite the authors stating an absence of adverse effects, the caffeine condition caused a significantly substantial rise in jitteriness compared to the placebo (ξ=0.27; p=0.043) and they registered a significantly greater increase from baseline in systolic blood pressure for CMT (ξ=0.37; p=0.020) and caffeine (ξ=0.37; p=0.025) compared to placebo.

More recently, Tartar et al. (2021) [29] also trialed caffeine (125 mg, or ~1.5 mg/kg), and a combination of 75 mg of Theacrine, 50 mg of Methylliberine, and 125 mg of caffeine (CDT) in a randomized, placebo-controlled, double-blinded, crossover study. The group of volunteers consisted of 50 amateur players [age: 18–40 years, mean body weight: 81.7 kg (SD=17.2), height: 177.6 (SD=9.1) cm], who accumulated at least 10 hours of practice in first-person shooter video games. These researchers tested the effects of each treatment on the Flanker Test of Inhibitory Control, which measures attention and inhibitory control; the Psychomotor Vigilance Task, which measures sustained attention through simple reaction time assessment; the Pattern Comparison Processing Speed Test, which assesses processing speed; the Dimensional Change Card Sort Test, which measures executive function. Additional tests included EEG alpha, beta, delta, and theta frequency bands while the volunteers performed the cognitive tests. These authors reported statistically significant increases in the Flanker test (attention and inhibitory control) score, from pre- to post-ingestion, for the CDT [from mean=60.6 (SD=9.9) to mean=63.0 (SD=8.1); p=0.004] and caffeine condition [from mean=60.0 (SD=10.4) to mean=63.1 (SD=8.7); p=0.002]. Significant declines (enhancement) were registered on the Psychomotor Vigilance Test reaction time, in the CDT condition from pre- to post-dose [from mean=283.4 (SD=90.0) ms to mean=267.5 (SD=63.2) ms; p=0.044]. They also observed significant decreases in delta power in the caffeine group from pre- to post-dose [from mean=31.5 (SD=20.1) to mean=25.9 (SD=14.9); p=0.035], but significant increases in the delta band (which may represent enhanced attention to internal cognitive processes) in the CDT group from pre to post-dose [from mean=25.8 (SD=13.7) to mean=29.6 to (SD=14.9); p=0.050] and theta bands (associated with higher greater cognitive control) [from mean=15.8 (SD=7.3) to mean=18.5 (SD=11.0); p=0.041]. No statistically significant differences were registered on the Pattern Comparison Processing Speed Test and Dimensional Change Card Sort Test. Regarding side effects, despite reporting jitteriness, heart rate, and blood pressure assessments, these authors provide no data or results regarding these variables.

Bloomer et al. (2022) [37] assessed the effects of a blend of caffeine and antioxidant polyphenols (AmaTea® Max) on experienced players of Fortnite, a third-person shooter video game. This placebo-controlled, double-blind, randomized study involved 49 healthy individuals [mean age: 22 (SD=3) y, body weight: 82 kg (SD=19), height: 178 (SD=8) cm), BMI 26 (SD=5) kg/m^2] which played video games a minimum of 4 h/day, 4 days a week. On three occasions, separated by a week, the volunteers ingested either a placebo, 270 mg (~3.3 mg/kg) of caffeine, or a blend of 270 mg of caffeine and polyphenol antioxidants (AmaTea®). The volunteers arrived at each laboratory visit in a 3-hour fasted state and played Fortnite during 4 periods of 1 hour each. Their cognitive performance was assessed through Fortnite videogame statistics, namely the number of "kills" per match and the overall placement (ranking) of their team. Additionally, they were subjected to the Digit Symbol Substitution test and the Reaction Time test, performed at baseline and repeated at 1, 2, 3, and after 4 hours of gameplay.

The AX-Continuous Performance Test was also applied at baseline and after 4 hours of Fortnite gaming. These authors didn't register statistically significant differences regarding any cognitive tests or any aspect of gaming performance. Regarding side effects, caffeine, and AmaTea® significantly raised systolic blood pressure (SBP) compared to the placebo (p<0.05). It increased from 123 (SD=13) at hour 0 to 131 (SD=13) mmHg at hour 3 for caffeine, and from 122 (SD=11) at hour 0 to 131 (SD=13) mmHg at hour 3 in the AmaTea® condition. Additionally, the caffeine condition, but not AmaTea®, was associated with significantly higher jitteriness compared to the placebo condition (p=0.02), increasing from 26 (SD=27) at hour 0 to 35 (SD=28) at hour 1.

In a crossover design study that hasn't been randomized, double-blinded, or controlled for placebo, Kriter (2020) [31] aimed to investigate if supplementation with caffeine, provided through an energy drink (Red Bull), improves recognition capacity and reaction time, as assessed through Tetris game scores. For this experiment, the author recruited 5 volunteers, which played a session of 5 rounds of Tetris, then drank the energy drink before playing an additional session of 5 rounds of the Tetris video game. Each session was preceded by 15 minutes of Tetris "warm-up". Assuming that the volunteers have received the "classic" Red Bull energy drink, one serving (250 mL) would have provided 80 mg of caffeine per serving, 21.5 g of sucrose, 5.3 g of glucose, 1,000 mg of taurine, 60 mg of glucuronolactone, 50 mg of inositol and vitamins (niacin, panthenol, B6, B12) [38]. Although the author reported gradual trends for improvements in Tetris score in the Red Bull condition, he didn't observe statistically significant differences between the two sessions of Tetris video gaming. No additional information was provided by the author regarding the participant characteristics or side-effect assessment [31].

In a randomized, double-blind, placebo-controlled, crossover trial, Schwager et al. (2023) [33] tested the acute effects of an energy drink (C4 Smart Energy) on the cognitive function and gaming performance of 45 healthy young adults [37 males, 8 females; mean age=25.2 (SD=5.8) y; height=173.2 (SD=8.9) cm; weight=76.7 (SD=15.4) kg; BMI=25.5 (SD=4.4) kg/m^2] who played video games at least 1 h per week.

On two occasions, separated by a one-week washout period, the participants ingested either a placebo beverage or a sugar-free energy drink containing 200 mg of caffeine, potassium, niacin, vitamin B12, citicoline, and tyrosine. Fourteen minutes after ingesting the drink, the volunteers were subjected to a battery of 10 cognitive tests (CNS Vital Signs) which included the Verbal Memory Test, Visual Memory Test, Finger Tapping Test, Symbol Digit Coding, Stroop Test, Shifting Attention Test, Continuous Performance Test, Perception of Emotions Test, Non-Verbal Reasoning Test, and the Four Parts Continuous Performance Test. These tests assessed 15 cognitive domains: verbal memory, visual memory, composite memory, psychomotor speed, reaction time, complex attention, cognitive flexibility, processing speed, motor speed, executive function, simple attention, social acuity, reasoning, sustained attention, and working memory. Afterward, the participants' gaming performance was assessed in five different video games: Tetris, Four-in-a-Row, Rayman Legend, FIFA-14, and Call of Duty: Advanced Warfare. Adverse events were also assessed, including blood pressure, oxygen saturation, heart rate, cardiac electrical activity, heart palpitations, nausea, vomiting, bloating, diarrhea, constipation, itching, headache, fatigue and sleep duration, sleep disruptions, and sleep quality. The energy drink condition outperformed the placebo condition in terms of cognitive flexibility (absolute mean or median difference [95% CI]=+4.3 [2.2; 6.4]; p<0.001; d=0.63), executive function (+4.3 [2.3; 6.3]; p<0.001; d=0.63), sustained attention (+2.1 [0.6; 3.6]; p=0.01; d=0.44), motor speed (+2.9 [0.8; 4.9]; p<0.001; d=0.44), psychomotor speed (+3.9 [0.1; 7.7]; p=0.04; d=0.32) working memory (+1.0 [0.1; 1.9]; p=0.02; d=0.35), and in Tetris gaming scores (+463 [−419; 2,065] points; p=0.049; d=0.30). There were no statistically significant differences in complex attention, composite memory, visual memory, verbal memory, reaction time, reasoning, processing speed, social acuity, or simple attention, nor the scores in the video games Four-in-a-Row, Rainbow Legends, FIFA-14, and Call of Duty: Advanced Warfare. Except for blood pressure, there were no significant differences regarding side effects. The energy drink condition raised systolic and diastolic blood pressure by 2.9–5.0 mmHg and 3.7–5.4 mmHg, respectively.

In a double-blind, placebo-controlled, parallel trial, Leonard et al. (2023) [30] tested the acute and 30-day effects of a combination of microalgae (Phaeodactylum tricornutum) and guarana extract on the cognitive function and video-game performance of experienced esports players. The 61 volunteers (51 males, 10 females) averaged 21.7 (SD=4.1) y, 173.4 (SD=8.2) cm, 73 (SD=13) kg, and 24.2 (SD=3.6) kg/m2. 35 subjects played a first-person shooter game (Call of Duty: n=18, Overwatch: n=7, Valorant: n=10), 13 played Super Smash Bros., 11 played League of Legends, and 2 played Rocket League. The volunteers were randomly distributed into three groups. One placebo group; one low-dose group that ingested 440 mg of Phaeodactylum tricornutum extract, including 4.4 mg of fucoxanthin and 500 mg of guarana, containing 40–44 mg (or ~0.5–0.6 mg/kg) of caffeine; and one high dose group that ingested 880 mg of Phaeodactylum tricornutum extract (8.8 mg of fucoxanthin) and 500 mg of guarana. A battery of cognitive tests was administered at baseline, 15 minutes after taking the DS, and after 60 minutes of competitive gameplay using the participants' favorite video game. Subjects took the DS for 30 days before repeating pre- and post-gaming cognitive function assessments. The cognitive tests included the Berg-Wisconsin Card Sorting Task, the Go/No-Go Task, the Sternberg Task, the Psychomotor Vigilance Task, and the Light Tracking Reaction Test. The video game's performance was assessed through in-game scores. Questionnaires were used to assess potential side effects, namely sleep quality and duration, dizziness, rapid heart rate, heart palpitations, shortness of breath, fuzzy vision, and anxiousness. No statistically significant differences were registered between the 3 groups regarding cognitive performance, in-game performance, or side effects. However, some statistically significant (p<0.05) positive effects on cognitive performance (reaction times, reasoning, learning, executive control, attention shifting, and impulsiveness) were observed after acute supplementation, but mainly after 30-day supplementation.

L-Arginine

In a parallel-group, placebo-controlled trial, Tartar et al. (2019) [14] tested the effects of a supplement (nooLVL®) containing 1500 mg (~17.4 mg/kg) of arginine silicate and 100 mg of inositol, administered for seven days, on the cognitive performance of 50 males and 10 female amateur esports players [mean age: 28.6 (SD=5.4) y, body weight: 86.0 kg (SD=17.3), height: 178.6 (SD=6.7) cm], BMI 26.9 (SD=4.7) kg/m^2), who played video games for ≥5 hours per week. On two visits (7 days apart), the volunteers completed the Trail Making Test (TMT Parts A and B), and the Stroop Tests before, and 15 min after dosing. The TMT-A, B, and Stroop Test were again applied after 60 min of video game playing. Additionally, the subject's performance was also assessed through in-game scores. No significant differences were detected regarding video game performance and cognitive tests except for the TMT – Part B test, conducted on the first visit, in which the treatment group made significantly fewer errors in comparison with the placebo group fifteen minutes after supplement ingestion (p=0.04). Additionally, these investigators reported minimal and similar frequency of adverse effects (blood pressure and heart rate) in both groups, but without describing them in detail.

In a later study, Sowinski et al. (2021) [25] trialed the same supplement [1500 mg of arginine silicate, or ~21.1 mg/kg) +100 mg of inositol] on 26 healthy individuals with a mean age of 23 (SD=5) y, 71.1 kg (SD=13.8) of body weight, 171 (SD=11) cm of height, and a BMI of 20.7 (SD=3.5) kg/m^2, on a set of cognitive tests and gaming performance. The volunteers were experienced esports players who played video games at least 5 hours a week in the past 6 months. In this double-blind, randomized, placebo-controlled, and cross-over trial, they acutely administered nooLVL®, or a placebo on two different occasions, separated by a 7 to 14-day interval. On each occasion, the volunteers fasted for 8 hours and then ingested the supplement or placebo (maltodextrin), before initiating a battery of cognitive tests, which included the Berg-Wisconsin Card Sorting Task test, Go/No-Go test, Sternberg Task Test, Psychomotor Vigilance Task Test, Cambridge Brain Sciences Reasoning and Concentration test, and a Visual Reaction Test. The subjects ingested the treatment, and 15 min later repeated the battery of cognitive tests. Hereafter, participants played their preferred eGame for one hour before repeating the battery of tests. No significant improvements in gaming performance were observed. In comparison with the placebo, supplementation with arginine+inositol only provided statistically significant improvements in the Sternberg Mean Present Reaction Time, namely in post-game 4 Letter Absent Reaction time (ES, as η_p^2=0.31; p=0.05), 6 Letter Present Reaction Time (η_p^2=0.41; p<0.01), 6 Letter Absent Reaction Time (η_p^2= 0.36; p=0.01), Mean Present Reaction Time (η_p^2=0.21; p=0.02), and Mean Absent Reaction Time (η_p^2=0.24; p=0.03). These investigators assessed side effects through a questionnaire. Reported adverse effects were sporadic and of mild severity, and there were no significant differences across regimens.

In a randomized, double-blind, placebo-controlled, parallel-group, prospective study, Emerson et al. (2022) [35] assessed the effects of nooLVL® on the cognitive performance of nine experienced esports players (18–32 y) who played video games at least 3–5 hours/week in the previous 6 months. The volunteers ingested 1600 mg of nooLVL® (600 mg of arginine, 105 mg of silicon, 385 mg inositol, and 60 mg potassium) per day for seven days, and were subjected to a battery of computerized cognitive tests at baseline, on day 1, and again 7 days after ingesting the supplement. These investigators detected statistically significant differences in the Stroop test (attention/concentration) when comparing baseline versus day 1 (p=0.0019), baseline versus day 7 (p=0.0005), and day 1 compared to day 7 (p=0.0369). Significance was also observed in the Mental rotations test (visual representation) when contrasting the baseline to day 1 (p=0.0506) and baseline to day 7 (p=0.0192). Outcomes of the Spatial Planning test (forethought and sequencing) also significantly improved when comparing day 7 to the baseline (p=0.0266). However, results from the Feature Match (visual perception), Polygons (object relationship), and Odd One Out (deductive reasoning) tests did not demonstrate significance (p values not reported).

Carbohydrates

In 2014, Lange et al. [32] conducted a randomized, placebo-controlled, parallel-group trial. Their purpose was to verify if the consumption of a sugar-containing drink after an initial self-control task (a go/no-go task) improved self-control performance in another self-control task (a Tetris video game). These authors recruited 70 university students

(62 female), who averaged 21.8 (SD=2.6) years, 21.5 (SD=2.8) kg/m^2, and 2.4 (SD=1.0) years of Tetris experience. The participants were randomly distributed into two groups. An experimental group consumed 250 mL of soda (7 Up®) containing 26.8 g of sugar [39], while a control group consumed 250 mL of sugar-free, artificially sweetened soda (7 Up Light®). All participants were asked to arrive at the laboratory in a fasted state (≥1.5 hours). After an initial blood glucose assessment, they completed a battery of behavioral tasks and psychometric questionnaires for about an hour and then performed the go/no-go task (75 initial training trials plus 450 subsequent test trials). Then, they consumed the drink (classic 7 Up® or 7 Up Light®). 10 to 15 minutes later, and after a second blood glucose assessment, the volunteers played Tetris for 10 minutes, commencing from level one, having been instructed to reach the highest total score possible. The investigators assessed various Tetris gaming performance parameters, namely the percentage of single-line clears, the percentage of four-line clears, the total number of lines, the number of restarts, and the total score. Although the authors registered a significant increase in blood glucose in the group that ingested the drink with sugar ($t(34)=10.04$, $p<0.001$, $d=3.44$), and a significant decrease in blood glucose in the control group ($t(34)=4.74$, $p<0.001$, $d=1.63$), they did not detect statistically significant differences between the two conditions, in terms of performance, on any of the variables related to performance in Tetris. No side effects were assessed or reported.

In a randomized, cross-over trial conducted in 2021, Rhoden et al. [27] tested the effects of an energy bar (Cliff bar) containing 21 g (~0.23 g/kg) of sucrose on the cognitive ability of eight males and one female amateur esports players who were members of a university esports club and played esports on average 18.9 (SD=14.3) hours per week [mean age: 20.3 (SD=1.2) y, body weight: 92.5 kg (SD=23.7), height: 179.3 (SD=4.5) cm), BMI 28.8 (SD=7.6) kg/m^2]. On one occasion, after at least an 8-hour night fast, they ingested the energy bar one hour before completing 60 minutes of gaming using two esports training platforms (Aim Hero and Osu!). The same procedure has been repeated on another occasion but in a fasted state. Osu! is a video game in which the user must use the mouse cursor to click and/or drag spherical objects and "sliders". Performance statistics comprised: targets missed, largest combo, accuracy (%), error pre (ms), error post (ms), unstable rate, and score. Aim Hero is a first-person shooter (FPS) style aim-training program used by FPS players to improve their aim. Recorded variables included: total shots, number of targets hit, accuracy (% of shots that hit the targets), time per hit(s), time to complete, and score. Despite significant increases in blood glucose levels in the fed versus fasted trial, no statistically significant differences were detected in gaming performance when comparing fed to fasted sessions ($p > 0.05$). No adverse effects were assessed or reported in this study.

Furukado et al. (2022) [34] led a randomized, crossover, double-blind, placebo-controlled study that investigated the effects of glucose ingestion on the cognitive performance of 20 male university students [mean age: 19.9 (SD=1.0) y, body weight: 63.9 kg (SD=6.0), height: 171.4 (SD=4.8) cm)] who typically did not play video games, during up to about 28 minutes of gameplay on the esport racing game "Gran Turismo Sport". On two occasions, separated by two weeks, they ingested either a 29 g weight candy containing 26.1 g (~0.41 g/kg) of glucose, or a placebo containing erythritol. The TMT-A and B tests were applied at baseline and the end of the game. EEG measurements of the alpha, beta, and sensorimotor rhythm waves were also performed before, 5, 10, and 25 min after the game started. Although no statistically significant differences were detected on the TMT-B tests, the glucose condition showed a significant decrease in the time required to complete the TMT-A test compared with the placebo condition (ES as $d=0.41$, $p=0.08$). There were no significant differences in EEG measurements except for increases in the glucose versus placebo condition at 25 minutes after starting the race game, in the alpha ($d=0.45$, $p=0.06$) waves, indicating greater relaxation, and SMR ($d=0.70$, $p=0.005$) wavebands, which refer to both relaxed and concentrated states. These authors didn't report the methodology for side effects assessment nor their occurrence.

Discussion

Summary of evidence

From the total of sixteen studies included in this review, ten included caffeine in the tested substances [13, 15, 26, 28, 29, 30, 31, 33, 36, 37]. Six studies trialed isolated caffeine [15, 26, 28, 29, 36, 37]. Three studies trialed energy drinks containing caffeine [13, 31, 33]. Two studies tested the effects of a combination of 125 mg caffeine, 75 mg methylliberine, and 50 mg theacrine [15, 29], one study trialed the effects of a mix of 270 mg of caffeine with polyphenols [37] and another assessed the effects of a combination of caffeine and fucoxanthin. Three investigations assessed the effects of a combination of 1500 mg arginine+100 mg inositol [14, 25, 35]. Two studies examined the effects of sucrose [27, 32], and another tested the effects of glucose [34].

All 16 studies involved acute interventions except for the investigations conducted by Tartar et al. (2019) [14] and Emerson et al. (2022) [35], in which the volunteers ingested an arginine-based supplement or a placebo for seven consecutive days, and the study authored by Leonard et al.

(2023) [30], which tested the effects of a combination of a microalgae extract with guarana ingested daily for 30 days. Most studies (n=10) included a crossover design [13, 15, 25, 26, 27, 28, 29, 33, 34, 37]. The investigations authored by Emerson et al. (2020) [35], Rhoden et al. (2021) [27], and Kriter (2020) [31] were the only ones that didn't include a placebo group. Excluding the study by Kriter (2020) [31] which didn't detail volunteers, and the Franke et al. (2017) [28] research, where the subjects averaged 37.3 (SD=12.5) years, all studies involved young adult volunteers.

The 16 studies included a total of 519 participants. Eight studies included females as subjects [14, 25, 27, 30, 32, 33, 35, 37]. Excluding the nine participants of the Emerson et al. (2020) [35] study, and the five participants of the Kriter (2020) trial [31], which didn't detail the sex of the participants, males comprised the majority (90.7%) of the remaining total volunteer sample (n=505) of the remaining 14 studies.

The majority (10) of the studies included in this review included experienced esports players as subjects [13, 14, 25, 26, 27, 28, 29, 30, 35, 37], while the remaining studies enrolled recreational gamers [15], inexperienced players [34], or did not describe subjects gaming expertise level [31, 33, 36].

Only five studies reported on the video game name that the volunteers regularly played. Thomas et al. (2019) [13] enlisted League of Legends players. Bloomer et al. (2022) enrolled third-person shooter (Fortnite) gamers. Sainz et al. (2020) [26] incorporated Fortnite and first-person shooter (Counter-Strike: Global Offensive) players. Leonard et al. (2023) [30] included Call of Duty, Overwatch, Valorant, Super Smash Bros., League of Legends, and Rocket League players. While Tartar et al. (2021) [29] also recruited first-person shooter (FPS) players, they didn't specify the game title. The study by Frank et al. (2017) [28] is notable for involving skilled and highly competitive chess players. Online chess is regarded as an esport genre and has also seen a surge in popularity [40].

Although not based on studies performed on esports players, there is ample scientific literature that supports the nootropic effects of caffeine. In their systematic review, Torres and Kim (2019) concluded that caffeine consistently lowers marksman reaction time and that doses of 100–200 mg every 2 hours might mitigate performance decrements in marksman accuracy caused by stress and fatigue [41]. It has also been shown to significantly improve alertness, executive control, and performance on complex and simple attention tasks, including reaction time, and accuracy on simple tasks. Attention seems to be the most consistently enhanced domain [42]. Another review concluded that a dosage of $\sim$0.5–4 mg/kg of caffeine improves reaction time, alertness, and vigilance. Additionally, caffeine helps to prevent the cognitive performance degradation associated with mental fatigue or sleep deprivation [43]. However, caffeine may cause undesirable effects, such as elevated blood pressure, anxiety, tremors, and decreased sleep quality [44]. Detrimental health problems, especially cardiovascular and psychological, have been documented in adolescents, mainly when ingesting high doses of caffeine [45]. According to EFSA, single doses of 3 mg/kg bodyweight do not raise health concerns for both adolescents and adults [44].

Caffeine may have a double-edged sword role in esports. The included studies reported significant improvements in a set of cognitive domains, including inhibitory control, cognitive flexibility, working memory, attention, time on target tracking, hit accuracy, and reaction speed [15, 26, 29, 33], which may be especially relevant for FPS players, in which accurate aim and speedier actions are considered two of the most crucial requirements for achieving victories [46], and caffeine may allow them to at least move up one level in the ranking system [47].

However, caffeine administration should be carefully considered as it may significantly impair gaming performance by increasing anxiety [29], impulsivity, and jitteriness [15], which may be limited by its co-ingestion with MTL and THC [15, 29]. Moreover, the influence of caffeine on decision-making and complex judgment is still unclear [43] and its supplementation implies potential negative effects, including increased sleep latency, decrease sleep efficiency, and reduced total sleep time [44], all of which could harm esports competitors' sleep hygiene, which already shows a tendency to disrupted sleep patterns [48]. Higher cortisol levels and anxiety before a competitive event have been reported in highly-skilled esports players [49], and caffeine consumption by a non-fatigued and highly aroused individual may produce an excessive arousal state and degrade cognitive performance [43].

Regarding supplementation with arginine, Sowinski et al. (2021) [25] registered significantly improved reaction times in some cognitive tests, and Emerson et al. (2020) [35] reported significantly improved attention, visual processing, and spatial planning. These results contrast with those of Tartar et al. (2019) [14] who, except for a lower number of errors committed in the TMT – Part B test on one of two occasions, didn't observe statistically significant improvements in cognitive tests compared to a placebo. Moreover, both Sowinski et al. (2021) [25] and Tartar et al. (2019) [14] failed to detect significant improvements in video gaming performance.

Concerning carbohydrates, Rhoden et al. (2021) [27] and Lange et al. (2014) [32] didn't observe significant improvements in video game performance with the administration of 21 and 26.8 g of sucrose, respectively. On the other hand, Furukado et al. (2022) [34] noted significant improvements in attention and processing speed with 26.1 g of glucose, which has metabolic effects distinct from sucrose and has more solid scientific support as a nootropic in healthy adult subjects [50].

Limitations

As we restricted our search to four databases and papers published in the English language, we may have missed relevant articles and grey literature published in other databases and written in other languages. Because esports has a higher presence in Southeast Asia [51], relevant papers could be outlined in those countries' bibliographic databases. For the Emerson et al. (2022) [35], and Kriter (2020) [31] studies, only an abstract was available, which limited the amount of information we were able to analyze, extract and summarize. Of note, despite having been published, the study conducted by Rhoden et al. (2021) [27] has not been peer-reviewed.

The studies included in this review were affected by several limitations:

a) Some lifestyle and dietary-related variables may affect cognitive performance, act as confounders in controlled studies, and should be assessed. These include medicines [52], nicotine [53], alcohol intake [54], sleep perturbations [55], physical exercise [56], diet style (e.g. ketogenic diet) [57], breakfast intake/omission [58], caffeine [43], and DS (e.g. *Bacopa monnieri*) [59] intake. However, only five studies excluded medicine users [15, 25, 26, 28, 29, 34], while merely four studies excluded smokers [14, 26, 28, 29], two requested participants to abstain from alcohol [14, 37], four requested to stop DS intake [14, 15, 25, 30], two excluded DS users [15, 25, 26, 30], three assessed sleepiness or sleep duration/quality [26, 30, 36], two requested volunteers to refrain or moderate from physical exercise 24 h before testing [15, 26], four assessed the volunteer's typical diet (e.g. food diary) [15, 25, 30, 37], and only eight reported if volunteers ingested the DS in a fasted or fed state [15, 25, 27, 28, 30, 32, 36, 37].
b) Methodologies varied greatly among the studies that tested caffeine. Seven studies requested volunteers to abstain from caffeine intake [13, 14, 15, 26, 30, 36, 37], and six studies excluded consumers of caffeine-containing beverages [15, 25, 26, 28, 29, 30]. The maximum dose of caffeine allowed for inclusion in the five studies that enforced a daily limit also differed. Sainz et al. (2020) [26] applied a limit of 80 mg, Sowinski et al. (2021) [25] imposed a value of 200 mg, Franke et al. (2017) [28] excluded those who ingested five or more daily cups of coffee, while Tartar et al. (2021) [29] and La Monica et al. (2021) [15] set a limit of 400 mg of caffeine per day.
c) Although the circadian rhythm can modulate the effect of nutrients in the human body [60], only five studies reported the specific hours of the day when the DS were administered and the tests were performed [13, 26, 28, 36, 37].
d) Ideally, the dosage of DS to be administered should be adjusted to each individual's weight, which only happened in the studies conducted by Molesworth et al. (2008) [36] and Sainz et al. (2020) [26].
e) The cognitive tests and video games used in these studies have not been validated as tools to assess cognitive performance in esports players [13], and some have not been properly tested in any specific population, with no existing data on their reliability, validity, and sensitivity to pharmacological or dietary interventions [61]. Indeed, Toth et al. (2019) [47] found that the Stroop Task did not distinguish cognitive inhibition capacity among Counter-Strike: Global Offensive competitors of various levels of skill.
f) Cognitive performance may peak around young adults age [62] and some of the cognitive tests applied may not have been cognitively challenging enough for experienced esports players (ceiling effect) [14].
g) Experienced esports players tend to have a different brain structure, with thickening in several areas, and greater cognitive capacities than non-gamers, including higher attention, visual, and memory capacities [2, 19]. Moreover, different esports genres have specific mechanics and may require distinct sets of cognitive abilities [63]. Thus, the results of studies conducted on players of a genre and expertise level may not be applicable or undesirable in others. Nonetheless, only four studies reported esports player's expertise level [13, 15, 26, 28], while six stated the number of hours of video game play per day or week [13, 26, 27, 35, 36, 37], and seven disclosed on the specific video game genre the volunteers typically played [13, 26, 28, 29, 30, 32, 37].
h) Because they comprised mostly male volunteers (90.7%), the included investigations failed to account for potential sex inequalities. Sex differences may have operated as a confounder, and the results may not apply to female egamers. For example, caffeine has shown greater arousing effects in males [64, 65].
i) Only two studies performed sample size calculations [28, 30] and some trials lacked statistical power to identify statistically significant effects due to the small sample size; Five studies included $\leq$10 individuals [13, 15, 27, 31, 35], and Sainz et al. (2020) [26] only included 15 volunteers.
j) Ten out of the 16 studies included in this review received funds from companies that commercialize the studied supplement or had authors that reported

conflicts of interest [13, 14, 15, 25, 29, 30, 33, 34, 35, 37], which are more likely to present positive results to industry sponsors [66, 67].

k) Rhoden et al. (2021) [27] and Lange et al. (2014) [32] investigations tested sucrose, which has a distinct metabolism and may not provide the same cognitive effects as pure glucose or fructose [50].

l) It is common for DS to be misbranded [68, 69], and commercial energy drinks may be mislabeled and not contain the amount of caffeine described on the label [70], which may act as a confounder. When assessing the effects of a DS, validated analytical methods should be used for accurate quantification and purity assessment of its ingredients [71]. However, only two studies, La Monica et al. (2021) [15] and Sowinski et al. (2021) [25] had their DS tested by an independent third-party laboratory for purity and potency.

m) No study disclosed capsule composition (i.e., gelatin vs. cellulosic), which may have distinct disintegration and dissolution properties and consequently influence the ingredient's bioavailability and pharmacokinetics [72].

n) The methodology, study design, and cognitive tests used in the included studies vary greatly, making comparisons difficult.

o) The volunteers were assessed in a peaceful, low-stress testing environment that did not reproduce real competitive gaming conditions.

p) Only seven studies assessed side effects [14, 15, 25, 28, 29, 30, 37], limiting our ability to extract and provide information about adverse events associated with the DS investigated in the 16 studies included in this review.

Future directions

Although a limited number of DS have been trialed in esports players, an ample variety of dietary compounds have demonstrated cognitive-enhancing effects in healthy young individuals [73], which could also be useful for esports players and merit further study in this population. Tyrosine [74] and *Bacopa monnieri* [59] may be the most promising ones. As esports contests can suffer significant delays, or extend for several hours or even days at a time [46], supplementation with slow-release caffeine (300 mg/day) could be a preferable choice to support enhanced neural metabolism, improve cognition, offset possible sleep deprivation, minimize fatigue, and risk of adverse effects, including caffeine "crash" [75]. Thus, we propose that slow-release caffeine [75], varying doses of caffeine, and the co-ingestion of caffeine with other ingredients, such as glucose, tyrosine, green tea, vitamins, minerals, and other nutrients [76] should also be investigated in esports competitors, which will contribute to establishing optimal recommendations.

Glucose and carbohydrate sources of low, medium, and high glycaemic index (GI) values should be of special interest for future investigation on esports as the brain has a rapid metabolism and requires a minimum of 130 gr of glucose per day [77], its primary energy substrate in normal conditions. As its reserves are limited, this organ depends on a continued blood glucose supply, delivered by the liver [78]. Playing video games increases brain glucose consumption [79] and decreases glycemia [32]. In this context, glucose consumption may increase its availability, support brain areas under high cognitive load, and improve cognitive function [80]. Future studies that evaluate the effects of carbohydrates should involve amateur volunteers with less gaming time, in addition to professional esports players, as the ongoing practice of video games may decrease the brain's use of glucose over time [18].

Compared to arginine, supplementation with dietary nitrates, which are further reduced to nitrite, a NO reserve, may represent a more viable pathway to raise NO levels and increase blood-brain perfusion [81].

Future studies should account for and report on the esports genre, expertise level (e.g., amateur, semi-professional, or professional), and mean daily hours of gaming practice of the volunteers. They should also investigate which cognitive function parameters are independently associated with esports player performance, and then focus on assessing the acute and long-term effects of nootropics consumption on such variables. Quantifiable and validated performance metrics should be developed to measure the effects of DS on the cognitive and gaming performance of esports players. Additionally, we recommend that further investigations report the specific times of day when DS was administered and tests were performed. We also advise the recruitment of sample sizes that provide sufficient statistical power to detect effect sizes. Ideally, future research should also attempt to recreate the environmental characteristics typically observed in esports competitions.

Conclusion

This scoping review unveiled sixteen clinical trials. Ten assessed the effects of caffeine, two of which tested a combination of caffeine, methylliberine, and theacrine, one trialed the effects of a mix of caffeine and polyphenols, and another a combination of caffeine and fucoxanthin. Three studies assessed the effects of arginine, and three others studied the effects of carbohydrates on esports players.

The literature published to date suggests that caffeine may improve time on target tracking, hit accuracy, reaction speed, and the time required to strike a target, but may also impair gaming performance by increasing jitteriness, decisive reflection time, and losses on time-limited games. We advocate that scientific research into DS for esports is lacking and that additional high-quality research is required. The assessment of the nootropic potential of various nutritional supplements not yet tested in esports practitioners, including slow-release caffeine, nitrates, tyrosine, and others, could be considered for further research. Since research in this area has focused on the effects of caffeine on the performance of video gamers, and anticipating that more studies will be published soon, we do consider that this topic deserves to be addressed by a systematic review and meta-analysis.

Electronic supplementary material

The electronic supplementary material (ESM) is available with the online version of the article at https://doi.org/10.1024/0300-9831/a000790

ESM 1. Bibliographic databases search scheme (PDF).

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Paper III: Dietary Habits of esports Competitors: A Scoping Review

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Dietary Habits and use of Nutritional Supplements by esports Competitors - A Scoping Review

Hábitos alimentares e uso de suplementos nutricionais por competidores de esports - Uma revisão de escopo

Hábitos dietéticos y uso de suplementos nutricionales por competidores de esports - Una revisión del alcance

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Dietary Habits and use of Nutritional Supplements by esports Competitors - A Scoping Review

Hábitos alimentares e uso de suplementos nutricionais por competidores de esports - Uma revisão de escopo

Hábitos dietéticos y uso de suplementos nutricionales por competidores de esports - Una revisión de alcance

Abstract:

Background: Video games are associated with lower diet quality, and the popularity of esports has increased dramatically in recent years, potentiated by the COVID-19 pandemic lockdowns. Simultaneously, alcohol, energy drinks, and fast-food industries have increased their advertising investments for this audience. However, existing literature regarding esports players' dietary and supplementation habits is uncertain.

Objectives: To conduct a scoping review on esports players' dietary habits.

Design: Adopting the PRISMA extension for scoping reviews methodology, searches were conducted on Web of Science, Scopus, PubMed, Google Scholar, and Esports Research Network.

Results: Seventeen relevant publications have been uncovered, which surveyed a total of 8760 esports players. Four papers involved German, three USA, three Polish, two Portuguese, one Brazilian, one Norwegian, one Danish, one Hungarian, and one Chinese esports contenders. One international study included players from the USA, Australia, Canada, Germany, and the UK. Fourteen were cross-sectional, and three were observational studies. Ten studies applied web-based surveys, two applied questionnaires, three applied food diaries, and another three applied semi-structured interviews. Nine studies assessed caffeinated drinks intake, eight characterized alcohol consumption, six described fruit and vegetables, and four evaluated the consumption of dietary supplements.

Conclusion: This scoping review unveiled seventeen studies that included information regarding the dietary habits of esports players. The diet quality of esports players may be inadequate, ingesting fewer portions of fruits and vegetables than recommended. Additionally, caffeine consumption seems common in esports.

Keywords: esports, video games, nutrition, dietary supplements, caffeine, alcohol drinking.

Resumo:

Introdução: Os videojogos estão associados a uma dieta de menor qualidade, e a popularidade dos esports aumentou nos últimos anos, potenciada pela COVID-19. Simultaneamente, as indústrias do álcool, bebidas energéticas e *fast-food* aumentaram os seus investimentos publicitários para esse público. No entanto, desconhece-se a literatura existente sobre os hábitos alimentares e de suplementação dos jogadores de esports.

Objetivos: Realizar uma revisão de escopo sobre os hábitos alimentares dos jogadores de esports.

Materiais e Métodos: Adotando a extensão PRISMA para metodologia de revisões de escopo, foram conduzidas pesquisas na Web of Science, Scopus, PubMed, Google Scholar e Esports Research Network.

Resultados: Foram encontradas dezassete publicações relevantes, que incluíram um total de 8760 jogadores de esports. Quatro artigos envolveram competidores alemães, três dos EUA, três poloneses, dois portugueses, um brasileiros, um noruegueses, um dinamarqueses, um húngaros e um chineses. Um estudo internacional incluiu jogadores dos EUA, Austrália, Canadá, Alemanha e Reino Unido. Quatorze eram estudos transversais e três observacionais.

Dez estudos aplicaram questionários *online*, dois aplicaram inquéritos, três aplicaram diários alimentares e outros três aplicaram entrevistas semiestruturadas. Nove estudos avaliaram o consumo de bebidas cafeinadas, oito caracterizaram o consumo de álcool, seis de frutas e vegetais e quatro de suplementos alimentares.

Conclusões: Esta revisão de escopo revelou dezassete estudos que incluíram informações sobre os hábitos alimentares de jogadores de esports. A qualidade da dieta destes jogadores poderá ser inadequada, ingerindo menos porções de frutas e vegetais do que o recomendado. Além disso, o consumo de cafeína parece ser comum.

Palavras-chave: esports, videojogos, nutrição, suplementos alimentares, cafeína, consumo de álcool.

Resumen

Introducción: Los videojuegos se asocian con una menor calidad de la dieta, y la popularidad de los esports ha aumentado dramáticamente recientemente, potenciada por el COVID-19. También ha ido aumentando la publicidad de alcohol, bebidas energéticas y comida rápida dirigida a este público. Sin embargo, la literatura existente sobre los hábitos dietéticos y de suplementación de los jugadores de esports es incierta.

Objetivos: Realizar una revisión de alcance de los hábitos alimentarios de los jugadores de esports.

Materiales y métodos: Se adoptó la extensión PRISMA como metodología de búsquedas en Web of Science, Scopus, y PubMed.

Resultados: Se han descubierto diecisiete publicaciones relevantes, que encuestaron a un total de 8760 jugadores de esports. Cuatro artículos involucraron a contendientes de esports alemanes, tres estadounidenses, tres polacos, dos portugueses, un brasileños, un noruegos, un daneses, un húngaros y un chinos. Un estudio internacional incluyó a jugadores de EUA, Australia, Canadá, Alemania y el Reino Unido. Catorce fueron estudios transversales y tres fueron estudios observacionales. Diez estudios aplicaron encuestas basadas en la web, dos cuestionarios, tres diarios de alimentos y otros tres aplicaron entrevistas semiestructuradas. Nueve estudios evaluaron la ingesta de bebidas con cafeína, ocho el consumo de alcohol, seis frutas y verduras y cuatro suplementos dietéticos.

Conclusiones: Esta revisión reveló diecisiete estudios sobre los hábitos dietéticos de los jugadores de esports. La calidad de la dieta de los jugadores de esports puede ser inadecuada, ingiriendo menos porciones de frutas y verduras de las recomendadas. Además, el consumo de cafeína parece común.

Palabras clave: esports, videojuegos, nutrición, suplementos dietéticos, cafeína, consumo de alcohol.

1. Introduction

“esports” has been defined as organized video game competitions, played on a spectrum of professionalism (1). Some authors consider that esports originated in the early 90s, coinciding with the advent of the internet, electronic equipment, and software with multiplayer games support (2). Fast-forward to 2022, the industry of gaming and esports has been the subject of tremendous growth, which has been accelerated by the COVID-19 pandemic lockdown restrictions, and now rivals the popularity of classic sports (3).

Companies that commercialize drinks (alcohol and energy drinks) and low-quality hyper-processed foods (“junk food”) have been increasingly promoting their products at esports-related events (4). This topic concerns health authorities as video games are associated with increased sedentarism, low-quality food ingestion, and weight gain (5). Insufficient ingestion of fruits and vegetables is associated with an increased prevalence of chronic diseases and a decreased number of healthy life years (6). The consumption of sugary drinks, including energy and sports drinks, is positively associated with weight gain (7) and deteriorated oral health (8). Diet quality may also influence cognitive performance, as alcohol and diets based on hyper-processed or hyperenergetic foods promote body fat gain and neuroinflammation, which may decrease cognitive performance (9).

Additionally, various companies advertise dietary supplements of questionable efficacy for esports competitors and eGames fans (10). There is limited evidence regarding the safety and cognitive enhancing effectiveness of herbal supplements, including Gingko biloba, ginseng, and guarana (11), and these are frequently adulterated and misbranded (12). Despite existing evidence that supports its cognitive enhancing properties in healthy adults (11), caffeine consumption isn´t health risk-free and may cause anxiety, jitteriness, arrhythmia, and insomnia (13). The use of nutritional supplements by video gamers may be exaggerated and represents an additional health risk (14).

Although previous reviews were conducted on the topic of the health of video gamers, these didn't focus on esports players (15). Its organized and highly competitive nature, the recognition by the International Olympic Committee as a sport, and the existence of individuals who dedicate themselves part or full-time to esports, which may practice for up to 10 hours a day, distinguish esports from the recreational practice of video games and justify the need to direct greater attention to the health of esports players, including the nutritional aspects (16).

As the extent of existing data on the dietary and supplementation habits of esports competitors is unknown, it is necessary to comprehensively outline the investigation published in this field, examine research practices, and pinpoint knowledge gaps. Thus, we conducted a scoping review to systematically present the results regarding the dietary and supplementation habits of esports contestants, to perform a critical appraisal of the web surveys applied to esports players, and to identify research gaps on the topic of nutritional habits of esports competitors.

2. Materials and methods

This scoping review adopted the PRISMA extension for Scoping Reviews ScR methodology (17). A preprint for this project has been registered at The Open Science Framework (OSF) and is freely accessible (https://doi.org/10.17605/OSF.IO/FHACP).

Before developing the protocol for the review, a preliminary investigation of the existing literature was conducted on the Esports Research Network website to assess the existence of studies on this topic and to gather and define the esports-related terms to include in the systematic search. A protocol for reference search was drafted and piloted on the Web of Science database by both authors. Following the pilot phase, the goals were clarified, the search strategy was optimized, the eligibility requirements were adjusted, and the basic data-charting form to extract the information was tested and adjusted.

The following keywords and boolean operators were developed and applied in the searches conducted on the databases: (“esport*” OR “e-sport*” OR “egame*” OR “electronic sport*” OR “virtual sport*” OR “e-athlete*” OR “professional gaming” OR “competitive gaming” OR “competitive videogame*” OR “online gam*” OR “digital gam*” OR “computer gam*” OR “video gam*”) AND (“nutrition” OR “diet*” OR “food*” OR “beverage*” OR “drink*”).

In February 2024, the lead author employed the search strategy to perform a comprehensive literature search in the Web of Science, PubMed, Scopus, and Google Scholar databases in order to find potentially relevant publications. The full Esports Research Network library (https://esportsresearch.net/) was manually searched by reading the titles of the items for any pertinent publications.

Both authors reviewed the retrieved articles, selected the publications that would be assessed for possible inclusion in this review, and individually evaluated the full texts available before agreeing on the actual articles to be included. The search strategy was developed, tested, and optimized by the lead author in close collaboration with the university librarian.

The searches were limited to observational/cross-sectional studies published in academic journals between 1990 ("the birth decade of esports") (2) and 2023. To be included in the review, articles had to contain information regarding the dietary habits of esports competitors (e.g., fruit and vegetable intake, alcohol, coffee, or dietary supplements). Articles that did not meet the established criteria were excluded, including those focused on recreational or single-player video gaming. No linguistic limitations were applied, as advised by existing guidelines (18). However, articles without an English-language abstract, were not included. No age restrictions were applied regarding the age of the esports players participating in the studies included in the review. Following each database search, the retrieved citations were exported to Endnote X9. Duplicates, conference proceedings, thesis, books, reviews, meta-analyses, letters, commentaries, and studies conducted on animals were then removed. The remainder articles' titles and abstracts were scanned by both authors, and those that did not fulfill the eligibility requirements were excluded. Following the application of the search strategy, the lead author sought the full texts of all remaining articles, which were read and considered for inclusion in this review. References from included articles were also screened to identify potentially relevant articles. Divergences regarding the articles to be included were settled through discussion and consensus.

The complete search strategy employed for all databases is provided as Supplementary Material (SM1). The PRISMA 2020 Search Flow Diagram (19) was used as a template to detail the systematic research procedures and register the search results.

Because the methodology can influence the results, and in order to assess the bias, strengths, weaknesses, and applicability of study findings, it is recommended that studies that include surveys should comprehensively report the procedures applied, and provide access to the applied questionnaire, including information regarding its psychometric properties (20). The lead author applied The Checklist for Reporting Results of Internet E-Surveys (CHERRIES) (21) to critically evaluate the methodologic quality and applicability of the outcomes of the articles that applied web surveys, while the second author verified its application in a subsample.

The two authors collaborated to construct a data-charting form to extract the information considered most relevant to the topic of this review. This included the name of the first author, publication year, nationality study goals, population, age, sample size, age, study design, methodology, key findings, and conflicts of interest. In an iterative procedure, the two reviewers mapped the data autonomously, debated the findings, and updated the data-charting form as necessary. Disagreements over study selection, data extraction, and the final articles to include in this review were resolved by discussion.

3. Results

Figure 1. PRISMA 2020 Search Flow Diagram

The application of the search scheme resulted in the retrieval of a total of 3587 references: 1155 from PubMed, 980 from Google Scholar, 696 from Scopus, 746 from Web of Science, and 10 items from the Esports Research Network.

The next stage led to the exclusion of 588 duplicates, 109 items without an abstract available in English, 471 books, 288 clinical trials or controlled studies, 24 study protocols, 12 conference proceedings, 6 letters to the editor, commentaries, and others, 194 review articles and meta-analyses, 52 studies not conducted or related to humans, 1499 references not related to esports, and 9 items that didn´t contain information regarding the dietary habits of esports players.

After this process, the available papers for each of the 28 remaining references were retrieved. The screening of their references didn´t reveal additional papers to be included in the review. 9 items were excluded due to the absence of dietary consumption information on esports players, and 1 item was excluded due to being a preprint document, not yet peer-reviewed or published in an academic journal.

Finally, 17 studies (22-36) were included in this scoping review and thoroughly screened by the authors. For 18 studies, full articles were accessible

13 studies have been published in peer-reviewed scientific journals (22, 23, 25-32, 34-36), while the studies conducted by Jasny et al. (2021) (33) and Huth (2021) (24) were published in lesser-known, university journals.

3.1. Critical appraisal of web-based cross-sectional studies

Table 1. Critical appraisal of web-based cross-sectional studies (CHERRIES)

Of the ten studies that applied web-based surveys, only one (37) provided access to the complete questionnaire they applied as a table, appendix, supplementary material, or other forms. Additionally, the studies conducted by Huth (2021) (24) and Rudolf et al. (2020) (23) didn´t comment on the validity or reliability of the questionnaires applied. This assessment revealed the nine articles failed to meet the majority of the 30-item CHERRI guidelines. Matias et al. (2023) (38) reported 70% of the items, Rudolf et al. (2020) (23) and Soffner et al. (2023) (35) reported 50%, Friehs et al. (2022) (30) 46.7%, Kósa et al. (2022) (26) 33.3%, Trotter et al. (2020) (22) 30.0%, Ip et al. (2020) (25) 26.7%, and Huth (2021) (24) only conveyed 16.7%. Trotter et al. (2020) (22) and Huth (2021) (24) didn´t report the timeframe where the data was collected. Huth (2021) (24) and Ip et al. (2020) (25) didn´t state an institutional review board's approval. Only Soffner et al. (2023) (35) and Rudolf et al. (2020) (23) reported on adaptative questioning. Rudolf et al. (2020) (23) and Ribeiro et al. (2023) (37) were the only authors that described the participation and completion rates, and only Trotter et al. (2020) (22) and Ribeiro et al. (2023) (37) provided information regarding statistical corrections. No study reported on the following CHERRIES items: randomization of items or questionnaires, completeness check, review step, cookies used, IP check, and log file analysis.

3.2. Synthesis of results

Table 2. Data items

3.2.1. Interview-based studies

The goal of the Schubert et al. (2022) (29) study was to investigate how professional esports competitors perceived the use of compounds that improve performance, including energy drinks. They applied online semi-structured interviews to 9 male FIFA professional esports contestants (18 to 27 y) from clubs taking part in tier-top German FIFA tournaments. The data collected by these investigators suggest that the use of oral tobacco (e.g., Snus), energy drinks, and gaming boosters (e.g., LevlUp, Emporgy) is widespread among professional FIFA players. Gaming boosters are dietary supplements sold in powder form which typically contain high amounts of caffeine, some vitamins, and amino acids, and may also include herbal extracts.

Baumann et al. (2022) (27) interviewed twenty (17♂, 3♀) Norwegian students between 17 and 21 years of age (M = 19, SD = 1.4 years) who regularly competed in esports and practiced esports 5.5 hours per day on average. "Counter-Strike: Global Offensive" and "League of Legends" were the most popular game titles. The interview included questions regarding the volunteer's esports performance, lifestyle, and health habits, including dietary patterns. According to these authors, energy drink consumption was large, with approximately 75% ingesting it at least weekly, and about half of the responders consumed it daily, ingesting at least one unit (500 ml) on each occasion. This corresponds to an intake of at least 150 mg of caffeine per serving. The participants ate between three and four meals per day, excluding snack meals. Approximately half of the responders reported regularly skipping breakfast.

Jasny et al. (2021) (33) interviewed 12 seasoned players (M = 28 years) of a card game (Magic: The Gathering) regarding their training regimes for esports tournaments, including dietary habits. Four respondents stated that they strive to tailor the type and amount of food they ingest in their usual diet according to their bodies' requirements, predominantly to remain healthy. Seven participants stated that nutrition is very important during tournaments and change their dietary habits during these periods. The dominant practice is to avoid heavy foods and overeating, opting for easily digestible food, such as fruits and nuts, and drinking enough water to remain hydrated. One participant stated it is important to eat between the matches to avoid hunger and keep their sugar level up, and another reported that he struggles to eat during tournaments because stress makes him forget to eat.

3.2.2. Self-administered surveys

Friehs et al. (2022) (30) investigated the opinions regarding the use of performance-enhancing compounds in esports, including food and food supplements, by collecting data from three Reddit sources: a Reddit scraper, ad comments, and a survey. They attempted to elicit responses to five questions, three of which were about perceptions of dietary supplement intake. The survey was applied to 566 eGamers (477♂, 65♀, 23 others), which averaged 25.9 (SD = 6.6) years. Eight (1.4%) respondents identified as speedrunners, 12 (2.1%) as full-time, 26 (4.6%) as part-time, and 74 (13.1%) as amateur esports athletes, while 121 (21.4%) identified as casual, and 325 (57.4%) as competitive gamers. Regarding esports genres, 421 participants competed in shooters, 190 in a multiplayer online battle arena (MOBA), 179 in strategy, 139 in racing, 75 in fighting, and 43 in sports games. In response to the question "Do users in online communities disclose using enhancers to improve performance?", a large number of comments (30 out of 77) disclosed the use of some type of performance enhancer without being asked. For the question "What is the perceived prevalence of performance enhancement usage among top-level players?" on average respondents guesstimated that 81.3% of all professional players are using nutritional supplements (e.g., caffeine, tyrosine) and that about half (49.1%) use accepted drugs such as alcohol, nicotine, and cannabis. Participants' answers to the question "What are the perceived reasons for performance enhancement usage among top-level players?" included: stimulate body (65.4%), stimulate the mind (72.6%), calm body (21.7%), calm mind (21.2%), enhance perception (39.6%), reach a goal (18.6%), social pressure (14.7%), and curiosity (13.3%). Participants were also asked if they would use performance enhancers in general. 218 (39.2%) of the 556 participants said they would use performance enhancers, while 86 (23.7%) said they would use caffeine, food supplements, or "natural" substances.

Aiming to characterize the demographics and health behaviors of video gamers and esports Germany contestants, Rudolf et al. (2020) (23) applied an online survey to a total of 1066 individuals, which averaged 22.9 (SD = 5.9) years old, of which the majority were male (91.9%). The average amount of fruit and vegetables consumed per day was 2.7 (SD = 1.8) servings. There were no statistically significant differences regarding this variable between player status categories. Only 11% of the sample met the WHO's daily guideline of 400 grams of fruit or vegetables (39).

Recently, Huth (2021) (24) surveyed 339 German individuals (91.9% males; M = 26.5, SD = 6.8 years) to compare the dietary habits of esports competitors (n = 241) with non-players. These authors asked how healthy they thought their nutritional habits were on a 5-point scale, and assessed the frequency of consumption of various food groups by asking how often they consumed fruits, vegetables, alcohol, caffeine, sugary products, dairy, meat, noodles, and fast food over the past 4 weeks on a 9-point scale. Despite the absence of statistically significant differences regarding fast food, sugary products, dairy, noodles, and meat consumption, participating in esports was associated with poorer eating habits. Those who did participate in esports reported less concern with eating healthy foods (Mean Difference (MD) = -0.63; $p < 0.001$) and consumed fewer fruits (MD = -1.15; $p < 0.001$), and vegetables (MD = -0.91; $p < 0.001$), although they also drank less caffeinated (MD = -1.32; $p < 0.001$) and alcoholic drinks (MD = -1.06; $p < 0.001$). However, the authors stated that these differences may be due to confounding variables: esports players had slightly lower incomes and education levels (24), which is associated with a lower quality of dietary intake (40).

Trotter et al. (2020) (22) employed an online health assessment questionnaire that included self-reported alcohol intake among 1772 esports competitors (87.2% males). There were respondents from 65 different countries. The countries with the highest representation were the United States (n = 290), Australia (n = 180), Canada (n = 75), Germany (n = 41), and the United Kingdom (n = 26). They represented five distinct eGames and were divided into categories based on their game-rank level. About two-thirds (65.1%) stated they didn’t drink alcohol at all, while 34.9% stated they drank at least once a week. Those who consumed alcohol did so on an average of 1.8 days per week. Only 0.5% declared drinking every day.

The in-game rank of esports players was not related to drinking frequency ($F(3.1375) = 0.98$; $\eta_p^2 = 0.002$; $p = 0.40$).

Ip et al. (2021) (25) applied a web-based survey on video gamers engaged on internet forums and in-person on electronic games competitive events. The inquiry included questions regarding dietary supplements and alcohol consumption over the past 12 months. Five hundred and twenty-six respondents (84.2% males; M = 23.9, SD = 4.9 years) finished the inquiry with 77.0% being from the USA. 17.7% self-classified as recreational; 73.4% as amateur; 8.2% as semi-professional, and 0.8% as professional video gamers. The most reported substance was caffeine (58.1%) in the form of caffeinated drinks (33.8%), energy drinks (19.2%), and caffeine pills (5.1%). Other dietary supplements were also consumed: 3.8% used vitamin B12, 2.3% Yerba mate, 1.5% melatonin, 1.3% Guarana, 0.6% Ginkgo Biloba, 0.2% Kava, 0.2% Panax Ginseng and 0.2% had ingested Valerian. Regarding alcohol consumption, 38.6% exhibited binge drinking (defined as ≥ 5 drinks on one occasion) in the previous 12 months, and 12.9% were heavy drinkers (defined as ≥ 5 alcoholic beverages within the same event at least five days in a month). Binge drinking prevalence in this sample was higher compared to those registered in the USA for a reference population of adults aged 18 to 24 years (24.0%) and 25 to 34 years (26.0%) (41).

Kósa et al. (2022) (26) applied an online questionnaire to 2313 Hungarian esports players (92.4% males; 93.3% between 18 and 25 years). These authors aimed to characterize internet addiction and health risk factors associated with that condition, including alcohol intake. Their research revealed that 14.1% of respondents regularly consumed alcohol and that internet addiction was substantially linked to regular alcohol consumption (OR = 18.357; $p < 0.001$). This investigation also unveiled a lower prevalence of alcohol consumption among esports players (14.1%) when compared to a reference population (53.2%) (42).

Later, Goulart et al. (2023) (36) conducted a study that assessed sleep patterns and physical activity and detailed the dietary habits of esports players. They recruited 103 male and 16 female elite esports athletes aged 16 to 35 (mean = 23.1, SD = 5.0) who completed a set of surveys, cognitive testing, and ten days of food records via the Automated Self-Administered 24-Hour Dietary Recall (ASA24) software. The participants were classified as professional, elite, or avid esports athletes, and played for an average of 6.3 (SD = 1.1) days per week, and 4.8 (SD = 2.0) hours in each gaming session. The most played esports genres were action (96.6%; platformers, shooters, racing, and fighting), action-adventure (71.4%; e.g., Halo), adventure (70.6%), role-playing (66.4%), strategy (55.5%), casual (52.1%), sports and driving simulators (46.2%), and simulations (37.8%; towns, cities). The authors reported the average total daily consumption of dairy: 1.4 (SD = 0.8) cups, fruit: 0.4 (SD = 0.6) cups, vegetables: 1.1 (SD = 0.6) cups, whole grains: 0.7 (SD = 0.9) cups, fiber: 13.1 (SD = 5.6) g, caffeine: 74.6 (SD = 90.7) mg, and added sugar: 14.1 (SD = 10.8) g. The average macronutrient distribution of total energy was 17.3% for protein, 45.5% for carbohydrates, and 37% for fat. According to the authors, most participants didn´t ingest the recommended micronutrient values stipulated by the USDA Dietary Guidelines for Americans 2020-2025 (43). 95.7% didn´t reach the recommended dietary allowances (RDAs) for magnesium, 11.2% for phosphorous, 69.0% for zinc, 4.3% for selenium, 36.4% for vitamin B1, 21.6% for vitamin B3, 27.3% for vitamin B6, 76.9% for vitamin B9, 13.8% for vitamin B12, 97.4% for vitamin D, 94.2% for choline, 57.0% for omega 6, and 52.1% for omega 3. Moreover, most participants did not meet the daily recommended dose for vegetables (3 cups), fruits (2 cups), whole grains (1 cup), or dairy (3 cups) intakes, fiber (14 g/ 1000 kcal), and 83.5% exceeded the recommended upper limits for sodium (2300 mg), 63.6% for cholesterol (300 mg), and 66.1% for saturated fat (10% of total energy intake). The authors detected a positive association of cognitive performance with total vegetable intake ($r = 0.272$, $p = 0.003$), and with the ingestion of an amount of protein equal to or greater than 0.8 g/kg ($\beta = 0.812$, $p = 0.018$). They also detected positive and significant ($p < 0.05$) associations between cognitive performance and the intake of magnesium, phosphorous, potassium, sodium, zinc, selenium, thiamin, niacin, vitamins B6 and B12, folate, cholesterol, saturated, polyunsaturated, and monounsaturated fats, omega-6 and omega-3 fatty acids, and choline.

Lam et al. (2022) (28) conducted a cross-sectional descriptive study, to investigate the health profiles and health conditions of professional mobile-gaming athletes. They also inquired the volunteers regarding alcohol and coffee consumption habits. A total of 50 male Chinese esports players (M = 20.0 SD = 1.67 years) competing in a top-level MOBA tournament participated in this study. These investigators reported that 19.4% of the individuals consistently consumed alcohol and 28.6% regularly ingested coffee, and didn´t find a significant association between career duration and either alcohol intake ($p = 0.655$) or coffee consumption ($p = 0.946$). Interestingly, the list of health conditions reported by those players includes loss of appetite, of which 18.0% (n = 9) complained.

Szot et al. (2022) (31) applied Food Frequency Questionnaires to assess the dietary patterns of 233 male Polish esports players aged 18 to 26 years (M = 20.5, SD = 2.0). The participants played for 4 to 6 hours per day on average. One hundred and eighty-six (79.8%) were semi-professional players, and 47 (20.2%) had a trainer. The majority (69.1%) played Counter-Strike: Global Offensive and 30.9% played League of Legends. Most of the sample (74.8%) reported having 3 or 4 meals per day. Only 10.4% followed a regular meal pattern. Nearly a third (31.3%) ate the last meal 2 to 3 hours before going to bed. Approximately one quarter (27.0%) reported drinking 1.5 L or 6 glasses of fluids per day, 35.7% 2 L, and 37.4% more than 2 L per day. Nearly half of the sample (46.4%) reported drinking soft drinks, one-quarter (26.6%) reported drinking energy drinks, and 8.6% reported drinking alcohol three or more times per week. The average daily consumption frequency for soft drinks was 3.4 (SD = 1.6), 2.7 (SD = 1.4) for energy drinks, and 2.0 (SD = 1.0) for alcoholic drinks. Regarding unhealthy dietary patterns, three-quarters (75.5%) of the sample had fried foods, roughly half (54.9%) ingested sweets, 28.3% had fast food, 28.3% ate red meat, 23.6% ingested margarine/butter, and 22.8% consumed lard/coconut oil at least 3.5 days per week. Additionally, 28.7% regularly consumed salty snacks. Regarding healthy dietary patterns, only 13.7% ate fruit and 11.2% ingested vegetables at least 2 or 3 times a day. Just 14.6% of respondents consumed pulses, 15.0% had fish, 19.3% of respondents ate nuts, seeds, and oilseeds, 22.3% ingested olive oil or rapeseed oil, 30.1% ate whole grains, and 32.2% consumed wholegrain bread at least 3.5 days per week. These authors unveiled a lower prevalence of alcohol users in esports players (62.7%) when compared to a reference population (77.2%) (44).

Kulecka et al. (2023) (32) characterized and compared the gut microbiomes of 109 male Polish esports players (M = 20.9, SD = 2.4 years) to the microbiomes of a male control group (M = 22.9, SD = 2.2 years) which included 25 endurance athletes and 36 physical education students. The eGamers had a mean BMI of 23.5 (SD = 3.8) kg/m^2. The majority (52.4%) played Counter-Strike: Global Offensive, 46% League of Legends, and 1.6% StarCraft. 87% were classified as semi-professionals, with an average of 1.2 (SD = 0.9) years of experience, and 13% were classified as professional players, with an average of 6.4 (SD = 2.6) years of gaming experience. Of the initial sample, 59 esports players and 36 students also completed a quantitative dietary assessment performed through a three-day food diary and a weighting method, from which the investigators determined their average macronutrient intake. They reported the following values for energy (kcal) = 2154.9 (SD = 637.0); protein (g) = 98.0 (SD = 30.4); protein (%) = 18.8 (SD = 4.7); total carbohydrates (g) = 247.0 (SD = 77.5); carbohydrates (%) = 45.4 (SD = 9.7); sucrose (g) = 17.7 (SD = 16.3); fat (g) = 84.0 (SD = 36.4); fats (%) = 34.8 (SD = 8.9); SFAs (g) = 28.8 (SD = 16.4); PUFAs (g) = 7.1 (SD = 4.1);

TFAs (g) = 0.07 (SD = 0.12); fiber (g) = 15.5 (SD = 6.7); and alcohol (g) = 3.7 (SD = 16.0). These researchers found that the total energy value ($p < 0.01$), protein, carbohydrate, fiber, sucrose, and fructose, PUFAs, and cholesterol intake ($p < 0.001$) were significantly lower in the esports players diet compared to the physical students group.

Krarup et al. (2022) (34) purposed to examine cardiovascular, blood parameters, and dietary intake changes in eGamers during two 18-hour inactive video gaming periods, separated by a 6-hour interval, in a LAN party-like setup. For a total of 36 hours, the volunteers were free to play any genre of videogame, in single-player mode or in groups of 2 to 5 players. Additionally, they had free access to a snack and beverage bar and were served a warm meal in the evenings. This study involved nine Danish male esports competitors (M = 25.8, SD = 2.6 years), who registered their dietary intake in food diaries. On average, during the 42-hour experiment, the participants ingested a total of 8004.9 (SD = 438.4) kcal, of which 6160.6 (SD = 332.9) kcal were derived from foods and 1844.3 (SD = 365.3) kcal from beverages. Additionally, they ingested 6624.9 ml (SD = 801.2) of fluids and 1354.4 mg (SD = 106.6) of caffeine.

Soffner et al. (2023) (35) assessed the dietary habits and other health-related variables of German video gamers and esports competitors through a web-based survey, which included a food frequency questionnaire. Their sample totaled 817 individuals (87.1% males), with a mean age of 24.2 years (SD = 6.9). 210 respondents were categorized as "esports players" (20 professionals, 190 amateurs), and 607 as "video game players" (15 ex-professionals, 456 regular, and 136 occasional players). Regarding drinking behaviors, the total sample averaged a daily consumption of 7.8 (SD = 5.0) servings of water (1560 ml), 0.7 (SD = 1.3) servings of juice (140 ml), 0.9 (SD = 1.8) servings of soft drinks (180 ml), 0.4 (SD = 1.2) servings of light soft drinks (80 ml), 0.9 (SD = 1.4) servings of coffee (135 ml), 0.5 (SD = 1.2) servings of tea (75 ml), 0.2 (SD = 0.5) servings of energy drinks (50 ml), and 0.4 (SD = 0.7) servings of beer (132 ml). Esports players consumed a significantly greater daily amount of energy drinks ($M = 0.2$; $SD = 0.6$ servings) than video gamers ($M = 0.1$; $SD = 0.4$ servings; $p = 0.02$). According to the authors, almost a quarter of the respondents don't consume alcohol, but half of those under 18 years did ingest alcoholic drinks. They also reported a lower consumption of alcohol in this sample in comparison to a reference population.

On the topic of dietary behaviors, the majority of the participants (85.2%) didn´t adhere to a particular dietary regimen, whereas 14.8% reported being vegetarians or vegans. The total sample averaged a daily consumption of 1.6 ($SD = 1.2$) servings of bread/buns, 0.5 ($SD = 0.6$) of pasta, 0.4 ($SD = 0.5$) of rice, 0.3 ($SD = 0.6$) of cereals, 0.9 ($SD = 1.0$) of fruits, 1.7 ($SD = 1.6$) of vegetables, 0.6 ($SD = 0.8$) of potatoes, 0.2 ($SD = 0.4$) of nuts, 0.5 ($SD = 0.6$) of red meat, 0.4 ($SD = 0.5$) of poultry, 0.1 ($SD = 0.2$) of fish, 1.0 ($SD = 1.4$) of sausage, 0.8 ($SD = 1.0$) of cheese, 0.5 ($SD = 0.8$) of dairy products, 0.3 ($SD = 0.4$) of fast food, 0.2 ($SD = 0.4$) of chips & savory snacks, 0.2 ($SD = 0.3$) of sweet bakery products, and 0.6 ($SD = 0.8$) servings of sweets. Compared to the video games players, esports players reported a statistically significant greater average consumption of fast food (9.1, $SD = 11.6$ vs. 7.0, $SD = 10.0$ servings/month; $p < 0.01$), red meat (16.4, $SD = 18.5$ vs. 13.4, $SD = 15.6$ servings/month; $p = 0.02$), and poultry (12.8, $SD = 16.6$ vs. 9.7, $SD = 13.7$ servings/month; $p < 0.01$) In turn, video gamers consumed significantly greater amounts of sweets (18.2, $SD = 26.5$ vs. 14.1, $SD = 22.0$ servings/month; $p < 0.01$), sweet bakery products (0.2, $SD = 0.3$ vs. 0.2, $SD = 0.3$ servings/day; $p < 0.01$), dairy products (0.6, $SD = 0.9$ vs. 0.4, $SD = 0.6$ servings/day; $p < 0.01$) and cheese (0.8, $SD = 1.0$ vs. 0.7, $SD = 1.2$ servings/day; $p = 0.03$) than esports players. Fast food ($rho = 0.13$; $p < 0.01$), energy drinks ($rho = 0.14$; $p < 0.01$), and soft drinks ($rho = 0.14$; $p < 0.01$) were positively (poorly) correlated with video game playing time.

The purpose of Matias et al. (2023) (38) was to characterize gaming and health-related traits of Portuguese esports players, including certain facets of their eating patterns. These authors applied an online questionnaire on 235 players (85.1% males) aged 18 to 56 years old, with the range of 19 to 22 years representing 42.5% of the sample. The majority (81.3%) self-classified as amateurs, while 18.7% reported being semiprofessional or professional players. On average, this sample played video games for 3.5 (SD = 2.1) hours a day. Nearly a third (29.8%) reported consuming dietary supplements; the most consumed were animal-based protein (30%), multivitamins (15.7%), and creatine (14.3%). The mean coffee intake was 2.1 (SD = 1.0) cups per day, and more than half (60.4%) of the players reported drinking coffee daily. Consumption of snacks and beverages during gaming seasons was relatively low, as about three-quarters reported never drinking alcoholic (74.0%) or energy drinks (79.1%), and a little over half (55.7%) didn´t drink soft drinks.

Ribeiro et al. (2023) (37) applied an online survey to a sample of 274 (256 males) Portuguese and 305 (273 males) Brazilian esports players to characterize their dietary habits, sociodemographics, and gaming habits. With a median age of 24 y (P25 = 20; P75 = 30), 12.4% of the participants self-classified as professional esports players, 25.4% as semi-professional, and 62.2% as amateurs. They played esports for a median of 3.5 (P25 = 2.0; P75 = 6.0) hours a day. Almost a third (32.3%) consumed dietary supplements, mostly whey protein (59.4%), creatine (47.1%), and caffeine (33.2%). Just over half (53.7%) were classified as having a weak adherence to the Mediterranean diet, and the majority (84.5%) had fewer than five servings of fruits and vegetables per day. Nearly three-quarters (70.1%) consumed sweets or commercial pastries, while over half (65.8%) had coffee, 63.4% ate fast food, and almost a quarter (23.0%) ingested energy drinks on one or more occasions per week. Additionally, 78.1% had one or more servings of red or processed meat, and 40.9% had one or more sodas per day. Their daily average intake of caffeine from drinks was 179 mg per day. According to these authors, Portuguese and Brazilian esports players had a lower adhesion to the Mediterranean diet, lower consumption of fruits and vegetables, and a higher prevalence of breakfast omission, higher consumption of caffeine-based supplements, red or processed meat, fast food, soda, energy drinks, confectionery and sweets compared to a reference population. For both nationalities, higher degrees of Internet Gaming Disorder and professionalization correlated with a lower adhesion to the Mediterranean diet.

4. Discussion

4.1. Summary of the Evidence

The 17 relevant publications uncovered by this scoping review surveyed a total of 8760 esports players. Four papers involved German (23, 24, 29, 35), 3 USA (25, 30, 36), 3 Polish (31-33), 2 Portuguese (37, 38), 1 Brazilian (38), 1 Norwegian (27), 1 Danish (34), 1 Hungarian (26), and 1 Chinese (28), esports contestants. One international study included players from the USA, Australia, Canada, Germany, and the UK, among others (22).

Fourteen were cross-sectional studies (22-26, 28, 30-32, 34-38), and three were observational studies (27, 29, 33). Ten studies applied web-based surveys (22-26, 30, 35-37), two applied questionnaires (28, 31), three applied food diaries (32, 34, 36), and another three applied semi-structured interviews (27, 29, 33),

The methodological quality of the majority of the cross-sectional studies that applied web-based surveys may be suboptimal, as most failed to adhere to a significant proportion of the recommendations described in the CHERRIES checklist (21).

Six studies (22, 24-26, 34, 35) did not include information about the game genres in which the participants competed. Eight studies (23, 27, 28, 30-32, 37, 38) reported MOBA (e.g. League of Legends) competitors, and seven (23, 27, 30-32, 37, 38) reported shooter (e.g. CS:

GO) competitors, which is consistent with the findings of Lehnert et al. (2022) (45), who identified these game genres as the most popular in esports. According to the data from 16 studies that included information about sex, the majority of participants (90.0%) were male. Twelve studies (24, 25, 27-31, 34-38) included data on caffeine intake and ten (22, 24-26, 28, 30-32, 35, 38), on alcohol consumption. Six investigations (23, 24, 31, 35-37) reported on the consumption of fruit and vegetables, while only four (25, 30, 37, 38) assessed the consumption of dietary supplements.

The available data suggest that esports players commonly consume caffeine (22, 24-32, 34-38) and alcohol (22, 24-26, 28, 31, 32, 35). Moreover, one study reported a significantly higher consumption of energy drinks among esports players compared to video game players (46), and another described a higher consumption of caffein supplements in comparison to a reference population (37). Internet addiction has been significantly associated with a lower adhesion to a healthy dietary pattern (37), and regular alcohol consumption (26), and video gaming playing time correlated with increased consumption of energy (34), fast food, soft drinks, energy drinks (35, 37), and caffeine intake (47).

The existing data suggests that esports players consume less alcohol than reference populations. Trotter et al. (2020) (22), Huth (2021) (24), Kósa et al. (2022) (26, 42), Szot et al. (2022) (31, 44), and Soffner et al. (2023) (46) uncovered a lower consumption of alcohol in esports players, while Ip et al. (2021) (25, 41) registered a higher consumption in esports players compared to a reference, and Kulecka et al. (2023) (32) didn´t detected statistically significant differences between esports players and physical education students.

The majority of esports competitors do not follow healthy dietary patterns (22-27, 31, 34-37) and do not consume the amount of fruits and vegetables advised by the WHO (23, 31, 35-37, 39). The low intake of fruits and vegetables, and the consumption of fast food and alcohol may negatively impact these players' cognitive performance and general health (9).

Caffeine consumption involves potential side effects, including sleep disturbances, anxiety, jitteriness, cardiac arrhythmias, and increased blood pressure (13). EFSA has set 400 mg per day and single dosages of up to 200 mg for non-pregnant healthy adults as caffeine amounts that do not raise health concerns (13).

4.2. Limitations

The distinction between esports and general recreational multiplayer video gaming seems fuzzy as different authors attribute different definitions for esports (1). This hardened the choice on which publications to include in this review.

Despite the numerous scales and checklists available to assess the quality of observational studies, there is a lack of a gold standard, and the application of the available tools (e.g., the CHERRIES checklist) requires various levels of subjectivity (21, 48).

Additionally, this scoping review primarily gathered data on the most popular and typically sedentary esports genres (49). The dietary patterns of Exergames, or active esports games (for example, eracing), may be significantly distinct.

4.3. Future directions

Future studies should clearly describe the title of the esports game in which their participants train and compete, as there may be significant differences in the lifestyle and dietary habits between players of distinct esports genres. Also, it is necessary to address the potential link between video game disorder and diet quality, to define the potential impact of the esports genre and gaming rank on dietary practices, and to describe the dietary habits of exergame competitors. Additionally, it is crucial to characterize the micronutrient status of esports players. In particular, due to their prolonged indoor time, these individuals may be more susceptible to vitamin D deficiencies. This vitamin plays an important role in the healthy function of eyesight, the central nervous system, and sleep regulation (50), and these aspects are of paramount importance as performance in esports depends mostly on a high level of cognitive performance, including eye-hand coordination (51).

4.4. Conclusions

This scoping review unveiled 17 studies that contained information on the dietary habits of esports players. The majority of the studies that applied web surveys lack methodological adherence to existing guidelines and could be improved. From the available literature, one may infer that the dietary habits of esports competitors are not ideal and of similar or poorer quality than those of the general population, namely ingesting fewer daily amounts of fruits and vegetables. Conversely, esports players may consume less alcohol than the general population. Caffeine, in the form of coffee, energy drinks, guarana, yerba mate, and caffeine pills, has been referenced as the supplement of choice and is typically ingested by esports competitors.

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Huth (2021) (24), Baumann et al. (2022) (27), Schubert et al. (2022) (29), and Krarup et al. (2022) (34), didn´t report any funding information. Trotter et al. (2020) (22), IP et al. (2021) (25), Lam et al. (2022) (28), Friehs et al. (2022) (30), Szot et al. (2022) (31), Matias et al (2023) (38), and Ribeiro et al. (2023) (37), all stated that they did not receive any external funding. Kósa et al. (2022) (26), Kulecka et al. (2023) (32), and Jasny et al. (2021) (33), all reported receiving public funding. AOK Rhineland/Hamburg funded the Rudolf et al. (2020) (23), and Soffner et al. (2023) (35) studies. DairyMAX Inc. financially supported the Goulart et al. (2023) (36) investigation.

6. Declarations

6.1. Funding

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6.2. Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figure 1. PRISMA 2020 Search Flow Diagram

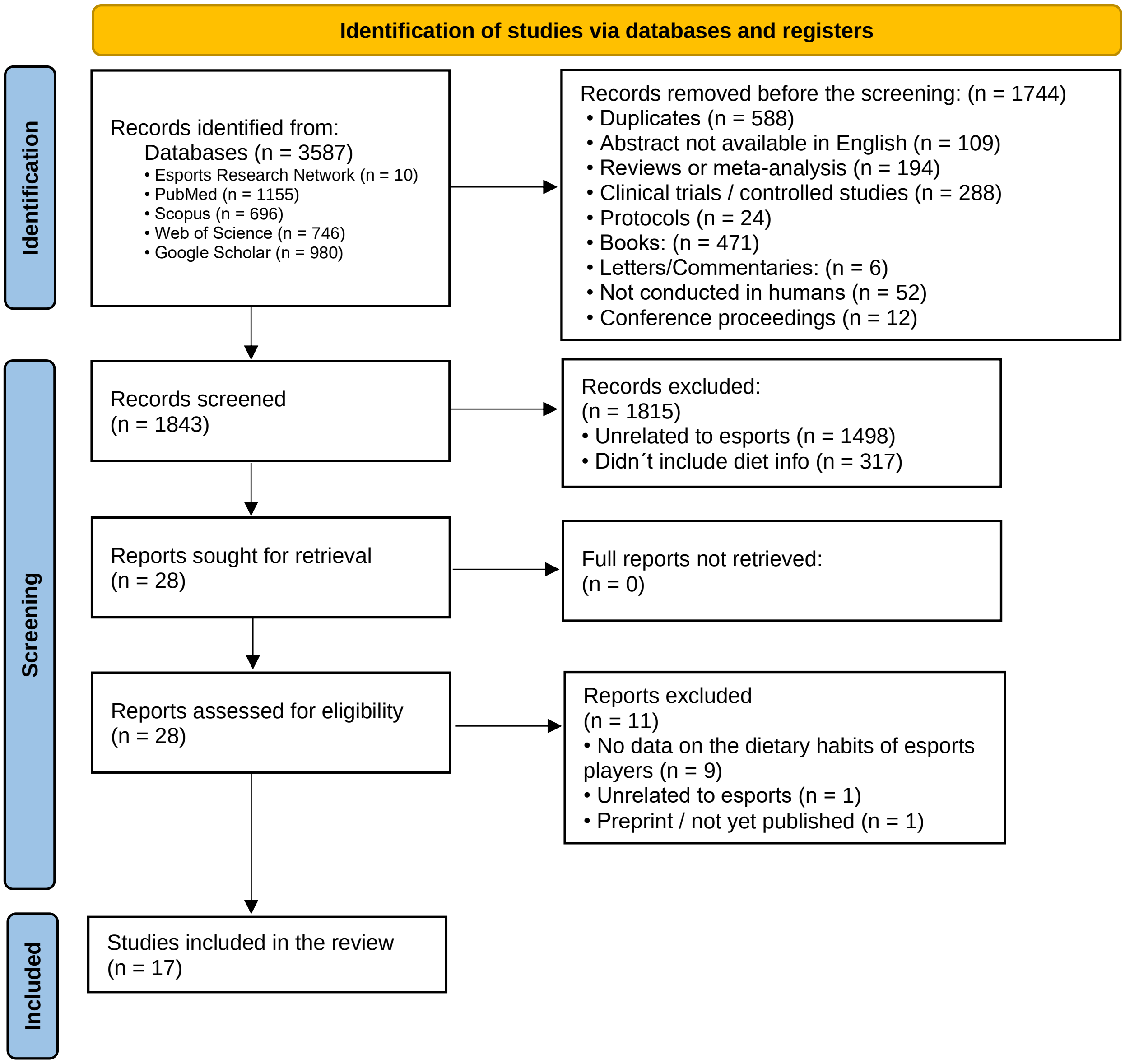

Table 1. Critical appraisal of cross-sectional studies (CHERRIES)

Item category	Checklist item	Friehs et al. (2022)	Rudolf et al. (2020)	Huth (2021)	Trotter et al. (2020)	Ip et al. (2020)	Kósa et al. (2022)	Goulart et al. (2023)	Soffner et al. (2023)	Matias et al. (2023)	Ribeiro et al. (2023)
Design	Describe survey design	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RB (Institutional Review Board) approval and informed consent process	IRB approval	✓	✓	-	✓	-	✓	✓	✓	✓	✓
	Informed consent	-	✓	-	✓	-	✓	✓*	✓	✓*	✓
	Data protection	*	-	-	-	-	-	-	-	-	✓
Development and pre-testing	Development and testing	✓*	✓	-	-	-	✓	✓*	✓*	-	✓
Recruitment process and description of the sample having access to the questionnaire	Open survey versus closed survey	✓	-	-	-	-	-	✓	✓	✓	✓
	Contact mode	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Advertising the survey	✓*	✓*	✓*	✓*	✓*	✓*	✓*	✓*	✓*	✓*
Survey administration	Web/E-mail	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Context	✓	✓	✓*	✓*	✓	-	✓*	✓*	✓*	✓
	Mandatory/voluntary	✓	-	-	✓	-	✓	✓	✓	-	✓
	Incentives	✓	✓	-	-	-	-	-	✓	-	✓
	Time/Date	✓	✓	-	-	✓	✓	-	✓	✓	✓
	Randomization of items or questionnaires	-	-	-	-	-	-	-	-	-	-
	Adaptive questioning	-	✓	-	-	-	-	-	✓	-	-
	Number of Items	-	✓*	-	-	✓*	✓*	-	✓*	-	✓
	Number of screens (pages)	-	-	-	-	-	-	-	-	-	✓
	Completeness check	-	-	-	-	-	-	-	-	-	-
	Review step	-	-	-	-	-	-	-	-	-	-
Response rates	Unique site visitor	-	-	-	-	-	-	-	-	-	✓
	View rate (Ratio of unique survey visitors/unique site visitors)	-	-	-	-	-	-	-	-	-	✓
	Participation rate (Ratio of unique visitors who agreed to participate/unique first survey page visitors)	-	✓	-	-	-	-	-	-	-	✓
	Completion rate (Ratio of users who finished the survey/users who agreed to participate)	-	✓	-	-	-	-	-	-	-	✓
Preventing multiple entries from the same individual	Cookies used	-	-	-	-	-	-	-	-	-	-
	IP check	-	-	-	-	-	-	-	-	-	-
	Log file analysis	-	-	-	-	-	-	-	-	-	-
	Registration	✓	-	-	-	-	-	-	-	-	-
Analysis	Handling of incomplete questionnaires	✓	✓	-	-	✓	-	-	✓	-	✓
	Questionnaires submitted with an atypical timestamp	✓	-	-	-	-	-	-	-	-	-
	Statistical correction	-	-	-	✓	-	-	-	-	-	✓

Abbreviations: ✓Described; ✓ Description incomplete; - Not described; * Not applicable.*

Table 2: Data items

Author (year)	Country	Study aims	Study population	esports genres	Sample size and sex	Age	Study design	Methodology	Key findings	Conflicts of interest
Schubert et al. (2022)	Germany	To explore the perceptions of esports professional players regarding the use of performance-enhancing substances.	esports professional players	Sports (FIFA)	n = 9 males	18 to 27 y	Observational study	Semi-structured interview	The use of oral tobacco, energy drinks, and gaming boosters is vulgarized among professional FIFA players.	Not stated
Baumann et al. (2022)	Norway	To assess the Norwegian esports students' sleep, nutritional, and physical activity habits and the link to health and performance.	esports competitors	Shooter, MOBA	n = 20 (17 males, 3 females)	M = 19 y SD = 1.4	Observational study	Semi-structured interview	~75% ingest energy drinks weekly, and ~50% daily, drinking ≥ 500 ml on each occasion. ~50% regularly skips breakfast.	None
Jasny et al. (2021)	Poland	To investigate the attitudes of seasoned competitive players of MGT and their training regimes for esports competitions.	Experienced competitive esports players	MGT	n = 12 (sex not reported)	M = 28 y (25 to 38 y)	Observational study	Semi-structured interview	The dominant practice is to avoid heavy foods and overeating, opt for easily digestible foods, such as fruits and nuts, and drink enough water to remain hydrated.	Not stated
Friehs et al. (2022)	USA and possibly other countries	To investigate the perceptions of performance enhancers usage in esports, including dietary supplements.	Casual gamers and esports competitors	Shooter, MOBA, Strategy, MMO, Racing, Fighting, Sports	n = 566 (477 males, 65 females, 24 others)	M = 25.9 y SD = 6.6	Cross-sectional study	Web-based survey	81.3% of professional players uses nutritional supplements (e.g. caffeine, tyrosine), and 49.1% uses "socially accepted drugs" such as alcohol, nicotine, and cannabis.	Not stated
Ip et al. (2021)	USA	To evaluate the frequency of illicit drug use and Internet Gaming Disorder (IGD) among adult gamers, as well as if any characteristics put someone at a higher risk for IGD.	Adult gamers including esports players	Not reported	n = 526 (84.2% males)	M = 23.9 y SD = 4.9	Cross-sectional study	Web-based survey	58.1% ingest caffeine through caffeinated drinks (33.8%), energy drinks (19.2%), and caffeine pills (5.1%). 3.8% uses vitamin B11, 2.3% Yerba mate, 1.5% melatonin, and 1.3% Guarana. 38.6% are binge and 12.9% heavy drinkers. Higher prevalence of binge drinking compared to a reference population.	None
Rudolf et al. (2020)	Germany	To characterize the demographics and health habits of video game and esports participants.	Video games and esports players	Shooters, MOBA, Strategy, Sports, MMO	n = 1066 (91.9% males)	M = 22.9 y SD = 5.9	Cross-sectional study	Web-based survey	The mean fruit and vegetable consumption is 2.7 (SD = 1.8) portions/day. Merely 11% ingest ≥ 5 pieces of fruit or vegetables per day.	None
Huth (2021)	Germany	To determine the possible variations in dietary behavior between individuals who participate in esports and those who do not.	esports players	Not reported	n = 339 (90% males)	M = 26.5 y SD = 6.8	Cross-sectional study	Web-based survey	esports players ingest less fruits and vegetables, but also less caffeinated drinks and alcohol compared to a reference population.	Not stated
Trotter et al. (2020)	65 countries; the most represented were the USA, Australia, Canada, Germany, and UK	To examine the link between obesity, physical activity, smoking habits, alcohol intake, and perceived health among esports competitors.	esports professional players	Not reported	n = 1772 (87.2% male among 851 who reported this information)	Not reported	Cross-sectional study	Web-based survey	esports players are more likely to be categorized as non-drinkers (65.1%), compared to international reference data.	None
Kósa et al. (2022)	Hungary	To assess the prevalence and health risk factors of internet addiction among adult esports players.	esports players including professionals	Not reported	n = 2313 (92.4% males)	18 to 25 y (90.3%) 26 to 35 y (7.9%) > 35 y (1.8%)	Cross-sectional study	Web-based survey	Lower prevalence of alcohol consumption in esports players (14.1%) compared to a reference population (53.2%). Internet addiction is significantly linked to regular alcohol consumption (OR = 18.357, $p < 0.001$).	None

Abbreviations: M = Mean; SD = Standard Deviation; MOBA = Multiplayer Online Battle Arena (e.g. League of Legends); MMO (Massive Multiplayer Online Game); Shooter = Third and First Person Shooter (e.g. Conter-Strike: Global Offensive); RTS = Real Time Strategy (e.g. StarCraft); HS = Hearthstone; TT = Teamfight Tactics; MGT = Magic The Gathering; PUFAs = Polyunsaturated Fatty Acids.

Table 2: Data items (Continuation)

Author (year)	Country	Study aims	Study population	esports genres	Sample size	Age	Study design	Methodology	Key findings	Conflicts of interest
Goulart et al. (2023)	USA	To characterize the nutrition, sleep, and physical activity of professional or highly competitive esports players as well as their relationship to cognitive performance.	Elite esports players including professionals	Action (platformers, shooters, racing, and fighting); Action-adventure (e.g. Halo); Adventure; Role-playing; Strategy; Casual; Simulation (sports, driving); Simulations (towns, cities).	n = 119 (103 males, 16 females)	M = 23.1 y SD = 5.0 (16 to 35 y)	Cross-sectional study	Web-based survey. Food diary (10 days) via ASA24 software	On average, the sample failed to meet existing guidelines, and doesn´t ingest the recommended amounts of fruits, vegetables, whole grains, fiber, and micronutrients. Excessive ingestion of sodium, saturated fat, and cholesterol also reported. The consumption of vegetables and the recommended amount of riboflavin, phosphorous, vitamin B12, selenium, and protein (≥ 0.8g/kg) is associated with superior cognitive performance ($p < 0.05$).	None
Lam et al. (2022)	China	To investigate the health profiles and health conditions of professional mobile-gaming players.	esports professional players	MOBA (mobile)	n = 50 males	M = 20.0 y SD = 1.7 (18 to 24 y)	Cross-sectional study	Questionnaire	19.4% consistently consume alcohol. 28.6% regularly ingest coffee.	None
Szot et al. (2022)	Poland	To characterize the dietary patterns of esports players.	esports players including professionals	Shooter, MOBA	n = 233 males	18 to 26 y	Cross-sectional study	Questionnaire	The sample exhibit irregular meal patterns and a Western diet style, with low fruit and vegetable intake, and relatively high fast food, fried food, red meat, salty snacks, sweets, soft drinks, and energy drink ingestion. Lower prevalence of alcohol users compared to a reference population.	None
Kulecka et al. (2023)	Poland	To characterize and compare the gut microbiomes of esports players to the microbiomes of a control group.	Physical education students, esports players	Shooter, MOBA, RTS	n = 95 males (59 esports players)	M = 20.9 y SD = 2.4	Cross-sectional study	Three-day food diary	Total energy, protein, carbohydrate, fiber, sucrose, PUFAs, and cholesterol intake are significantly lower in the esports players' diet compared to the controls (physical education students). No significant differences regarding alcohol intake.	None
Krarup et al. (2022)	Denmark	To examine changes during two 18-hour inactive video gaming periods.	esports competitors	Not reported	n = 9 males	M = 25.8 y SD = 2.6	Cross-sectional study	Food diary (2 days)	Over 42 hours, the volunteers ingested a total of 8004.9 (SD = 438.4) kcal, 6624.9 ml (SD = 801.2) of fluids, and 1354.4 mg (SD = 106.6) of caffeine.	None

Abbreviations: M = Mean; SD = Standard Deviation; MOBA = Multiplayer Online Battle Arena (e.g. League of Legends); MMO (Massive Multiplayer Online Game); Shooter = Third and First Person Shooter (e.g. Conter-Strike: Global Offensive); RTS = Real Time Strategy (e.g. StarCraft); HS = Hearthstone; TT = Teamfight Tactics; MGT = Magic The Gathering; PUFAs = Polyunsaturated Fatty Acids.

Table 2: Data items (Continuation)

Author (year)	Country	Study aims	Study population	esports genres	Sample size	Age	Study design	Methodology	Key findings	Conflicts of interest
Soffner at al. (2023)	Germany	To research the dietary habits and other health-related variables of gamers and esports competitors.	Video games and esports players	Not reported	n = 817 (87.1% males)	M = 24.2 y SD = 6.9	Cross-sectional study	Web-based survey	Daily water consumption average 7.8 (SD = 5.0) daily servings and represented the main source of fluid intake. They also haved 0.9 (SD = 1.8) servings of soft drinks, 0.9 (SD = 1.4) of coffee, 0.2 (SD = 0.5) of energy drinks, and 0.4 (SD = 0.7) servings of beer per day. The sample averages a daily consumption of 0.9 (SD = 1.0) servings of fruits, 1.7 (SD = 1.6) of vegetables, 0.3 (SD = 0.4) of fast food, 0.2 (SD = 0.4) of chips and savory snacks, 0.2 (SD = 0.3) of sweet bakery products, and 0.6 (SD = 0.8) servings of sweets. Fast food (rho = 0.13; p < 0.01), energy drinks (rho = 0.14; p < 0.01), and soft drinks (rho = 0.14; p < 0.01) are positively (poorly) correlated with video game playing time. Higher consumption of energy drinks among esports players compared to video game players. Lower alcohol consumption in the total sample compared to a reference population.	None
Matias et al. (2023)	Portugal	To characterize gaming and health-related traits of esports players	Esports players	Shooter, MOBA, Sports simulators	n = 235 (85.1% males)	18 to 58 y 42.5% had 19 to 22 y	Cross-sectional study	Web-based survey	29.8% uses dietary supplements, mostly animal protein (30%), multivitamins (15.7%), and creatine (14.3%). The average coffee intake is 2.1 (SD = 1.0) cups/day. 60.4% drinks coffee daily. Regarding consumption of snacks and beverages ≥ 1-3 days per month, while gaming, 36.6% of the total sample eats chocolate, 35.7% eats fast food, 33.2% have soda, 16.2% drinks alcoholic beverages, and 14.5% drinks energy drinks.	None
Ribeiro et al. (2023)	Portugal & Brazil	To characterize the sociodemographics, gaming, and dietary habits of esports players.	Esports players	Shooter, MOBA, Racing simulators, Sports simulators	n = 274 (256 males) Portuguese & n = 305 (273 males) Brazilian	Median = 24 y (P25 = 20; P75 = 30)	Cross-sectional study	Web-based survey	32.3% uses dietary supplements, mostly whey protein (59.4%), creatine (47.1%), and caffeine (33.2%). 84.5% eats < 5 servings of fruits and vegetables per day. 70.1% eats sweets or commercial pastries, 65.8% have coffee, 63.4% eats fast food, and 23.0% have energy drinks on ≥ 1 occasions per week. 78.1% have ≥ 1 servings of red or processed meat, and 40.9% have ≥ 1 sodas per day. The average caffein consumption from drinks is 179 (SD = 208) mg per day. 23.0% never eats breakfast, and 47.5% skips it ≥ 3 days per week. Portuguese and Brazilian esports players display lower adhesion to the Mediterranean diet, lower consumption of fruits and vegetables, higher prevalence of breakfast omission, higher consumption of caffeine supplements, red or processed meat, fast food, soda, energy drinks, confectionery and sweets when compared to a reference population. Higher levels of Internet Gaming Disorder and professionalization correlated with a lower adhesion to the Mediterranean diet.	None

Abbreviations: M = Mean; SD = Standard Deviation; MOBA = Multiplayer Online Battle Arena (e.g. League of Legends); MMO (Massive Multiplayer Online Game); Shooter = Third and First Person Shooter (e.g. Conter-Strike: Global Offensive); RTS = Real Time Strategy (e.g. StarCraft); HS = Hearthstone; TT = Teamfight Tactics; MGT = Magic The Gathering; PUFAs = Polyunsaturated Fatty Acids.

Paper IV: Sociodemographics, Playing Habits, Adherence to the Mediterranean Dietary Pattern, Dietary Supplements Intake, Physical Activity Level, and Degree of Internet Gaming Disorder of Portuguese Chess Players

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Sociodemographics, playing Habits, adherence to the Mediterranean dietary pattern, dietary supplements intake, physical activity level, and degree of Internet gaming disorder of Portuguese chess players

Sociodemografía, hábitos de juego, adherencia al patrón dietético mediterráneo, ingesta de suplementos dietéticos, nivel de actividad física y grado de trastorno del juego en Internet de jugadores de ajedrez portugueses

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ABSTRACT

Introduction: Lifestyle and gaming habits may influence chess players' adhesion to healthy dietary patterns. This study aims to characterize Portuguese chess players sociodemographics, playing traits, adherence to the Mediterranean diet (MD), dietary supplement (DS) consumption, physical activity level, degree of internet gaming disorder (IGD) and to study predictors of adherence to the MD.

Methods: Data was gathered using an online survey disseminated through social networks, which included questions regarding sociodemographics, chess playing habits, the PREDIMED questionnaire, DS consumption, the International Physical Activity Questionnaire, and the Internet Gaming Disorder Scale.

Results: The 192 respondents (93.8 % males) had a mean of 41 years (SD = 14), high education (mean = 15.1 y, SD = 1.7), and played chess for 6.3 hours (SD = 9.7) a week. Most (58.9 %, n = 113) reported moderate adherence to the MD, 30.2 % (n = 58) ingested DS, 64.1 % (n = 123) adhered to the WHO Physical Activity Recommendations, and no subject was classified with IGD.

Higher Elo scores correlated with higher red/processed meat consumption (OR = 4.935, p = 0.005). A greater volume of chess play related to higher consumption of pastries and sweets (OR = 3.127, p = 0.007). Higher IGD scores were associated with lower adhesion to the MD (OR = 1.067, p = 0.019).

Conclusions: The most dedicated chess players may be less concerned with maintaining a balanced diet and may require supervision from health professionals.

Funding: None to disclose.

Keywords: Video Games; Dietary Supplements; Diet, Mediterranean; Sedentary Behavior; Internet Addiction Disorder.

Registration/publication of the protocol: No protocol was registered for this study.

RESUMEN

Introducción: El estilo de vida y los hábitos de juego pueden influir en la adhesión de los jugadores de ajedrez a patrones dietéticos saludables. Este estudio pretende caracterizar la sociodemografía de los ajedrecistas portugueses, sus rasgos de juego, su adherencia a la dieta mediterránea (DM), el consumo de suplementos dietéticos (DS), el nivel de actividad física, el grado de trastorno de los juegos de Internet (IGD) y estudiar los predictores de la adherencia a la DM.

Metodología: Los datos se recolectaron mediante una encuesta en línea difundida a través de redes sociales, que incluyó preguntas sobre datos sociodemográficos, hábitos de juego de ajedrez, cuestionario PREDIMED, consumo de DS, Cuestionario Internacional de Actividad Física y Escala de Trastorno de los Juegos de Internet.

Resultados: Los 192 encuestados (93,8 % hombres) tenían un promedio de 41 años (DE = 14), educación alta (media = 15,1 años; DE = 1,7), y jugaban al ajedrez 6,3 horas (DE = 9,7) por semana. La mayoría (58,9 %; n = 113) refirió una adherencia moderada a la DM, 30,2 % (n = 58) ingirió DS, 64,1 % (n = 123) adhirió a las recomendaciones de actividad física de la OMS y ninguno fue clasificado con IGD.

Puntuaciones Elo más altas se relacionarán con un mayor consumo de carne roja/procesada (OR = 4,935; p = 0.005). Un mayor volumen de juego de ajedrez se relacionó con un mayor consumo de repostería comercial (OR = 3,127; p = 0.007). Puntuaciones más altas de IGD se asociaron con una menor adhesión a la DM (OR = 1,067; p = 0.019).

Conclusiones: Los jugadores de ajedrez más dedicados pueden estar menos preocupados por mantener una dieta equilibrada, y pueden requerir supervisión de profesionales de la salud.

Financiación: Ninguno para revelar.

Palabras clave: Juegos de Vídeo; Suplementos Dietéticos; Dieta Mediterránea; Conducta Sedentaria; Trastorno de Adicción a Internet.

Registro/publicación del protocolo: No se registró ningún protocolo para este estudio.

KEY MESSAGES

- Our sample register a lower consumption of fruits and vegetables, higher red or processed meat intake, and remain seated for longer hours a day than a reference population.
- A higher level of chess skill or dedication correlated with inadequate dietary habits.
- The most consumed dietary supplements were multivitamins-minerals with the purpose of increase energy/decrease fatigue and maintain good health.

INTRODUCTION

Chess originated about 1,500 years ago, and the number of players has been increasing in recent years. Netflix's "The Queens Gambit" and the COVID-19 pandemic have led to increased online chess competición and video sharing on Twitch and YouTube[1].

While sports nutrition research has typically focused on the most physically taxing sports such as athletics[2], mind sports received less attention. Chess relies on cognitive domains such as fluid and crystallized intelligence, processing speed, and short-term memory[3], and has been recognized as a sport by the International Olympic Committee since 2004[4].

In order to get an edge over opponents chess players may resort to “smart drugs” and stimulating DS such as caffeine to boost their cognitive abilities and minimize fatigue[5]. However, this practice has been considered a menace to the fair play policy in chess[6], and DS consumption represents a potential health hazard[7].

Sedentarism[8], inadequate dietary habits, and obesity are all linked to decreased cognitive function, in part due to raised neuroinflammation[9].

The rise in online chess websites[1] may be escalating the prevalence of IGD, linked to poor physical and cognitive health, sleep disturbances, and inadequate diet, including excessive caffeine consumption[10].

In contrast, a healthy lifestyle that includes physical activity[8], an adequate BMI, and adherence to a balanced diet (e.g., Mediterranean diet)[9] correlates with optimal cognition.

Fornal-Urban et al.'s 2008 study on Polish elite chess players found that 41.1 % skipped breakfast, only 13.3 % ate fruit and vegetables daily, and 57.2 % consumed sweets daily[11].

Justified by the scarcity of scientific literature, this investigation's main objectives were to characterize Portuguese chess players' sociodemographics, playing traits, adherence to the MD, DS consumption, physical activity level, degree of IGD, and to study the predictors of adherence to the MD.

METHODS

Study Design

This research project complied with the Declaration of Helsinki of the World Medical Association and received approval from an ethics committee of the University of Porto (No. 82/2022/CEFCNAUP/2022). An online survey was applied to a convenience sample of chess players between 1 July 2022 and 30 September 2022 by email, on chess-related websites, and Facebook pages and groups.

Inclusion criteria

Participants in this cross-sectional study had to be adult Portuguese chess players resident in Portugal, aged 18 to 69 and had played the game for at least six months. There were no rewards for taking part.

Survey administration

The survey was applied through Google form and is available as supplementary material (SM1). The survey's design, execution, and report adhered to the CHERRIES checklist statement[12], also provided as a supplement (SM2).

230 participants completed the questionnaire, 38 were excluded due to failure to comply with inclusion criteria or incoherent data, and 192 were included.

Questionnaires included

The survey included questions related to socioeconomic level[13], weight and height, chess playing habits, the PREDIMED questionnaire[14,15], DS consumption[13], the International Physical Activity Questionnaire - Short Form (IPAQ-SF), and the Internet Gaming Disorder Scale - Short-Form (IGDS9). The PREDIMED, IGDS9, and IPAQ-SF have been previously validated in the Portuguese population.

Corrective equations for BMI were applied to compensate for misestimated weight and height[16]. BMI (kg/m^2) was classified according to the World Health Organization cut-offs[17]. Permission for the use of PREDIMED (www.predimed.es) and IGDS9 were granted.

Statistics

Descriptive statistics were produced for all variables. Skewness and kurtosis were used to evaluate the normality of quantitative variables, and all had a distribution close to the normal, that is, between -1 and 1 for both coefficients.

Binary logistic regression models were applied to study the predictors of overall low (< median) adherence to the MD style and non-compliance with each of the 14 items evaluated by PREDIMED. Independent variables included: sex, age, BMI, physical activity level, weekly hours of chess practice, number of chess competitions in the prior 12 months, number of years of chess practice, Elo score, registration in the FPX, and total IGD score. The independent variables included in the regression models were tested for multicollinearity, and all VIF values (using dummy variables for categorical ones) were below 2.6. For the overall adherence to the MD style, both univariate (raw) and multivariate (adjusted) models are presented, while for individual items we present the adjusted models.

Fisher's exact test was used to assess the independence between DS use and sex, marital status, and employment status. The comparison between participants who did vs. those who did not use DS was performed using independent samples t-test for age, BMI, and household size and Mann-Whitney's test for education and income.

The significance for all analyses was established at 5 %. SPSS® Statistics 28.0 for Windows was used for all statistical analysis (IBM Corp., Armonk, NY, USA).

RESULTS

Sociodemographics and BMI

The 192 participants averaged 41.1 years (SD = 14), had a BMI of 26.2 kg/m² (SD = 4.3), and were predominantly male (93.8 %; n = 180), with a high education level (mean = 15.1 y; SD = 1.7). Lisbon was home to 27.6 % (n = 53), and 21.9 % (n = 42) lived in Porto city.

Additional information is detailed in Table 1.

Table 1. Sociodemographic characteristics.

	%	n
Sex		
Male	93.8	180
Female	6.3	12
Age		
18 to 29 years	24.5	47
30 to 39 years	20.8	40
40 to 49 years	26.6	51
50 to 59 years	16.7	32
60 to 69 years	11.5	22
BMI		
Underweight (BMI < 18.5 kg/m^2)	2.6	5
Normal range (BMI ∈ [18.5; 25.0[kg/m^2)	41.7	80
Pre-obesity (BMI ∈ [25.0; 30.0[kg/m^2)	35.9	69
Obesity class I (BMI ∈ [30.0; 35.0[kg/m^2)	16.7	32
Obesity class II (BMI ∈ [35.0; 40.0[kg/m^2)	3.1	6
Education		
9 years	2.1	4
12 years	16.7	32
14 years	4.7	9
≥ 16 years	76.6	147
Household income[a]		
Low (< 1456 €)	21.4	36
Middle (1456 to 2910 €)	48.8	82
High (> 2910 €)	29.8	50
Marital status		
Married or living in a de facto relationship	52.1	100
Single	40.1	77
Divorced	7.8	15
Employment status		
Worker	77.6	149
Unemployed	4.7	9
Other	17.7	34

[a]23 participants didn´t report household income.

Chess-related variables

The subjects have been playing chess for a mean of 21.1 y (SD = 15.1) and averaged 6.3 h (SD = 9.7) of chess practice per week. 64.6 % (n = 124) were registered in the FPX. 66.1 % (n =

127) reported having an Elo Score, with a mean score of 1679 (SD = 306), and 68.2 % (n = 131) participated in at least one chess competition in the prior 12 months, with an average of 6.2 (SD = 8.0) chess competitive events.

PREDIMED and Dietary Habits

Our sample had a mean total PREDIMED score of 7.0 (SD = 1.7). 24.5 % (n = 47) of participants were classified as having weak adherence, 58.9 % (n = 113) moderate-to-fair adherence, and 16.7 % (n = 32) had good or very good adherence to the MD. In total, 75.0 % (n = 144) of the sample ingested less than five portions of fruit and vegetables a day, while the daily consumption averaged 3.3 servings (SD = 1.9).

Compliance with each PREDIMED item is presented in Table 6, available as supplementary material (SM3).

Dietary Supplements

From our total initial sample (n = 192), 30.2 % (n = 58) reported having ingested DS supplements in the prior 12 months. Multivitamin-mineral complexes (41.4 %, n = 24) and whey protein (31.0 %, n = 18) were the most consumed type of supplement (Table 2).

Table 2. Types of dietary supplements consumed.

	%	n
Multivitamin/mineral complex	41.4	24
Whey protein	31.0	18
Sports bars	29.3	17
Magnesium	29.3	17
Omega 3	24.1	14
Caffeine	19.0	11
Vitamin C (ascorbic acid)	17.2	10
Sports drinks	13.8	8
Energy drinks	13.8	8
Creatine	13.8	8
Vitamin D3 (cholecalciferol)	12.1	7
Vegetable protein (soy pea rice)	10.3	6
Vitamin B12 (cobalamin)	10.3	6
Calcium	8.6	5
Gingko biloba	8.6	5
Glucosamine	8.6	5
Carbohydrates	6.9	4
Complex B vitamins	6.9	4
BCAAs	5.2	3
Chondroitin	5.2	3
Brewer's yeast	5.2	3
Vitamin E	5.2	3
Essential Amino Acids	3.4	2
Iron	3.4	2
Glutamine	3.4	2
Guarana	3.4	2
L-carnitine	3.4	2
Potassium	3.4	2
Flavonoids	1.7	1
Ginseng	1.7	1
Iodine	1.7	1
Lysine	1.7	1
Nitrates / Beetroot Juice	1.7	1
Vitamin B3 (niacin)	1.7	1
Zinc-selenium	1.7	1

The main reasons reported for consuming DS were to increase energy/decrease fatigue (44.8 %, n = 26), maintain good health (44.8 %, n = 26), prevent/treat diseases or injuries (36.2 %, n = 21) (Table 3).

Table 3. Reasons for using dietary supplements.

	%	n
Increase energy/decrease fatigue	44.8	26
Keep me healthy	44.8	26
Prevent/treat illness or injury	36.2	21
Gain muscle mass	27.6	16
Improve sports performance	24.1	14
Improve cognitive performance	19.0	11
Speed up recovery	17.2	10
Compensate for eating errors	17.2	10
Gain strength	17.2	10
Increase concentration/focus	15.5	9
Decrease stress	10.3	6
Cognitive stimulation	6.9	4
Lose weight	6.9	4
Help to relax	5.2	3
Increase resistance	5.2	3
Increase emotional control	5.2	3
Gain weight	1.7	1
Doctor's prescription	1.7	1
Make me faster	1.7	1

Nearly one third of DS consumers (31.6 %, n = 18) cited medical doctors as a source of information regarding DS, followed by scientific articles (24.1 %, n = 14). The majority of the DS consumers (29.3 %, n = 17) in this sample purchased their DS in supplement stores/herbalists, followed by online stores (27.6 %, n = 16).

Most DS users reported being very well (27.6 %, n = 16) or well-informed (34.5 %, n = 20) about DS.

Only the employment status had a statistically significant relationship with supplement intake (p = 0.005), with DS users presenting a slightly higher proportion of active workers and no unemployed. Additional information regarding DS consumption is available as supplementary material (SM4).

Physical Activity Level

On the IPAQ-SF, 45.8 % (n = 88) of respondents were classified as having a high, 33.3 % (n = 64) moderate, and 20.8 % (n = 40) low physical activity level. According to the stated data, 64.1 % (n = 123) of respondents adhere to the WHO Physical Activity Recommendations, while 35.9 % (n = 69) don't. Regarding sedentary behavior, our sample averaged 6.4 (SD = 0.2) daily hours of sitting.

IGD

The sample averaged 13.5 points (SD = 5.4) on the IGDS9. No respondent accumulated a total score ≥ 36, and thus no subject was classified as presenting IGD.

Logistic regression results

Sex: The chances of non-compliance regarding vegetable intake (OR = 0.157, *p* = 0,026) were lower, and the use of olive oil as the main cooking fat (OR = 22.243, *p* = < 0,001) were higher for females compared to males (table 7, SM3).

Age: Higher age was associated with lower chances of scoring a PREDIMED total value below the median (< 7), in both raw (OR = 0.977, *p* = 0.027) and adjusted models (OR = 0.967, *p* = 0.031) (Table 4).

The chances of non-compliance concerning fruit (OR = 0.955, p = 0.009), red and processed meats (OR = 0.933, *p* = < 0.001), wine (OR = 0.936, *p* = 0.019), legumes (OR = 0.966, *p* = 0.023) and fish or shellfish (OR = 0.969, *p* = 0.042) consumption were also lower for older individuals (Table 7, SM3).

BMI: Chances for non-compliance regarding the intake of butter, margarine, or cream were higher for individuals with higher BMI (OR = 1.120, *p* = 0.009), as well as the chances of non-compliance regarding the use of olive oil as main cooking (OR = 1.183, *p* = 0.032), and fish or shellfish consumption (OR = 1.087, *p* = 0.036) (Table 7, SM3).

Table 4. Predictors of overall low adherence to the Mediterranean Diet.

		PREDIMED Total < Median			
		Crude model		**Adjusted model[d]**	
p (Model)		**- - -**		**0.260**	
Nagelkerke's R2		**- - -**		**0.120**	
	n	***p***	***Exp(β) (95 % CI)***	***p***	***Exp(β) (95 % CI)***
Sex		0.478		0.334	
Male	180		1 (Ref.)		1 (Ref.)
Female	12		0.639 (0.186; 2.200)		0.515 (0.134; 1.977)
Age	192	0.027*	0.977 (0.957; 0.997)	0.031*	0.967 (0.938; 0.997)
BMI	192	0.379	1.030 (0964; 1.101)	0.055	1.078 (0.998; 1.164)
PA level		0.961		0.823	
Low	40	0.848	0.929 (0.437; 1.976)	0.937	1.036 (0.435; 2.467)
Moderate	64	0.794	0.917 (0.479; 1.757)	0.581	0.814 (0.392; 1.692)
High	88		1 (Ref.)		1 (Ref.)
Chess practice/week (h)[a]		0.454		0.372	
1st tercile	79		1 (Ref.)		1 (Ref.)
2nd tercile	56	0.215	1.548 (0.775; 3.092)	0.223	1.586 (0.755; 3.334)
3rd tercile	57	0.737	1.126 (0.563; 2.252)	0.911	0.957 (0.438; 2.091)
No. of competitions[b]		0.625		0.475	
1st tercile	90		1 (Ref.)		1 (Ref.)
2nd tercile	45	0.537	0.794 (0.382; 1.652)	0.554	0.768 (0.320; 1.841)
3rd tercile	57	0.632	1.177 (0.604; 2.292)	0.495	1.359 (0.563; 3.284)
Years of chess practice		0.575		0.658	
1st tercile	68		1 (Ref.)		1 (Ref.)
2nd tercile	61	0.750	0.893 (0.446; 1.789)	0.564	0.791 (0.356; 1.757)
3rd tercile	63	0.301	0.692 (0.345; 1.389)	0.712	1.211 (0.438; 3.345)
ELO score		0.598		0.769	
NR[c] (reference)	69		1 (Ref.)		1 (Ref.)
≤1700	63	0.337	0.712 (0.355; 1.425)	0.501	0.747 (0.320; 1.747)
>1700	60	0.876	0.946 (0.472; 1.895)	0.865	0.922 (0.363; 2.345)
Registered in the FPX		0.625		0.913	
No	68		1 (Ref.)		1 (Ref.)
Yes	124		0.862 (0.475; 1.584)		0.954 (0.407; 2.233)
Total IGD score	192	0.019*	1.067 (1.011; 1.126)	0.052	1.062 (0.999; 1.129)

Abbreviations: BMI = Body Mass Index, CI = Confidence Interval, FPX = Portuguese Chess Federation, IGD = Internet Gaming Disorder, n = Sample size, OR = Odds Ratio, PA = Physical Activity Level, Ref. = Reference. Exp(β) < 1 implies a total PREDIMED score above the median; Exp(β) > 1 implies a total PREDIMED score below the median. [a]Number of hours of chess practice per week. [b]Number of chess competitions in the prior 12 months. [c]NR = Not reported or reported "zero". [d]Model adjusted for all the independent variables. *p <0.05.

Chess related-variables: The likelihood of non-compliance concerning pastries or sweets consumption was greater for individuals with longer weekly chess practice (3rdtercile) compared to those with less (1st tercile) (OR = 3.127, *p* = 0.007).

The chances of non-compliance concerning red and processed meat consumption were found for those with a higher Elo rating versus individuals who didn't report an Elo rating (OR = 4.935, *p* = 0.005). Despite not reaching statistical significance, participants with an Elo rating > 1700 tended for a greater likelihood (OR = 2.148, *p* = 0.118) of non-adherence to vegetable consumption (table 5).

Physical Activity Level: The likelihood of non-compliance concerning vegetable intake was greater for individuals with low (OR = 2.837, *p* = 0.021) and moderate (OR = 2.664, *p* = 0.012) compared with those with high physical activity level. A similar outcome was found concerning fruit consumption for those with low levels of physical activity (OR = 4.580, *p* = 0.015) (table 7, SM3).

IGD: In the unadjusted model, the chances for a total PREDIMED score below the median were higher for those with a higher total IGD score (OR = 1.067, *p* = 0.019) (table 4). In addition, the likelihood of non-compliance regarding fish or shellfish consumption was greater for players with higher IGD scores (OR = 1.078, *p* = 0.021) (Table 5).

Table 5. Predictors of non-compliance of chess-related variables with specific PREDIMED items.

		3. Vegetables ≥ 2 servings/day		5. Red or processed meats < 1 serving/day	
p (Model)				0.011*	
Nagelkerke's R2				0.195	
	n	p	OR (95 % CI)	p	OR (95 % CI)
Chess practice (h/week)[a]		0.295		0.414	
1st tercile	79		1 (Ref.)		1 (Ref.)
2nd tercile	56	0.817	1.094 (0.511; 2.343)	0.252	1.642 (0.703; 3.837)
3rd tercile	57	0.135	1.830 (0.828; 4.042)	0.888	0.941 (0.401; 2.203)
No. of competitions[b]		0.732		0.318	
1st tercile	90		1 (Ref.)		1 (Ref.)
2nd tercile	45	0.587	0.782 (0.322; 1.900)	0.133	0.484 (0.188; 1.247)
3rd tercile	57	0.448	0.705 (0.286; 1.740)	0.382	0.643 (0.239; 1.731)
Years of chess practice		0.806		0.516	
1st tercile	68		1 (Ref.)		1 (Ref.)
2nd tercile	61	0.582	0.794 (0.349; 1.806)	0.273	0.597 (0.237; 1.502)
3rd tercile	63	0.570	0.744 (0.268; 2.066)	0.866	0.912 (0.315; 2.640)
ELO score		0.020*		0.016*	
NR[c] (reference)	69		1 (Ref.)		1 (Ref.)
≤1700	63	0.291	0.630 (0.268; 1.485)	0.297	1.642 (0.647; 4.169)
>1700	60	0.118	2.148 (0.824; 5.600)	0.005	4.935 (1.609; 15.138)
Registered in the FPX		0.394		0.414	
No	68		1 (Ref.)		1 (Ref.)
Yes	124		1.456 (0.614; 3.453)		0.678 (0.267; 1.723)
Total IGD score	192	0.673	1.014 (0.952; 1.079)	0.936	0.997 (0.928; 1.071)

Abbreviatures. n: Sample size, p: Probability value, OR: Odds Ratio, CI: Confidence Interval, Ref.: Reference, BMI: Body Mass Index, PA: Physical Activity Level, FPX: Portuguese Chess Federation, IGD: Internet Gaming Disorder, [a]Number of hours of chess practice per week, [b]Number of chess competitions in the prior 12 months, [c]NR: Not reported or reported an ELO score of zero. Note: All logistic regressions were adjusted for sex, age, BMI, and physical activity level. For each PREDIMED item, ORs <1 imply better compliance. ORs >1 imply poorer compliance.

Table 5. Continuation.

		10. Fish or seafood ≥ 3 servings/week		11. Commercial pastries/sweets ≤ 2 occasions/week	
p (Model)		0.001*		0.062	
Nagelkerke's R2		0.246		0.159	
	n	p	OR (95 % CI)	p	OR (95 % CI)
Chess practice (h/week)[a]		0.725		0.026*	
1st tercile	79		1 (Ref.)		1 (Ref.)
2nd tercile	56	0.769	0.893 (0.419; 1.902)	0.107	1.929 (0.868; 4.286)
3rd tercile	57	0.424	0.724 (0.327; 1.599)	0.007*	3.127 (1.363; 7.173)
No. of competitions[b]		0.867		0.825	
1st tercile	90		1 (Ref.)		1 (Ref.)
2nd tercile	45	0.871	0.929 (0.381; 2.266)	0.864	1.082 (0.441; 2.654)
3rd tercile	57	0.713	1.187 (0.475; 2.967)	0.655	0.811 (0.324; 2.030)
Years of chess practice		0.684		0.201	
1st tercile	68		1 (Ref.)		1 (Ref.)
2nd tercile	61	0.874	0.936 (0.415; 2.112)	0.073	2.167 (0.930; 5.050)
3rd tercile	63	0.490	1.430 (0.517; 3.954)	0.402	1.571 (0.546; 4.526)
ELO score		0.053		0.672	
NR[c] (reference)	69		1 (Ref.)		1 (Ref.)
≤1700	63	0.653	1.222 (0.510; 2.930)	0.705	1.186 (0.490; 2.875)
>1700	60	0.087	0.434 (0.167; 1.131)	0.667	0.806 (0.301; 2.155)
Registered in the FPX		0.446		0.696	
No	68		1 (Ref.)		1 (Ref.)
Yes	124		1.408 (0.584; 3.393)		0.839 (0.348; 2.024)
Total IGD score	192	0.021*	1.078 (1.011; 1.150)	0.514	1.021 (0.960; 1.086)

Additional logistic regression results regarding predictors of non-compliance with each of the 14 PREDIMED items is provided as supplementary material (SM3).

DISCUSSION

Sociodemographics

The collected data imply that the majority of the sample is male (93.8 %), and from the middle and upper classes as they were more likely to be employed, reported high levels of education, and reasonably high monthly incomes (> 1455 €).

Our results suggest that higher age correlates with lower chances for a total PREDIMED score below the median and lower chances of non-compliance regarding fruit, red and processed meats, wine, legumes, and fish or shellfish consumption. This is in line with the IAN-AF 2015-16 study, which registered greater adherence to the MD in older individuals[13].

BMI

Excessive body fat significantly raises the risk of a myriad of health complications, including cardiovascular diseases, metabolic syndrome[18], mild cognitive impairment, and brain atrophy[9], which could impair chess performance.

According to a national inquiry conducted in 2015-16, excessive adiposity characterizes more than half of the adult Portuguese population, with 36.5 % being overweight, and 21.6 % obese[13]. This scenario appears rather similar for our sample of Portuguese chess players as the majority classified either as overweight (35.9 %) or obese (19.8 %).

Chess-Related Variables

Our study detected a positive association between a higher Elo rating and non-compliance for red and processed meat consumption and a trend for non-compliance regarding vegetable ingestion. An additional positive association between a higher number of hours of chess play per week and non-compliance concerning the consumption of pastries and sweets was found.

Fornal-Urban et al. (2008) reported high consumption of sweets in a sample of young (8 to 19 years) Polish elite chess players. 21.5 % of respondents reported eating sweets several times per day. More than half (57.2 %) declared consuming a sweet at least once per day, and a considerably greater proportion (79.2 %) ingested at least one sweet per day on tournament days[11]. Additionally, 13.3 % only ate fruit and vegetables once a day and 39.5 % included them in at least three meals per day[11].

As becoming a highly competitive and successful chess player requires extensive chess practice (3,000 to 23,600 hours)[19], the increased dedication and consequent proficiency in chess may translate into lower care or inhibitory control regarding diet quality[20]. Indeed, our sample reported 6.3 hours of chess practice per week, and Fornal-Urban et al. (2008) registered notoriously greater values, with a weekly average of 11.5 h (SD = 6.4) for high-ranked youth chess players[11].

Additionally, given that most respondents in our sample had college degrees, the most dedicated and professional chess players may acknowledge glucose as the brain's primary energy source[9] and be aware of its potential nootropic qualities. Thus, they might resort to sweet pastries, sugary confectionaries, and soft drinks as sources of simple sugars to enhance their performance in chess practice and competitions.

We theorize that highly cognitively demanding chess practice may increase stress and anxiety, and decrease blood glucose due to increased brain glucose consumption[9], which may increase cravings for carbohydrate-rich foods[21], particularly on competition days[11].

Mediterranean Dietary Pattern

Besides affecting health and body composition, dietary habits also influence cognition[9]. Existing literature suggests that healthy dietary patterns correlate with optimum brain performance[9]. Compared to a control diet, a meta-analysis of randomized controlled studies found significant effect sizes (ES) in favor of an MD for eight cognitive domains, including global cognition (ES = 0.24, 95 % CI = -0.00; 0.47), working memory (ES = 0.20, 95 % CI = -0.02; 0.42), and executive function (ES = 0.22, 95 % CI = -0.04; 0.48)[22], which contribute to chess gaming performance[3].

According to the IAN-AF 2015-16 study, 15.7 % of Portuguese adults (18 to 64 years) have high, 50 % moderate, and 34.3 % low adherence to the MD[13]. Our research uncovered slightly better adhesion values. 16.7 % of our sample was categorized with high adherence to the MD, 58.9 % as moderate, and 24.5 % of subjects had low compliance. Additionally, the IAN-AF 2015-16 survey found that 57 % of Portuguese adults do not consume the minimum amount of fruit and vegetables recommended by the WHO (400 g/day)[13]. Our study revealed lower conformity to the WHO recommendations: 75 % of chess players ingested less than 5 portions a day, while only a quarter (25 %) ingested at least that amount.

Typically low in nutrients and rich in added sugars, the ingestion of soft drinks has been correlated to health-damaging weight gain[9]. 18.2 % of our sample reported consuming one or more soft drinks per day. In comparison, the prevalence of daily consumption of ≥ 220 g of soft drinks in the IAN-AF 2015-16 inquiry was 15 % for adults[13].

According to a meta-analysis, the risk of colorectal cancer increases by 17 % (95 % CI = 5 %; 31 %) for 100 grams of red meat and by 18 % (95 % CI = 10 %; 28 %) for 50 grams of processed meat consumed daily[23]. The IAN-AF 2015-16 investigation determined that 25.5 % of Portuguese adults ingest more than 100 to 150 g of red meat per day[13]. In contrast, our study registered notoriously higher values (67.7 %) for the daily consumption of ≥ 100 to 150 grams of red or processed meat.

Dietary Supplements Consumption

A reference Portuguese population reported similar values for frequency of DS consumption, with 29.2 % of adults (18 to 64 years) admitting the use of DS[13], mainly multivitamin complexes (37.8 %)[13]. Additionally, 26 % reported the same main motivation for utilizing DS: "To lessen fatigue or enhance focus"[24].

Although the employment status differed between those who reported the intake of DS and those who did not, this result has little relevance to practice as our total sample only included nine unemployed individuals and also due to the existence of the “Other” category.

Sedentarism and Physical Activity

Our sample averaged more than six daily hours (6.4; SD = 0.2) spent sitting, a slightly higher value than the 5.5 h/day reported in the IAN-AF 2015-16 study[25]. Sedentary activity may negatively impact overall health as it raises the risk of cardiovascular diseases, diabetes mellitus, malignancies, and all-cause mortality[8]. In contrast, physical exercise correlates with optimal cognitive performance[8] and it is reasonable to presume that fitness training may also help to enhance chess-related abilities including memory, cognitive processing speed, and fluid intelligence[3].

The IAN-AF 2015-16 survey revealed that only 27.1 % of the Portuguese adult population had a high level of physical activity, while 30.6 % had a moderate, and 42.3 % had a low level[25]. In comparison, our inquiry registered a higher prevalence of high (45.8 %) and moderate (33.3 %) levels of physical activity in chess players, with 64.1 % adhering to the WHO Physical Activity Recommendations[26]. Moreover, low, and moderate levels of physical activity were negatively associated with fruit and vegetable consumption, respectively, compared to high physical activity levels.

Contrary to the anecdotal belief that esports contestants are inactive, top-level esports competitors of various esports titles have been documented to be physically active. A survey conducted in Portugal, which applied the IPAQ-SF to 433 players of a distinct esports title (EA SPORTS™ FIFA), reported even higher percentages for “high” levels of physical activity (84.5 %) while reporting 12.9 % for “moderate” and only 2.5 % for “low” levels of physical activity. Additionally, the median daily sitting time was lower (5.3 h) than ours[27], and relatively similar to the mean 5.5 h/day reported in the IAN-AF 2015-16 inquiry[25].

IGD

IGD is associated with decreased mental health and poorer healthy habits, including sedentarism, insufficient sleep, and poor nutrition[28]. As our sample averaged 13.5 (SD = 5.4) on the IGD total score, it doesn´t seem affected by gaming disorder. Although no respondent met the classification criteria for IGD, a higher score was associated with a lower total PREDIMED score and greater chances of non-compliance regarding fish or shellfish consumption, which may suggest less concern about adhering to an adequate dietary pattern due to greater dedication to the game.

Lower educational levels are linked to lower income, shorter longevity, unhealthy lifestyles, inactivity[29], and lower adherence to the MD[30]. The fact that most respondents (76.6 %) had at least a bachelor's degree may partially explain why our sample reported higher levels of physical activity and greater adherence to the MD than those reported by the IAN-AF 2015-16 study[13].

Limitations

This investigation carries intrinsic limitations. Significant bias may have occurred due to users' self-selection (volunteer effect), and duplicate responses, submitting fraudulent information, or purposefully erroneous responses. The low number of female respondents in our sample also limited comparisons between sexes.

CONCLUSIONS

Portuguese chess players are predominantly male, with higher education, belong to a medium-high socioeconomic stratum, and practice chess for 6,3 hours/day on average. They exhibit an approximate similar profile of BMI, MD adherence, DS intake, and a higher physical activity level compared to a reference population. However, they also register more daily hours spent sitting, a lower consumption of fruit and vegetables, and a higher consumption of red or processed meat.

Higher IGD scores associated with a lower adhesion to the MD and fish or shellfish consumption. Greater Elo scores correlated with higher red and processed meat consumption and a trend for lower vegetable ingestion. Moreover, a higher number of hours of chess play per week related to greater consumption of pastries and sweets. The most dedicated chess players may be less concerned with maintaining a balanced diet and may require supervision from health professionals. Additional investigations are needed to clarify the influence of diet-related variables and chess playing performance.

AUTHORS' CONTRIBUTIONS

FJR conceived the study, designed, and applied the survey, collected, and cleaned the descriptive statistical data, and drafted the manuscript. RP conceived and performed the statistical analysis and helped to draft the manuscript. All authors have read and approved the final version of the manuscript.

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CONFLICTS OF INTEREST

The authors express that there are no conflicts of interest when writing the manuscript.

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Paper V: Dietary Habits and Gaming Behaviors of Portuguese and Brazilian Esports Players

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Article

Dietary Habits and Gaming Behaviors of Portuguese and Brazilian Esports Players

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Abstract: As the esports industry grows, marketing campaigns for fast food, soft drinks, alcoholic and energy drinks, and dietary supplements at related events intensify. Portuguese and Brazilian esports players' dietary patterns remain unexplored. This study aimed to characterize the dietary and gaming habits of esports players. We applied an anonymous, open online survey to a convenience sample of esports players that included the PREDIMED and the Internet Gaming Disorder Scale. The survey was shared through email and social media platforms, including Facebook, Twitter, Instagram, Discord, WhatsApp, and Twitch. The sample (n = 579) was predominantly male (91.4%), averaged 26.1 (SD = 7.0) years, and 25.9 (SD = 5.5) kg/m^2. Most reported a weak (53.7%) adherence to the Mediterranean diet. Almost a third (32.3%) consumed dietary supplements. Our sample presented a low adhesion to the Mediterranean dietary pattern, low consumption of fruit and vegetables, and high consumption of fast food, red and processed meat, soft drinks, and dietary supplements, including caffeine-based supplements. Dietary supplement consumption was related to a higher adhesion to the Mediterranean diet, and a higher level of professionalization and internet gaming disorder correlated with a lower adhesion. In conclusion, we infer that Portuguese and Brazilian esports players follow an unbalanced diet.

Keywords: esports; video games; nutrition; diet; dietary supplements; caffeine; Mediterranean diet; PREDIMED; gaming disorder; IGDS9

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1. Introduction

Esports involves the competitive practice of video games against other players. Some of the most well-known esports games include first-person shooters such as Counter-Strike: Global Offensive and multiplayer online battle arena games such as League of Legends [1]. This hypercompetitive activity demands a high level of cognitive aptitude, mental agility, fine motor skills, fast reaction times, and resistance to mental fatigue [2].

The esports industry has been expanding and gaining an audience at an extraordinarily fast pace. The worldwide overall viewership for esports is expected to reach around 600 million people around 2023 [3]. The number of individuals who regularly play video games is also increasing and has possibly reached a staggering value of 2.7 billion in 2020 [4]. The United States, Germany, China, Republic of Korea, and South Africa are some of the countries that have recognized esports as an official sport [5]. They officially featured in the lead-up to the 2018 Olympic Winter Games in Pyeongchang, Republic of Korea, and the Tokyo 2020 Olympics [6].

Alcohol, soft drinks, energy drinks, and fast food companies have embraced this trend and are sponsoring esports-related events, encouraging poor dietary habits in esports players and spectators [7,8].

Inadequate dietary habits are linked to lower performance in a variety of cognitive areas, which might be explained in part by ethanol neurotoxicity, increased brain inflammation caused by high fat and high sugar consumption, and increased adiposity [9]. Contrarily, a healthier diet pattern (i.e., Mediterranean diet), composed mostly of whole grains, legumes, vegetables, fruit, and a modest amount of fish, dairy, and olive oil, is associated with optimal cognitive functioning in healthy adults [10–12].

Playing video games is associated with sedentarism, which increases weight gain and health risks [13,14]. Thus, esports players may require medical attention [15,16] and nutritional counseling [17] to optimize their health and performance. Nonetheless, the evidence for an association between esports practice and increased BMI is either null or mixed, and further research is required [18].

At least six investigations have assessed some aspect of the dietary habits of esports players [17,19–23].

In 2020, Rudolf and colleagues [17] applied an online survey to 1066 German video gamers and esports players and registered an average consumption of 2.7 (SD = 1.8) servings of fruit and vegetables, with only 11% of the sample meeting the WHO guidelines (≥400 g/day) [24].

Through an online survey, Huth (2021) [19] compared the dietary habits of German esports competitors (n = 241) with non-players (n = 98). The esports players expressed less concern with following a balanced diet (mean difference (MD) = −0.63; p < 0.001), ingested fewer portions of fruits and vegetables (MD = −1.15; p < 0.001), and drank fewer caffeinated beverages (MD = −1.32; p < 0.001) than non-players.

In 2023, Soffner and colleagues [20] characterized the dietary habits of 607 German video gamers and 210 esports players through an online food frequency questionnaire. The total sample averaged a daily consumption of 0.9 (SD = 1.0) of fruits, 1.7 (SD = 1.6) of vegetables, 0.5 (SD = 0.6) of red meat, 0.3 (SD = 0.4) of fast food, 0.2 (SD = 0.4) of chips and savory snacks, 0.2 (SD = 0.3) of sweet bakery products, 0.6 (SD = 0.8) servings of sweets, 0.9 (SD = 1.8) servings of soft drinks (180 mL), 0.4 (SD = 1.2) servings of light soft drinks (80 mL), 0.9 (SD = 1.4) servings of coffee (135 mL), and 0.2 (SD = 0.5) servings of energy drinks (50 mL). Esports players consumed a significantly greater daily amount of energy drinks (M = 0.2; SD = 0.6 servings) than video gamers (M = 0.1; SD = 0.4 servings; p = 0.02). Esports competitors also reported a statistically significant greater average consumption of fast food (9.1, SD = 11.6 vs. 7.0, SD = 10.0 servings/month; p < 0.01), and red meat (16.4, SD = 18.5 vs. 13.4, SD = 15.6 servings/month; p = 0.02) than video game players. Fast food (rho = 0.13; p < 0.01), energy drinks (rho = 0.14; p < 0.01), and soft drinks (rho = 0.14; p < 0.01) were positively (poorly) correlated with video game playing time.

In 2022, Szot and collaborators [21] assessed the dietary patterns of 233 Polish esports players through Food Frequency Questionnaires. Only 13.7% consumed fruit, and 11.2% ingested vegetables at least two or three times a day. Concerning unhealthy dietary patterns, the average daily consumption frequency for soft drinks was 3.4 (1.6), and 2.7 (1.4) for energy drinks. Three-quarters (75.5%) of the sample regularly consumed fried foods, roughly half (54.9%) ingested sweets, 28.3% had fast food, 28.3% ate red meat, and 28.7% consumed salty snacks.

In 2021, through a web-based survey, Ip et al. [22] assessed the dietary supplement consumption of 526 competitive video gamers, mostly United States citizens (77.0%). The most consumed DS was caffeine (58.1%), followed by vitamin B12 (3.8%), Yerba mate (2.3%), melatonin (1.5%), and Guarana (1.3%).

Goulart et al. (2023) [23] also assessed the dietary habits of USA esports players (n = 119) through food records and verified that the majority did not consume the recommended daily amount of vegetables (three cups), fruits (two cups), whole grains (one cup), dairy (three cups), and fiber (14 g/1000 kcal) described in the USDA Dietary Guidelines for Americans 2020–2025. Moreover, 83.5% surpassed the advised upper limits for sodium (2300 mg), 63.6% for cholesterol (300 mg), and 66.1% for saturated fat (10% of total energy intake).

Although esports has begun to draw the attention of the scientific community, health research [15] and nutrition for esports is still lacking, and, to date, no published study has yet assessed the dietary habits of Portuguese or Brazilian esports players. The inclusion of players of the Brazilian nationality was justified by the significant number of Brazilians living in Portugal, estimated to be 276,200 in 2020 [25], where several Brazilian esports players competed in Portuguese esports teams. Moreover, Brazil shares many traits, such as language, historical, commercial, and cultural ties with Portugal [26]. In addition, there were not any publications regarding the dietary habits of Brazilian esports players despite Brazil being one of the countries with the largest number of players, only surpassed by the USA and China [27], and despite being considered one of the countries in which esports has the greatest potential for expansion, especially in esports titles played on mobile devices [28].

This study aimed to characterize the esports gaming behaviors, degree of internet gaming disorder, and dietary habits of Portuguese and Brazilian esports competitors. Additionally, we intended to investigate associations between sociodemographic and esports-related variables and the level of adherence to the Mediterranean diet.

The finding presented in this original article may contribute to fill a knowledge gap in scientific literature and informing health professionals and individuals involved in esports on the dietary habits and gaming behaviors of Portuguese and Brazilian esports players. It may also serve as a foundation for public health institutes and esports organizations to develop strategic interventions to enhance the eating habits of these competitors.

2. Materials and Methods

A convenience sample of esports competitors was invited to respond to an anonymous, open online survey. The inquiry was conducted between 1 December 2022 and 30 June 2023. It was disseminated via email to esports organizations and through social media platforms, including Facebook, Twitter, Instagram, Discord, WhatsApp, and Twitch.

2.1. Inclusion/Exclusion Criteria

The study required participants to be between 18 and 69 years, have Portuguese or Brazilian nationality, and have played esports for at least six months. Individuals who did not fit these requirements were excluded. No rewards were offered for taking part in this investigation.

2.2. Survey Administration

A landing page was created on Google Sites, which contained two hyperlinks for two versions of the survey, generated on Google Forms: one specific for Portuguese and another for Brazilian participants. Google Analytics 4 was applied on the landing page to determine the number of unique site visitors, view rate, participation rate, and completion rate.

Each Google Form contained an easy-to-read summary of the study, a permission request, an email address for additional information requests, the anticipated conclusion time, and an invitation to participate. The Google Form, available as Supplementary Material (SM1), totaled 47 questions spread across seven pages. The survey was designed, applied, and reported accordingly to the CHERRIES checklist statement and was successfully pre-tested for functionality by the research team [29].

2.3. Questionnaires Included

The inquiry included:

Generic questions regarding nationality, sex, birth date, self-reported weight and height, education attainment, and professional occupation. Self-reported weight and height were used to calculate BMI (kg/m^2), which was categorized based on the World Health Organization's standards [30]. To minimize misreport bias, an equation was applied to predict BMI values based on self-reported weight and height [31].

Inquiries on gaming habits, namely, the number of hours of esports play per day, the number of competitions in the past 12 months, how many years and months playing esports, member of an esports team (yes or no), registration within an esports federation, level of professionalization (amateur, semi-professional, or professional), eGame that the respondent plays competitively, and their gaming rank.

The PREvención con DIeta MEDiterránea" (PREDIMED): It consists of fourteen multiple-choice questions that evaluate the typical ingestion of olive oil, spreadable fats, nuts, fruits, vegetables, legumes, fish or shellfish, meat, sugary drinks, wine, sweets, and stir-fried foods. The final score ranges from 0 to 14. We used three categories of Mediterranean diet adherence: low for values under 5, moderate for values between 6 and 9, and good for values above 10 [32,33]. Permission for PREDIMED (www.predimed.es, accessed on 2 October 2022) [32,33] utilization, including its Portuguese [34] and Brazilian version [35], was requested and obtained from the original authors. Additionally, from the data obtained in the PREDIMED questionnaire, we sought to determine the prevalence of individuals who did not comply with the World Health Organization's fruit and vegetable consumption recommendations (at least 400 g/day) [24].

Fast-food and caffeine intake: An eight-item Likert scale was applied to assess breakfast omission, ranging from "Never" to "7 days", and fast food and caffeinated beverages with a scale ranging from "Never" to "4 or more per day". The Brazilian caffeine content table (BraCaffT) was used to calculate the amount of caffeine that the respondents consumed from beverages [36].

A questionnaire consisting of five questions related to the consumption of DS, including types of DS consumed, reasons for DS consumption, sources of information, and place of acquisition.

The Internet Gaming Disorder Scale—Short-Form (IGDS9) characterizes the level of engrossment concerning online video gaming [37]. It has nine questions, with responses given on a 5-point Likert scale, with 1 denoting "Never", and 5 denoting "Very often". The overall score will vary between 9 and 45, with larger values indicating a higher risk of gaming addiction. The classification was based on the cut-off scores set by Severo et al. (2020): >16 points for moderate, and >21 points for high internet gaming disorder (IGD) risk [38]. Permission to use the IGDS9 was granted through email [37].

The anonymous electronic data gathered on Google Forms was downloaded and saved in a password-protected Excel file format (.xlsx) while complying with the EU's General Data Protection Regulation [39].

2.4. Statistics

Microsoft Excel was used to organize, evaluate, and generate descriptive statistical data for the downloaded records. All statistical analysis was performed using IBM® SPSS® Statistics 29.0 for Windows (IBM Corp., Armonk, NY, USA). The significance value for all statistical tests was established at <0.05.

The following variables were generated and added to SPSS: "PREDIMED total score" (0 to 14); "portions of fruit and vegetables/day"; "<5 portions of fruits and vegetables/day" (no, yes); "portions of red and processed meat/day"; "<1 portion of red and processed meat/day" (no, yes); "No. of soft drinks/day"; "<1 soft drink/day" (no, yes); "No. of commercial pastries or sweets/week"; "<1 commercial pastry or sweet/week" (no, yes); "breakfast consumption frequency"; "frequency of fast food intake/week"; "IGDS9 total score" (0 to 45); No. of answers "Very often"; "nationality" (Portuguese, Brazilian); "sex" (male, female); "age" (18 to 69); "age—quartiles" (18 to 20, 21 to 23, 24 to 29, $\geq$30 y); "years of education" (0 to 16); "university education" (no, yes); "member of an esports team" (no, yes); "level of professionalization" (amateur, semi-professional or professional); "BMI" (kg/m^2); "BMI—terciles" (<25, 25 to 30, >30 kg/m^2); "federate athlete" (no, yes), "No. of esports titles played" (1 to 10); "No. of years playing esports"; "No. of years playing esports—terciles" (<5, 5 to 10, >10); "No. of hours of esports play/day"; "No. of hours of esports play/day—terciles" ($\leq$2.5, 2.5 to 5, $\geq$5 h/day); "No. of competitions in the past 12 months"; "No. of competitions in the past 12 months—terciles" (0, 1–3, $\geq$4); "caffeine intake" (mg); "caffeine intake—terciles" ($\leq$48, 48 to 224, >224 mg/day); "DS intake" (no, yes); "No. of DS ingested" (0 to 17); "DS consumed" (originally 40 answers, grouped into

8 categories: Proteins, Amino acids, Carbohydrates, Vitamin-mineral complexes, Isolated vitamins, Isolated minerals, Herbs, and Caffeine); "Reasons for using DS" (17 options); "Information sources about DS" (15 options); and "Place of acquisition of DS" (8 options).

Descriptive statistics were generated for each variable, and their normalities were assessed through skewness and kurtosis. Skewness and kurtosis exhibited a normal distribution (between −1 and 1) only for the "PREDIMED total score", "IGDS9 total score", "portions of red and processed meat/day", "No. of soft drinks/day", and "No. of commercial pastries or sweets/week" variables.

Data from Portuguese and Brazilian players were compared using Student's *t*-test for "PREDIMED total score", "IGDS9 total score", "portions of fruit and vegetables/day", "portions of red and processed meat/day", "No. of soft drinks/day", "No. of commercial pastries or sweets/week", and Mann–Whitney's U test for "level of professionalization", "age", "BMI", "years of education", "No. of hours of esports play/day", "No. of competitions in the past 12 months", "No. of years playing esports", "No. of esports titles played", "breakfast consumption frequency", "frequency of fast food intake/week", "caffeine intake", and "No. of DS ingested". Crosstabulations and Fisher's exact test were used to describe the relationship between the "sex", "<5 portions of fruits and vegetables/day", "<1 portion of red and processed meat/day", "<1 soft drink/day", "<1 commercial pastry or sweet/week", "member of an esports team", "DS intake", and "federate athlete" variables and "nationality".

3. Results

The Google website received 2039 unique visitors overall; 1566 (76.8%) of them navigated to the Google form that included the survey, and 711 (45.4%) of those completed it.

A total of 132 responses were rejected: four for stating a nationality other than Portuguese or Brazilian, nine for not having played esports for at least six months, 105 for being less than 18 years old, one for reporting being older than 69, two for not reporting the esports title they played competitively, one for reporting zero hours of esports play per day, and ten for providing nonsensical answers. As a result, the information from 579 individuals was included and examined in this study.

3.1. Socio-Demographic Characteristics

A little more than half were Brazilian (52.7%; n = 305), and the remaining were of Portuguese nationality. This sample was predominantly male (91.4%; n = 529), aged between 18 and 29 years (75.0%; n = 434). The median number of years of schooling was 14 years, with about one-third of the sample (37.0%; n = 214) reporting having completed university education. Concerning employment status, 43.9% (n = 254) of the sample reported being an employee, whereas about one fifth (21.1%; n = 122) reported being a student worker, and another fifth (22.3%; n = 129) a student (Table 1).

Table 1. Socio-demographic characteristics.

	Total	Brazilian	Portuguese	
	***n* (%)**	***n* (%)**	***n* (%)**	***p***
Sex				0.104 ^{F}
Male	529 (91.4)	273 (89.5)	256 (93.4)	
Female	50 (8.6)	32 (10.5)	18 (6.6)	
Age, years (Mdn; P25, P75)	24 (20, 30)	23 (20, 28)	26 (22, 31)	<0.001 ^{M}
18 to 29 y	434 (75.0)	250 (82.0)	184 (67.2)	
30–39 y	110 (19.0)	47 (15.4)	63 (23.0)	
40–49 y	28 (4.8)	6 (2.0)	22 (8.0)	
50–59 y	6 (1.0)	2 (0.7)	4 (1.5)	
60–69 y	1 (0.2)	0 (0.0)	1 (0.4)	

Table 1. *Cont.*

	Total	Brazilian	Portuguese	
	n (%)	*n* (%)	*n* (%)	*p*
BMI, kg/m^2 (Mdn; P25, P75)	24.6 (22.3, 28.5)	25.2 (22.5, 30.2)	24.2 (22.2, 26.7)	0.005 [M]
Underweight (<18.5 kg/m^2)	26 (4.5)	16 (5.2)	10 (3.6)	
Normal range ([18.5; 25.0] kg/m^2)	283 (48.9)	133 (43.6)	150 (54.7)	
Pre-obesity ([25.0; 30.0] kg/m^2)	162 (28.0)	79 (25.9)	83 (30.3)	
Obesity class I ([30.0; 35.0] kg/m^2)	65 (11.2)	48 (15.7)	17 (6.2)	
Obesity class II ([35.0; 40.0] kg/m^2)	43 (7.4)	29 (9.5)	14 (5.1)	
Education, years (Mdn; P25, P75)	14 (12, 16)	13 (12, 16)	14 (12, 16)	0.010 [M]
0–9 y	32 (5.5)	14 (4.6)	18 (6.6)	
10–12 y	189 (32.6)	97 (31.8)	92 (33.6)	
13–14 y	124 (21.4)	83 (27.2)	41 (15.0)	
14–15 y	20 (3.5)	20 (6.6)	0 (0.0)	
≥16 y	214 (37.0)	91 (29.8)	123 (44.9)	
Employment status				<0.001 [F]
Student	129 (22.3)	64 (21.0)	65 (23.7)	
Working Student	122 (21.1)	89 (29.2)	33 (12.0)	
Worker	254 (43.9)	105 (34.4)	149 (54.4)	
Unemployed	60 (10.4)	36 (11.8)	24 (8.8)	
Other [a]	14 (2.4)	11 (3.6)	3 (1.1)	

Abbreviations: Mdn = median; P25 = 25th percentile; P75 = 75th percentile; BMI = Body mass index; [M] = Mann–Whitney U test; [F] = Fisher's exact test. [a] Other includes: retired, permanently disabled, student, domestic worker, or performing mandatory military service.

About half of the sample was classified as having a normal weight (48.9%; $n = 283$, whereas 46.6% ($n = 270$) were overweight.

Compared to Portuguese, Brazilian players had a significantly lower "age" ($p < 0.001$), fewer "years of education" ($p = 0.010$), and a higher "BMI" ($p = 0.005$). The proportion of males and females was not different among Brazilian and Portuguese players ($p = 0.104$).

3.2. Esports-Related Variables

The respondents reported playing esports for 8.1 (SD = 5.1) years, practicing esports 4.4 (SD = 3.2) hours a day, and participating in a total of 7.6 (SD = 10.4) competitions in the past 12 months on average. Most respondents reported being amateur esports players (62.2%; $n = 360$), whereas the remaining self-classified as semi-professional or professional players. About a quarter (25.9%, $n = 150$) stated they were a member of an esports league or federation (Table 2).

Table 2. Data on esports-related variables.

	Total	Brazilian	Portuguese	
	n (%)	*n* (%)	*n* (%)	*p*
Level of professionalization				<0.001 [M]
Professional	72 (12.4)	58 (19.0)	14 (5.1)	
Semi-professional	147 (25.4)	72 (23.6)	75 (27.4)	
Amateur	360 (62.2)	175 (57.4)	185 (67.5)	
Federated athlete	150 (25.9)	48 (15.7)	102 (37.2)	<0.001 [F]
Member of an esports team	89 (15.4)	89 (29.2)	143 (52.2)	<0.001 [F]
Reported eGame rank	423 (73.1)	245 (80.3)	178 (65.0)	<0.001 [F]
Competed in the past 12 months	374 (64.6)	187 (61.3)	187 (68.2)	0.083 [F]
No. of competitions in the past 12 months (Mdn; P25, P75)	2 (0, 5)	2 (0, 5)	2 (0, 5)	0.241 [M]
No. years playing esports (Mdn; P25, P75)	8.0 (5.0, 12.0)	8.0 (5.0, 12.2)	7.0 (4.0, 11.0)	0.011 [M]
No. hours of esports play/day (Mdn; P25, P75)	3.5 (2.0, 6.0)	4.0 (3.0, 6.8)	3.0 (2.0, 4.0)	<0.001 [M]
No. esports titles played (Mdn; P25, P75)	3 (1, 5)	5 (5, 5)	1 (1, 2)	<0.001 [M]

Abbreviations: Mdn = median; P25 = 25th percentile; P75 = 75th percentile; [M] = Mann–Whitney's U test; [F] = Fisher's exact test.

The Brazilians played esports for a significantly higher number of hours per day ($p < 0.001$), had been playing esports for more years ($p = 0.011$), played a higher number of esports titles ($p < 0.001$), and reported a higher level of professionalization ($p = 0.011$) than the Portuguese players. Additionally, a significantly lower proportion of Brazilians reported being members of an esports team ($p < 0.001$) or federation ($p < 0.001$).

Most participants played First Person Shooter games (70.5%; *n* = 408), with the Multiplayer Online Battle Arena genre being the second most popular (35.1%; *n* = 203), followed by racing simulators (26.1%; *n* = 151), and other sports simulators (12.4%; *n* = 72) games.

The specific esports titles with the most players were League of Legends (25.9%; n = 150), Counter-Strike: Global Offensive (24.7%; *n* = 143), Valorant (17.4%; *n* = 101), and FIFA 2022/23 (12.3%; *n* = 71).

The respondents averaged a total score of 18.9 (SD = 6.8) on the IGDS9 scale, with 2.6% (*n* = 15) accumulating a total score of 36 points or higher. About a quarter (26.8%; *n* = 155) of the total sample answered "Very often" on at least one of the eight questions included in the IGDS9 (Table 3).

Table 3. Data on the IGDS9 results.

	Total	Brazilian	Portuguese	
	***n* (%)**	***n* (%)**	***n* (%)**	***p***
IGDS9 total score (m; sd)	18.9 (6.8)	20.9 (7.1)	16.7 (5.7)	<0.001 ^{T}
IGDS9 total score > 16	329 (56.8)	206 (67.5)	123 (44.9)	
IGDS9 total score > 21	177 (30.6)	129 (42.3)	48 (17.5)	
IGDS9 total score ≥ 36	15 (2.6)	12 (3.9)	3 (1.1)	

Abbreviations: m = mean; sd = standard deviation; ^{T} = independent sample's *t*-test.

Brazilian esports players displayed a significantly higher overall IGDS9 score ($p < 0.001$) than Portuguese players.

3.3. Dietary Habits

More than half of our sample (53.7%; *n* = 311) classified as having poor adherence to the Mediterranean diet pattern (PREDIMED), and most respondents (84.5%; *n* = 489) stated eating less than five servings of fruits and vegetables per day. Over half (63.4%; *n* = 367) stated consuming fast food, 70.1% (*n* = 406) sweets or commercial pastries, 65.8% (*n* = 381) coffee, and almost a quarter (23.0%; *n* = 133) reported drinking energy drinks on one or more occasions per week. The consumption of caffeine derived from caffeinated drinks averaged 179 (SD = 208) mg per day (Table 4).

Table 4. Data on the PREDIMED related variables.

	Total	Brazilian	Portuguese	
	***n* (%)**	***n* (%)**	***n* (%)**	***p***
PREDIMED total score (m; sd)	5.4 (2.2)	4.7 (2.1)	6.1 (2.1)	<0.001 ^{T}
Weak adherence (≤5)	311 (53.7)	205 (67.2)	106 (38.7)	
Moderate to fair adherence (6 to 9)	247 (42.7)	96 (31.5)	151 (55.1)	
Good or very good adherence (≥10)	21 (3.6)	4 (1.3)	17 (6.2)	
Portions of fruits and vegetables/day (m; sd)	2.5 (1.9)	2.3 (1.9)	2.8 (1.9)	<0.001 ^{T}
<5 portions/day	489 (84.5)	264 (86.6)	225 (82.1)	0.168 ^{F}
≥5 portions/day	90 (15.5)	41 (13.4)	49 (17.9)	
Portions of red and processed meat/day (m; sd)	1.6 (1.2)	1.6 (1.2)	1.6 (1.1)	0.814 ^{T}
<1 portion/day	127 (21.9)	79 (25.9)	48 (17.5)	0.016 ^{F}
≥1 portion/day	452 (78.1)	226 (74.1)	226 (82.5)	
No. of soft drinks/day (m; sd)	0.8 (1.2)	1.0 (1.3)	0.7 (1.1)	<0.001 ^{T}
<1 drink/day	342 (59.1)	159 (52.1)	183 (66.8)	<0.001 ^{F}
≥1 drink/day	237 (40.9)	146 (47.9)	91 (33.2)	
No. of commercial pastries or sweets/week (m; sd)	2.2 (2.1)	2.2 (2.3)	2.1 (2.0)	0.424 ^{T}
<1 occasion/week	173 (29.9)	96 (31.5)	77 (28.1)	0.413 ^{F}
≥1 occasion/week	406 (70.1)	209 (68.5)	197 (71.9)	

Abbreviations: m = mean; sd = standard deviation; ^{T} = independent sample's *t*-test; ^{F} = Fisher's exact test.

Additionally, more than three-thirds of the respondents (78.1%; *n* = 452) ate one or more servings of red/processed meat, and 40.9% (*n* = 237) consumed one or more soft drinks per day.

When comparing the data of Portuguese players with those of Brazilian players, Portuguese players displayed a statistically significant higher PREDIMED total score ($p < 0.001$), a higher consumption of fruit and vegetables ($p < 0.001$), and a lower consumption of soft drinks ($p < 0.001$). No significant differences were observed for red and processed meat ($p = 0.814$) and commercial pastries and sweets ($p = 0.424$).

Significant relationships were observed between nationality and the number of soft drinks ($p < 0.001$) and portions of red and processed meat consumed per day ($p < 0.016$), corresponding to a greater consumption of red and processed meat in the Portuguese and a greater intake of soft drinks in the Brazilians. No significant associations were registered between nationality and the number of portions of fruits and vegetables ingested daily ($p = 0.168$) and the weekly consumption of commercial pastries or sweets ($p = 0.413$).

Regarding the breakfast meal, almost a quarter of our sample never ate breakfast (23.0%; $n = 133$) and almost half (47.5%; $n = 275$) skipped breakfast on three or more days per week (Table 5).

Table 5. Data on breakfast, fast food, and caffeinated drinks.

	Total	Brazilian	Portuguese	
	n (%)	*n* (%)	*n* (%)	*p*
Breakfast consumption frequency				
Never	133 (23.0)	75 (24.6)	58 (21.2)	
One day/week	15 (2.6)	5 (1.6)	10 (3.6)	
Two days/week	46 (7.9)	22 (7.2)	24 (8.8)	
Three days/week	53 (9.2)	24 (7.9)	29 (10.6)	
Four days/week	28 (4.8)	16 (5.2)	12 (4.4)	
Five days/week	57 (9.8)	30 (9.8)	27 (9.9)	
Six days/week	34 (5.9)	17 (5.6)	17 (6.2)	
Seven days/week	213 (36.8)	116 (38.0)	97 (35.4)	
Breakfast consumption frequency, days per week (Mdn; P25, P75)	5 (1, 7)	5 (1, 7)	5 (0, 5)	0.809 ^{M}
Fast food intake				
Never	212 (36.6)	101 (33.1)	111 (40.5)	
1 occasion/week	229 (39.6)	114 (37.4)	115 (42.0)	
2 to 4 occasions/week	118 (20.4)	74 (24.3)	44 (16.1)	
5 to 6 occasions/week	12 (2.1)	10 (3.3)	2 (0.7)	
1 occasion/day	6 (1.0)	4 (1.3)	2 (0.7)	
2 occasions/day	2 (0.3)	2 (0.7)	0 (0.0)	
Fast food intake, occasions per week (Mdn; P25, P75)	1 (0, 1)	1 (0, 3)	1 (0, 1)	0.002 ^{M}
Caffeine from caffeinated drinks, mg/day (Mdn; P25, P75)	112 (27, 256)	112 (32, 241)	116 (22, 291)	0.652 ^{M}
Coffee intake				0.036 ^{M}
Never	198 (34.2)	117 (38.4)	81 (29.6)	
1 occasion/week	35 (6.0)	18 (5.9)	17 (6.2)	
2 to 4 occasions/week	58 (10.0)	23 (7.5)	35 (12.8)	
5 to 6 occasions/week	40 (6.9)	24 (7.9)	16 (5.8)	
1 occasion/day	61 (10.5)	38 (12.5)	23 (8.4)	
2 occasions/day	78 (13.5)	36 (11.8)	42 (15.3)	
3 occasions/day	54 (9.3)	19 (6.2)	35 (12.8)	
≥4 occasions/week	55 (9.5)	30 (9.8)	25 (9.1)	
Energy drinks intake				<0.001 ^{M}
Never	444 (76.7)	213 (69.8)	231 (84.3)	
1 occasion/week	62 (10.7)	45 (14.8)	17 (6.2)	
2 to 4 occasions/week	45 (7.8)	29 (9.5)	16 (5.8)	
5 to 6 occasions/week	8 (1.4)	5 (1.6)	3 (1.1)	
1 occasion/day	8 (1.4)	6 (2.0)	2 (0.7)	
2 occasions/day	3 (0.5)	2 (0.7)	1 (0.4)	
3 occasions/day	1 (0.2)	0 (0.0)	1 (0.4)	
≥4 occasions/day	8 (1.4)	5 (1.6)	3 (1.1)	

Abbreviations: Mdn = median; P25 = 25th percentile; P75 = 75th percentile; ^{M} = Mann–Whitney's U test.

No statistically significant differences were observed regarding breakfast consumption frequency ($p = 0.809$) and caffeine intake ($p = 0.652$) between the Brazilian and Portuguese players; however, Brazilian players did consume fast food more frequently than Portuguese players ($p = 0.002$).

3.4. Dietary Supplements Intake

Almost a third of the total sample (32.3%; n = 187) stated consuming DS in the past 12 months (Table 6). The most consumed DS were whey protein (59.4%; n = 111), creatine (47.1%; n = 88), caffeine (33.2%; n = 62), and multivitamin-mineral (30.5%; n = 57) (Figure 1).

Table 6. Consumption of dietary supplements.

	Total	Brazilian	Portuguese	
	***n* (%)**	***n* (%)**	***n* (%)**	***p***
Ingested DS in the prior 12 months	187 (32.3%)	106 (34.8%)	81 (29.6%)	0.213 [F]
No. of DS ingested (Mdn; P25, P75)	0 (0, 2)	0 (0, 2)	0 (0, 2)	0.194 [M]

Abbreviations: Mdn = median; P25 = 25th percentile; P75 = 75th percentile; DS = Dietary supplements; [F] = Fisher's exact test; [M] = Mann–Whitney's U test.

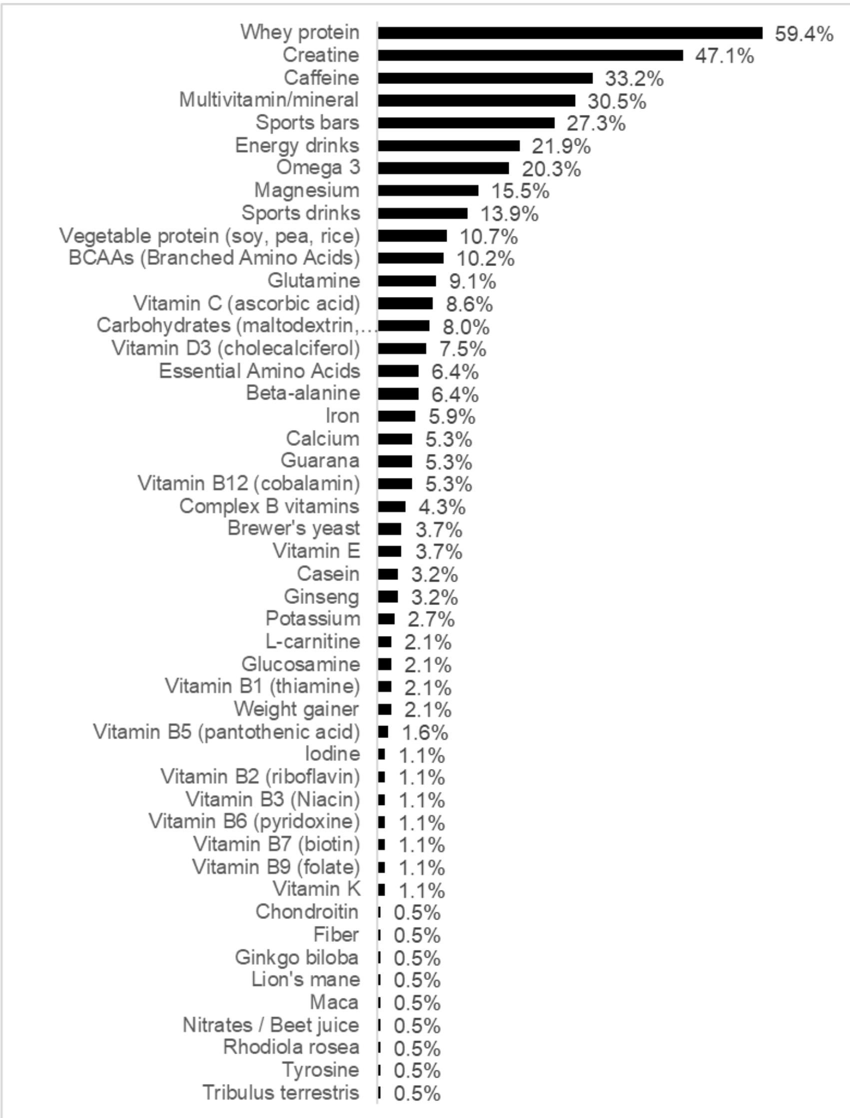

Figure 1. Types of dietary supplements consumed.

No statistically significant differences were found between Brazilian and Portuguese players regarding DS consumption in the past 12 months (p = 0.213) or the number of DS ingested (p = 0.194).

The top five reasons for using DS were: to improve athletic performance (84.5%; *n* = 158), prevent health problems or treat illness/injury (58.8%; *n* = 110), improve cognitive performance (56.7%; *n* = 106), gain muscle mass (51.9%; *n* = 97), and increase energy/decrease fatigue (49.7%; *n* = 93) (Table 7).

Table 7. Reasons for using supplements.

	Total	Brazilian	Portuguese
	***n* (%)**	***n* (%)**	***n* (%)**
Prevent/treat illness or injury	158 (84.5)	102 (96.2)	56 (69.1)
Improve cognitive performance	110 (58.8)	68 (64.2)	50 (61.7)
Gain muscle mass	106 (56.7)	66 (62.3)	40 (49.4)
Increase energy/decrease fatigue	97 (51.9)	60 (56.6)	39 (48.1)
Speed up recovery	93 (49.7)	54 (50.9)	29 (35.8)
Compensate for bad eating habits	48 (25.7)	26 (24.5)	22 (27.2)
Lose weight	32 (17.1)	20 (18.9)	13 (16.0)
Decrease stress	30 (16.0)	19 (17.9)	10 (12.3)
Gain weight	15 (8.0)	7 (6.6)	8 (9.9)

Nutritionists (42.2%; *n* = 79), medical professionals (23.5%; *n* = 44), athlete recommendations (19.8%; *n* = 37), and personal trainers (19.3%; *n* = 36) were the most frequently cited sources of DS related knowledge (Table 8).

Table 8. Information sources about dietary supplements.

	Total	Brazilian	Portuguese
	***n* (%)**	***n* (%)**	***n* (%)**
Nutritionist	79 (42.2)	42 (39.6)	37 (45.7)
Medical doctor	44 (23.5)	27 (25.5)	20 (24.7)
Recommendations from athletes	37 (19.8)	24 (22.6)	16 (19.8)
Personal trainer	36 (19.3)	21 (19.8)	15 (18.5)
Friends	32 (17.1)	21 (19.8)	12 (14.8)
Scientific articles	31 (16.6)	21 (19.8)	10 (12.3)
Other healthcare professionals	27 (14.4)	20 (18.9)	9 (11.1)
Other means of communication	27 (14.4)	15 (14.2)	9 (11.1)
Trainer	24 (12.8)	12 (11.3)	6 (7.4)
Relatives	18 (9.6)	12 (11.3)	6 (7.4)
Recommendations from other esports players	8 (4.3)	7 (6.6)	1 (1.2)
Newspapers/magazines	6 (3.2)	5 (4.7)	1 (1.2)
Television	4 (2.1)	4 (3.8)	0 (0.0)
Personal experience/self-taught	3 (1.6)	3 (2.8)	0 (0.0)

Regarding adherence to the Mediterranean dietary pattern, represented by PREDIMED total score, when encompassing data relating to both nationalities, the univariate ANOVA returned statistical significance for nationality, sex, DS intake, and IGDS9 total score (Table 9). Portuguese nationality was associated with a higher PREDIMED total score ($p < 0.001$, $eta_p^2 = 0.052$), as well as being a female ($p = 0.034$, $eta_p^2 = 0.008$). Not having consumed DS in the past 12 months ($p < 0.001$, $eta_p^2 = 0.029$), and a higher IGDS9 total score ($p = 0.002$, $eta_p^2 = 0.017$) were associated with a lower PREDIMED total score.

Table 9. Relation between PREDIMED total score (dependent variable) and characteristics of Portuguese and Brazilian esports players (Univariate ANOVA).

Corrected Model: $p < 0.001$, $eta_p^2 = 0.173$, Adjusted $R^2 = 0.142$					
	n	**EMM**	**B**	***p***	**eta_p^2**
Nationality				<0.001	0.052
Portuguese	274	6.195	1.082	<0.001	0.052
Brazilian	305	5.113	(Ref.)		
Sex				0.034	0.008
Male	529	5.326	−0.655	0.034	0.008
Female	50	5.981	(Ref.)		
Age (quartiles)				0.502	0.004
18 to 20 years	151	5.559	−0.306	0.268	0.002
21 to 23 years	129	5.463	−0.402	0.143	0.004
24 to 29 years	154	5.728	−0.137	0.573	0.001
≥30 years	145	5.865	(Ref.)		
Higher education				0.504	0.001
No	221	5.593	−0.121	0.504	0.001
Yes	358	5.714	(Ref.)		
No. of hours of esports play/day (terciles)				0.956	0.000
≤2.5	194	5.673	0.059	0.803	0.000
[2.5; 5.0]	175	5.674	0.060	0.786	0.000
≥5	210	5.614	(Ref.)		
No. of competitions in the past 12 months (terciles)				0.054	0.010
0	205	5.476	−0.520	0.042	0.007
1 to 3	177	5.490	−0.506	0.026	0.009
≥4	197	5.996	(Ref.)		
No. of years playing esports (terciles)				0.874	0.000
≤5	196	5.612	−0.024	0.915	0.000
[5; 10]	214	5.714	0.079	0.721	0.000
>10	169	5.636	(Ref.)		
Member of an esports team				0.793	0.000
No	346	5.681	0.054	0.793	0.000
Yes	233	5.627	(Ref.)		
Level of professionalization				0.316	0.004
Amateur	360	5.876	0.404	0.201	0.003
Semi-professional	147	5.613	0.140	0.653	0.000
Professional	72	5.472	(Ref.)		
BMI (terciles)				0.207	0.006
<25.0 kg/m^2	309	5.725	0.334	0.170	0.003
[25.0; 30.0] kg/m^2	162	5.845	0.454	0.080	0.005
≥30.0 kg/m^2	108	5.391			
Caffeine intake (terciles)				0.356	0.004
≤48 mg	196	5.633	−0.183	0.398	0.001
[48; 224] mg	197	5.513	−0.303	0.152	0.004
>224 mg	186	5.816	(Ref.)		
DS intake				<0.001	0.029
No	392	5.280	−0.748	<0.001	0.029
Yes	187	6.028	(Ref.)		
IGDS9 total score	579		−0.042	0.002	0.017

Abbreviations: EEM = Estimated marginal mean; B = Regression coefficient; BMI = Body Mass Index; DS = Dietary Supplement; eta_p^2 = Partial eta squared; Ref. = Reference.

When analyzing the data for Portuguese and Brazilians separately, the univariate ANOVA returned distinct results. The relationship with sex was not significant in either country, whereas DS intake remained significant in both groups, with the Brazilian ($p = 0.004$, $eta_p^2 = 0.029$) and Portuguese ($p = 0.010$, $eta_p^2 = 0.026$) non-users of DS presenting a lower PREDIMED total score. The IGDS9 total score remained significant only for the Brazilian, associating with a lower PREDIMED total score ($p = 0.018$, $eta_p^2 = 0.020$). In addition, a significant relationship regarding the level of professionalization emerged for the Portuguese players ($p = 0.010$, $eta_p^2 = 0.036$), with amateurs (estimated marginal mean (EMM) = 6.664) presenting a higher PREDIMED total score compared to semi-professionals (EMM = 5.886) and professionals (EMM = 5.263).

4. Discussion

4.1. BMI

A higher BMI or adiposity has been associated with an increased risk for a variety of health problems and greater morbidity [40]. Increased neuroinflammation, gray matter atrophy in specific brain areas, diminished cognitive capacity [9], and lower esports performance [41], were also reported.

According to data provided by the Brazilian Institute of Geography and Statistics (IBGE), by 2019, 60.3% of Brazilian adults (≥18 years) were overweight, and 25.9% were obese [42]. In Portugal, more than half (58.1%) of the adults exhibited excessive adiposity. 36.5% were classified as being overweight and 21.6% as obese, according to a national inquiry conducted between 2015 and 2026 (IAN-AF 2015-16) [43].

In comparison, 46.6% of the participants in our study had excess weight. More specifically, 28.0% were categorized as pre-obese and 18.7% as obese. This could have been due to our younger sample compared with that of studies conducted in reference populations [42,43], as increased age is associated with weight gain in adults [44].

When stratifying by age groups, in comparison with a reference population, our sample of Brazilian esports players presented lower pre-obesity prevalence from 18 to 24 years old (20.4% vs. 33.3%) and from 25 to 39 years (36.0% vs. 57.6%). However, they presented a higher prevalence of obesity in the same age groups: 18–24 years (18.3% vs. 10.7%) and 25–39 years (33.3% vs. 23.7%) [42].

Our sample of Portuguese esports players presented a higher prevalence of pre-obesity in those aged between 18–24 years (24.4% vs. 19.1%) and those aged 35–44 years (48.7% vs. 37.1%), but not among the subgroup of 25–34 years (27.0% vs. 31.8%) compared to a reference population. The prevalence of obesity was also slightly higher for players aged between 18–24 years (6.5% vs. 6.3%) and 25–34 years (14.0% vs. 10.8%), but not among those aged 35–44 (15.4% vs. 20.2%) [43].

These findings imply that esports participation may be linked to a higher prevalence of pre-obesity and obesity in particular age groups among Brazilian and Portuguese esports participants.

Furthermore, we observed significantly higher BMI values in Brazilian compared to Portuguese esports players ($p = 0.005$), which may have been related to their significantly lower PREDIMED total score ($p < 0.001$), lower consumption of fruit and vegetables ($p < 0.001$), higher consumption of soft drinks ($p < 0.001$), and higher consumption frequency of fast food ($p < 0.002$).

4.2. Internet Gaming Disorder

Internet gaming disorder is a disorder that implies an uncontrollable obsessive dedication to online video games, resulting in adverse physical and psychological consequences. It is associated with interpersonal difficulties, sleep disturbances, low dietary quality, and exaggerated caffeine intake [45].

In a study conducted in Brazil in 2017, Severo et al. (2020) applied the IGDS9 questionnaire to 555 students (57.5% male) with a mean age of 20.3 (SD = 5.4) years who had played video games in the previous 12 months. They found that 38.2% of the volunteers had a moderate (score 16 to 20) and 13.5% had a high risk (score > 21) of gaming disorder [46]. When applying the same cut-off points, our research uncovered a higher percentage of individuals with a score higher than 16 (56.8%) and 21 (30.6%). This may have been due to our study including a sample with a higher percentage of males (91.4%) and dedicating longer periods to video games, which have been reported as a risk factor for IGD by Severo et al. (2020) [46]. We may also have a high proportion of multiplayer online battle arena (MOBA) game players, which seem to be at a higher risk for IGD, compared to first-person shooter (FPS) players [47].

In comparison, Ip et al. (2021) surveyed 526 adult video gamers in the USA (23.9; SD = 4.9 years) and reported that 2.3% of their total sample formally met the diagnostic criteria for IGD [22]. Of note, these investigators used a score $\geq$ 36 as an indicator of IGD, and, using that same value, we registered a prevalence of 2.6% (n = 15), which represented a slightly higher prevalence.

Regarding the two nationalities covered in our study, we found significantly higher IDGS9 total score values in Brazilian esports players compared to Portuguese ones ($p < 0.001$).

4.3. Mediterranian Diet Adherence

The IAN-AF 2015-16, conducted in Portugal, also applied the Mediterranean Diet Score and revealed that 15.7% of the Portuguese adult population has a high adherence, 50.0% moderate and 34.3% low adherence to the Mediterranean dietary pattern [43]. In comparison, we report that a mere 3.6% of our total sample was classified as having good or very good adherence, 42.7% moderate to fair adherence, and 53.7% with weak adherence in the PREDIMED score.

Our Brazilian sample had a significantly lower PREDIMED total score compared to Portuguese respondents ($p < 0.001$), which may have been related to differences in public food policy, food culture, and food availability between the two countries [48].

Our analysis revealed that DS consumption was associated with a higher PREDIMED score, whereas a higher IGD total score and a higher level of professionalization correlated with a lower PREDIMED score. As seen in other studies, those that consumed DS were probably more health-conscious people who cared more about following a healthy diet [49].

Other research also demonstrated an association between a higher degree of IGD and a higher prevalence of inadequate dietary habits [45]. The attempt to prolong game periods can lead to the choice of more convenient but less nutritionally adequate food options, such as fast food, and longer periods of distraction can decrease the awareness of what is being ingested and decrease the ability to regulate food ingestion [50]. It is also likely that increasing professionalization, implying a higher commitment to esports, results in less concern with following a healthy eating pattern.

4.4. Fruits and Vegetables

Fruits and vegetables provide a host of benefits that extend beyond their vitamin, mineral, and fiber contents. These foods include a range of bioactive compounds that benefit health and decrease all-cause mortality [51] and have been associated with optimal cognitive performance in young adults [52] and delayed cognitive decline in older individuals [53].

According to the IBGE, in 2013, 62.7% of Brazilian adults aged 18 years or over did not ingest the recommended amount of fruits and vegetables [42]. As reported by the IAN-AF 2015-16 research, the average daily consumption of "Fruit, vegetables, and legumes" by the Portuguese population is 312 g/day, and 57% of Portuguese adults (18 to 64) do not consume the minimum amount of vegetables and fresh fruits recommended by the WHO (400 g/day) [24,43].

Our study uncovered even higher values of non-compliance, with 84.5% of the total sample not reaching the recommended five portions of fruits and vegetables per day. Moreover, our sample of Portuguese players reported significantly higher average consumption of fruit and vegetables than the Brazilian players ($p < 0.001$).

4.5. Breakfast Omission

According to a meta-analysis, skipping breakfast $\geq$3 days per week increases the risk for overweight/obesity by 11% (95% CI: 4 to 19%) compared to $\leq$2 days per week [54].

It also correlates with higher visceral adiposity [55], decreased sleep quality [56], lower intake of vitamins and minerals [57], fatigue exacerbation, diminished attention, inferior academic performance [58], and inhibitory control [59].

As the brain depends mainly on glucose as a fuel source, with glucose requirements increasing by up to 12% in the context of cognitively demanding activities [9], having a breakfast that includes carbohydrates-containing foods may be crucial for the optimize cognitive performance of esports players that regularly includes intensive esports training sessions and competitions on their schedules.

In a 2007 study conducted in Brazil, 30% of 100 students (19 to 39 years) at a university in the city of Campinas reported skipping breakfast [60]. In another study, conducted in 2002, which involved 185 students (18 and 19 years old) of a Brazilian public university, 37% stated omitting breakfast [61]. According to the IAN-AF 2015-16 national survey, 6.4% of Portuguese adults regularly omit breakfast, with a higher prevalence of breakfast skipping among adolescents (8.4%) [43].

Regarding this topic, 23% of our respondents admitted never having breakfast, whereas 47.5% reported skipping breakfast on three or more occasions per week. No statistically significant differences were observed regarding the median frequency of breakfast intake when comparing Brazilian to Portuguese esports players (p = 0.809).

4.6. Fast Food Intake

In addition to being associated with increased weight and more prevalence of health problems [62], higher fast food consumption correlated with lower executive function and visual memory capacity in university students [63].

According to data collected by the IBGE, in 2019, 6.6% of Brazilians aged 18 or over regularly replaced at least one meal with sandwiches, snacks, or pizza [42]. According to the IAN-AF 2015-16, Portuguese adults consumed fast food (snacks, fried foods, and pizza) on 12.5% of the days and registered an average consumption of 23.3 g of fast food per day [43].

Our study revealed that 39.6% of respondents ingested fast food on one, 20.4% on two to four, and 3.5% on five or more occasions per week. Despite the distinct methodologies applied in these studies, we can infer that fast food consumption was more prevalent in our sample of esports players compared to a reference population. Additionally, we registered a significantly higher consumption of fast food among players of Brazilian nationality compared to Portuguese nationality (p = 0.002).

4.7. Red Meat

Red and processed meat is linked to an increased risk of colon cancer, with a 17% (95% CI: 5 to 31%) higher relative risk for daily consumption of 100 g of red meat and 18% for 50 g of processed meat [64].

According to the 2015-16 IAN-AF survey, about a quarter (25.5%) of Portuguese adults eat between 100 and 150 g of red meat daily [43]. In divergence, our study found much higher results (78.1%) for daily consumption of an amount equal to or greater than 100 to 150 g of red or processed meat.

Although we did not observe significant differences between the two nationalities regarding the number of servings of red and processed meat eaten per day (p = 0.814), we found that a higher proportion of Brazilian players ate less than one serving of red and processed meat per day, compared to the Portuguese (p = 0.016).

4.8. Soft Drinks

Soft or sugary drink consumption has been associated with increased body weight [65], poorer oral health [66], lower consumption of milk and calcium [67], inferior sleep quality [68], and decreased cognitive performance, specifically in the working memory, visual scanning and tracking, and executive function domains [69].

As stated by the IBGE in 2019, 9.2% of Brazilians ingest soft drinks regularly [42]. A national survey (VIGITEL Brasil 2018) found that the frequency of adults who drink soft drinks on five or more days of the week ranges from 6.0% in João Pessoa to 23.0% in Porto Alegre [70]. According to the IAN-AF 2015-16, Portuguese adults (18 to 64 years) consume soft drinks on 15.8% of the days, at an average of 99.6 mL per day.

In comparison, we found that 40.9% of our total sample consumed one or more soft drinks daily, with a significantly higher average daily consumption of soft drinks in the Brazilian compared to the Portuguese players ($p < 0.001$).

4.9. Caffeine Intake

Regular light to moderate caffeine intake has been associated with a lower risk of all-cause mortality, cardiovascular mortality, and a decreased risk of developing conditions such as obesity, type 2 diabetes mellitus, depression, dementia, and some types of cancer [71,72]. However, caffeine also increases the risk of harmful events, including decreased sleep duration and quality, increased anxiety, and nervousness [73].

According to a national survey conducted between 2008 and 2009, which included individuals aged 10 years and older, Brazilians ingest an average of 115.7 mg of caffeine per day from foods and beverages. For individuals aged between 19 and 30 years, the mean intake was 110.2 mg/day, and 125.2 mg/day for those aged 31 to 50 years [74]. Based on data collected in a national survey carried out in 2009 in Portugal, Pinhão and colleagues found that, on average, Portuguese people aged 18 to 29 ingested 148 mg, and those with 30 to 44 years consumed 220 mg of caffeine per weekday from food and beverages [75].

We registered a median daily consumption of 112 mg of caffeine, with 65.8% ingesting coffee and 23.0% consuming energy drinks at least once a week. In comparison, Ip et al. (2021), who surveyed 526 adult video gamers in the USA, reported that 79.5% and 45.1% regularly consumed caffeinated and energy drinks, respectively [22]. Additionally, Skarupova and colleagues (2018) observed that 74.2% of 3952 Czech and Slovak players of massively multiplayer online games aged 11 to 59 consumed caffeine while playing [76].

Although we did not observe significant differences between the two nationalities regarding caffeine consumption ($p = 0.652$), we did observe that Brazilian players' consumption of coffee ($p = 0.036$) and energy drinks ($p < 0.001$) was significantly higher than that of Portuguese players.

4.10. Dietary Supplements Intake

Two studies characterized DS consumption in Brazilian urban areas. A study conducted in São Paulo between 2007 and 2008, which involved 865 individuals aged between 12 and over 60, found that only 6.35% consumed DS, mainly vitamins and minerals (41%), protein (5%), branched amino acids (5%), nutrient-enriched foods (4%), energy drinks (4%), meal replacements for weight loss (2%), and others (5%) [77]. Another investigation took place in Brasília between 2016 and 2017 and involved 506 volunteers aged 20 years or over, of which 35% used DS. The most consumed were vitamins and minerals (55%), proteins (44%), omega-3 (21%), creatine (6%), caffeine (5%), and energizers (2%) [78].

The use of DS in the previous 12 months has been reported by 29.2% of the Portuguese adult population (18 to 64 years). The most consumed DS were multivitamin complexes (33.1%), mineral salts (33.1%), and isolated vitamins (21.3%), such as folic acid and vitamin C, and other categories of DS (15.5%), including whey protein and omega 3 fatty acids [43].

Our study unveiled a higher prevalence of DS consumption (32.3%) than those reported by the studies conducted in the Brazilian and Portuguese populations. The most consumed DS were whey protein (59.4%), creatine (47.1%), caffeine (33.2%), and multivitamin-mineral (30.5%). The differences in DS consumption may have been related to our sample being mostly of young adult age, in which the majority (84.5%) sought to improve some aspect of athletic performance or augment their muscle mass (51.9%).

We did not observe statistically significant differences regarding the proportion of consumers of DS (p = 0.213) and the number of DS ingested (p = 0.194) between our sample of Brazilian and Portuguese players.

Our study also uncovered a significantly higher prevalence of caffeine supplements consumption compared to a reference population, and even higher than those reported by Ip et al. (2021), who surveyed 526 adult video gamers in the USA and found that 12.1% (n = 27) had consumed caffeine pills in the previous 12 months [22]. This higher caffeine consumption through drinks and DS could be related to the ultra-competitive nature of esports, the relatively high number of hours dedicated to video gaming, or sleep perturbations. As about half of our sample admitted using DS to boost their cognitive performance (56.7%) or increase energy/decrease fatigue (49.7%); they may have resorted to caffeine for that purpose.

Although their efficacy has not yet been assessed in esports players, we find it intriguing that two of the DS with the highest nootropic potential in young adults, tyrosine [79] and Bacopa monnieri [80], were seldom used by our respondents.

4.11. Limitations

This survey was conducted during the winter and spring, between December and June, and, therefore, the nutritional data obtained only concerned this period of seven months of the year [81].

Although considered valid measurement tools, the retrospective nature of the questionnaires applied in this investigation implies the possibility of memory errors [82]. Furthermore, web-based surveys may be vulnerable to substantial bias due to the participant's self-selection (volunteer effect) [29]. Due to the anonymous nature of the survey, the possibility of duplicate responses remains.

When available, we compared our data with those reported by other studies that used different methodologies, which limited comparisons.

We did not characterize the city, district, or state of residence, which may modulate the eating behaviors and lifestyles of the population [70]. Justified by the need to keep the questionnaire reasonably short and quick to complete, we restricted our caffeine intake assessment to the most commonly consumed sources of caffeine (coffee, tea, cola, and energy drinks) [73] and did not assess physical activity level or sleep-related variables.

The Brazilian caffeine content table (BraCaffT) [36], developed in Brazil and specific for the Brazilian population, was used to determine the amount of caffeine ingested through beverages, which may translate into a less accurate assessment of caffeine consumption for Portuguese esports players.

4.12. Final Remarks

The young adult age is a crucial period of human development in which inappropriate eating habits can have irreversible or difficult-to-reverse negative health consequences, which will extend throughout adult life [83]. This topic is especially relevant for esports players, as nutrition affects cognitive performance, on which esports players depend for prime performance during training and competition [9].

This study adds to the evidence that most Portuguese and Brazilian esports players have a low level of adherence to a healthy eating pattern. It is necessary to promote healthier dietary habits in this population while involving esports organizations and public health institutions.

Compared to the Portuguese, Brazilian players are more vulnerable and more in need of this type of intervention since they have a lower average age, fewer years of education, a higher level of professionalism, a higher number of hours dedicated to esports play, higher IGD score, higher unemployment, and a higher degree of dietary inadequacy, as demonstrated by lower PREDIMED scores, lower consumption of fruit and vegetables, and higher coffee, energy drinks, soft drinks, and fast-food consumption.

This research may serve as a basis for the development of strategies to promote appropriate eating habits among Portuguese and Brazilian esports players.

4.13. Future Directions

Future investigations should apply food diaries to Portuguese and Brazilian esports players to assess their eating habits more accurately, including fluid consumption, for further insight regarding possible dietary inadequacies, including micronutrient intake deficits.

Additionally, one could test the hypothesis that greater adherence to a healthy dietary pattern, such as the Mediterranean diet, is associated with higher cognitive and video gaming performance in esports players.

5. Conclusions

Our sample presented a low adhesion to the Mediterranean dietary pattern, low compliance to the WHO recommended amount of vegetables and fruit, and high consumption of fast food, red meat, soft drinks, and dietary supplements, including caffeine-based supplements.

In comparison with the Brazilians, Portuguese esports players are older, have a lower BMI, a lower IGD score, a higher adhesion to the Mediterranean diet, higher consumption of fruit and vegetables, lower consumption of soft drinks and fast-food, a higher educational level, a higher number of members of esports teams and federate players, play esports fewer hours a day, have been playing esports for fewer years, play a lower number of esports titles, and display a lower level of esports professionalization.

For both nationalities, the consumption of dietary supplements was associated with a higher adhesion to the Mediterranean diet and a higher degree of gaming disorder correlated with a lower adhesion to this dietary regimen. For the Portuguese players, a higher level of professionalization was associated with a lower adhesion to the Mediterranean diet.

We infer that Portuguese and Brazilian esports players adhere to an unbalanced diet. We advocate for the implementation of initiatives to promote healthy eating habits in this community, preferably with the support of esports organizations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/nu15194200/s1, SM1: Google Form containing the questionnaire, SM2: Excel file containing Univariate ANOVA results (Tables S1 and S2).

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Paper VI: Hydration Status of Portuguese esports Players in a Live Competition

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Hydration Status of Esports Players in a Live Competition

Etat d'hydratation de joueurs de e-sport lors d’une compétition en présentiel

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Abstract

Objectives: esports are an increasingly popular activity that involves professional players. Dehydration hinders cognitive performance, on which these competitors rely heavily. This observational study assessed the hydration state of esports players on a competition day and its possible associations with esports and lifestyle-related features.

Methods: The hydration status of esports players was assessed on a tournament day through urine-specific gravity and by comparison with the Armstrong urine color chart. Binary logistic regression and univariate analysis of variance were applied to assess the relationships between urine-specific gravity and age, BMI, hours of sleep per day, hours of video game play per day, esports title, physical activity level, and professionalism level.

Results: Ninety-eight esports players participated in this study. The average urine-specific gravity, assessed through refractometry, was 1.020 (SD = 0.007) g/cm³. 10.2% were classified as well hydrated, 25.5% with minimal dehydration, 60.2% with significant dehydration, and 4.1% with serious dehydration. Considering the eight-color urine chart method, 16.3% were classified with minimal dehydration, 65.3% with significant dehydration, and 18.4% as serious dehydration. There were no significant associations between hydration status and lifestyle-related variables ($p > 0.05$). The results of the two methods of assessing hydration status presented a positive, moderate, and statistically significant correlation ($r = 0.711$, $p < 0.001$). The agreement between the two classifications was 56.1%, with Cohen's kappa showing a weak agreement ($k = 0.213$, $p < 0.001$) even if with linear ($k = 0.330$, $p < 0.001$) or quadratic ($k = 0.471$, $p < 0.001$) weighting.

Keywords: esports, hydration, urine color chart, urine specific gravity.

Résumé

Objectifs: le e-sport est une activité de plus en plus populaire qui à haut niveau, implique des joueurs professionnels. La déshydratation entrave les performances cognitives, essentielles pour la réussite en e-sport. Cette étude observationnelle a évalué l'état d'hydratation de joueurs de e-sport lors d'une journée de compétition et ses relations possibles avec la pratique de e-sport et les caractéristiques liées au mode de vie.

Méthodes: l'état d'hydratation des joueurs de e-sport a été évalué un jour de tournoi par la mesure de la gravité spécifique de l'urine et par comparaison avec le nuancier d'urine d'Armstrong. La régression logistique binaire et l'analyse univariée de la variance ont été appliquées pour évaluer les relations entre la gravité spécifique de l'urine et l'âge, l'IMC, le temps quotidien de sommeil, les heures de jeu vidéo par jour, le type de e-sport, le niveau d'activité physique et le niveau de professionnalisme.

Résultats: Quatre-vingt-dix-huit joueurs de e-sport ont participé à cette étude. La gravité spécifique moyenne de l'urine, évaluée par réfractométrie, était de 1,020 (ET = 0,007) g/cm^3. 10,2 % des joueurs étaient considérés comme bien hydratés, 25,5 % avec une déshydratation minime, 60,2 % avec une déshydratation importante et 4,1 % avec une déshydratation grave. Si on considère la méthode du diagramme d'urine à huit couleurs, 16,3 % ont été considérés avec une déshydratation minimale, 65,3 % avec une déshydratation importante et 18,4 % avec une déshydratation grave. Il n'y avait pas d'associations significatives entre l'état d'hydratation et les variables liées au mode de vie ($p > 0,05$). Les résultats obtenus avec les deux méthodes d'évaluation de l'état d'hydratation présentaient une corrélation positive, modérée et statistiquement significative ($r = 0,711$, $p < 0,001$). La concordance entre les deux méthodes était de 56,1 %, le kappa de Cohen montrant un faible accord ($k = 0,213$, $p < 0,001$) même avec une pondération linéaire ($k = 0,330$, $p < 0,001$) ou quadratique ($k = 0,471$, $p < 0,001$).

Mots-clés: e-sport, hydratation, nuancier d'urine, gravité spécifique de l'urine.

1. Introduction

esports may be defined as an organized competitive activity involving two or more human players, supported by computer interfaces [1]. esports popularity has increased consistently over the last decade and has risen drastically in recent years, boosted by the lockdowns imposed during the Covid-19 outbreak [2].

Water, a vital nutrient, accounts for 50 to 70% of the human body's weight and around 75% of the brain [3]. Maintaining optimum hydration status is essential for overall health [3] and mental performance [4]. While the brain appears capable of compensating for fluid limitation for short periods, it may be unable to sustain the required increased effort for longer hours [5], and decrements in cognitive performance and moodiness have been reported with values as low as 0.22% body mass loss [6], with most evidence demonstrating impaired cognitive capacity with > 2% [4].

Dehydration negatively affects reaction time, attention, short-term memory, visual perception, concentration and task completion, increases fatigue, and “tension” [7]. Conversely, water intake significantly improved mood and cognitive performance [7-9].

Participating in esports requires strategic and analytical thinking, decision-making speed, low reaction times, high precision of movements, hand-eye coordination, spatial orientation, and fatigue resistance, depending on the video game genre [10]. Because esports players rely primarily on their cognitive performance [10], remaining euhydrated is an important variable to consider, particularly on competition days. Esports competitions can span several hours or even days [11], during which contestants face high psychological stress on par with athletes in traditional sports [12]. This may induce hyperthermia [13], sweating [14], polyuria [15], gastrointestinal disturbances such as diarrhea [16], and sleep disturbances [17, 18], which are detrimental to hydration status. Live competitions can force esports players to cover long distances and air travel [19], and remaining in hot and humid environments also increases the risk of hypohydration [20].

The European Food Safety Authority (EFSA) recommends a total water intake of 2.0 L for women and 2.5 L for men, including water from foods [21]. However, the Portuguese median total water intake is 2.0 L/day for women and 2.4 L/day for men aged 18 to 64, accounting for food sources [22]. This means that half of this population consumes less water than is advised by EFSA [21]. Goulart et al. (2023) [23], which applied food diaries to 103 male and 16 female elite esports players, reported an average consumption of 2041.8 (SD = 907) mL of water from all sources, including foods. Szotet et al.

(2023) [24] reported that 37.4% of 233 male Polish professional and semi-professional esports competitors [20.5 (SD = 2.0 y)] drank less than 1.5 L of liquids per day. Assuming 75% of the daily water intake comes from beverages and 25% from food, the average daily water intake appears to be lower than the recommended values for a relevant proportion of young men [21, 25].

Despite dehydration being common at the population level, affecting approximately 20% of European adults [26], this topic has been largely neglected. To our knowledge, this is the first study to assess the hydration status of esports players. This research examined esports players' hydration status during live tournaments and its possible associations with age, BMI, esports (esports title, hours of video game play per day, and professionalism level) and lifestyles-related (hours of sleep per day, and physical activity level) characteristics.

2. Methods

This study received approval from the ethics committee of the Faculty of Nutrition and Food Sciences of the University of Porto (Nº 125/2023/CEFCNAUP) and complied with the Declaration of Helsinki of the World Medical Association. A protocol for this study has been registered at Open Science Framework (https://doi.org/10.17605/OSF.IO/2HF36).

To be included in this study, volunteers had to be esports players, enrolled in a live esports tournament, and aged 18 or over. Exclusion criteria included having been diagnosed with diseases that are likely to alter hydration status (e.g., kidney disease), reporting any condition that makes it difficult or impossible to collect urine (e.g., urinary incontinence), and the consumption of substances that affect hydration status (e.g., some dietary supplements and medications).

The esports teams participating in the events were previously informed by email about the progress of the study and received generic information regarding its purpose and methodology. Data were collected during the spring season at three live esports tournaments that took place in northern Portugal: the “Porto Academic Esports” on the 29th, 30th of April, and 1st of May; the “Famalicão Extreme Gaming” on May 26; and the “National College Esports Championship” on the 8th, 9th, and 10th of June. The "Porto Academic Esports" and “National College Esports Championship” events were exclusive to university students, while the “Famalicão Extreme Gaming” event was open to any esports player/team. These tournaments included four esports titles: Counter-Strike: Global Offensive (CS: GO), League of Legends (LOL), Valorant, and FIFA 23.

All participants were requested to: read a description of the current study and sign an informed consent form; complete a brief questionnaire; keep a card with an identification number to show researchers when delivering their urine sample; and provide a mid-stream urine sample in a labeled, sterile 120 ml bottle.

Questionnaires and urine samples were gathered between 10:00 and 20:00, from 90 min before, until 5 min after the end of each team´s competition. Most of the samples were collected between 60 and 15 min before each team's competition began. Most matches lasted between 30 and 60 min. The event's organizers, staff, and esports players did not receive any recommendations on diet, fluid availability, fluid intake, or hydration status.

A self-report questionnaire was applied on paper and pencil. It included 16 questions regarding nationality, age, sex, weight, height, professionalism level (amateur, semi-professional, professional), the esports title in which the player competed, Elo rating or Rank, number of hours of daily practice of video games, number of hours of sleep per day and the Brief Physical Activity Assessment Tool (BPAAT). It also included open-ended questions concerning the occurrence of pathologies, the use of dietary supplements, and medicine intake in the previous 30 days.

The BPAAT assesses and compares the physical activity level to current recommendations. It consists of two questions that evaluate the frequency and duration of moderate and vigorous physical activity performed during a typical week [27]. The total score (ranging from 0 to 8) is derived by summing the scores from the two questions. Individuals with a total score between 0 and 3 are classified as insufficiently active, and those with a total score of ≥ 4 as sufficiently active [27].

BMI (kg/m^2) was calculated from self-reported weight and height and corrected according to the equations developed by Pinhão (2014) [28]. BMI values were then categorized using the WHO cut-off points [29].

The hydration state was assessed by comparing the urine-specific gravity (USG) values of a small volume of each volunteer's urine with the density of double-distilled water (1.000 g/cm^3) in a portable digital refractometer (ATAGO PAL-10S, Japan) with automatic temperature compensation, resolution of 0.0001 g/cm^3 and accuracy of 0.001 g/cm^3. The same investigator performed three analyses for each sample, calculated the average of the three results, and applied the USG cutoff values described by Casa et al. (2000): < 1.010 g/cm^3 = well hydrated; 1.010 to 1.020 g/cm^3 = minimal dehydration; 1.021 to 1.030 g/cm^3 = significant dehydration; and > 1.030 g/cm^3 = serious dehydration [30].

The urine samples were also visually compared to the Armstrong (2000) 8-color urine scale (Ucol), and the following cutoff values were applied: 1 or 2 = well hydrated; 3 or 4 = minimal dehydration; 5 or 6 = significant dehydration; and > 6 = serious dehydration [30].

The urine specimens were stored at room temperature and examined within 24 hours. The same researcher performed all urine-related evaluations in a well-lit space at room temperature.

The preliminary data was screened, edited, and prepared using Microsoft® Excel® 365, 64-bit. For the statistical analysis, IBM® SPSS® Statistics 29.0 software was used with significance set at 0.05.

The following variables were generated and set in SPSS: Nationality [Portuguese, Brazilian, Other (Honduran)]; Sex (Male, Female); Age (years); BMI (kg/m^2); BMI category (Underweight, Normal range, Pre-obesity, Obesity class I); Education (years); Professionalism level - 3 categories (Amateur, Semi-professional, Professional); Professionalism level - 2 categories [Amateur, and Professional ("Semi-professional" plus "Professional")]; Video game practice (hours/day); Video game practice - terciles (≤ 2 h, 2 to 4 h, > 4 h)]; Sleep (hours/day); Physical activity level (Sufficiently active, Insufficiently active); USG value (g/cm^3); USG hydration state (Well hydrated, Minimal dehydration, Significant dehydration, Serious dehydration); USG hydration state - 2 categories: [Hydrated ("Well hydrated" plus "Minimal dehydration") and dehydrated ("Significant dehydration" plus "Serious dehydration")]; Ucol value (1 to 8); Ucol hydration level (Well hydrated, Minimal dehydration, Significant dehydration, Serious dehydration)..

Descriptive statistics included absolute (n) and relative (%) frequencies for categorical variables and means and standard deviations (SD) for quantitative variables. Skewness and kurtosis were used to assess the normality of quantitative variables.

Pearson's correlation coefficient (r) and Cohen's kappa were used to assess the association between the hydration-related outcomes obtained through USG and Ucol.

A binary logistic regression model was used to predict significant/serious hypohydration assessed by the USG method based on "Age", "BMI", "Sleep (hours/day)", "Professionalism level - 2 categories", "esports title", "Video game practice - terciles" and "Physical activity level" as independent variables. Additionally, a univariate analysis of covariance (ANCOVA) was conducted with "USG value" as the dependent variable, "BMI", "Sleep (hours/day)", "Professionalism level - 2 categories", "esports title", "Video game practice - terciles" and "Physical activity level" as fixed factors, and "Age" as covariate.

For data interpretation and reporting, we used the USG values as these are more sensitive than the subjective assessment of urine color [31].

3. Results

Insert Table 1 here!

A total of 98 esports players participated in the study. None reported an untreated health condition or the consumption of dietary supplements or medications that affect hydration status, and thus, none was excluded.

Most of the sample was Portuguese (96.9%), predominantly male (93.9%), and all had completed at least 12 years of education. The mean age was 21.7 (SD = 4.7) years, and their average BMI was 23.5 (SD = 3.3) (Table 1).

Insert Table 2 here!

Most participants self-described as amateurs (75.5%), about half (55.1%) played the esports title LOL, and 21.4% played CS: GO. They reported playing video games for 3.3 (SD = 2.1) hours a day on average. Regarding physical activity level, the majority of the sample (66.3%) was characterized as sufficiently active and reported sleeping for an average of 7.1 (SD = 1.1) hours a day (Table 2). Only 23,5% reported the consumption of dietary supplements in the past 30 days.

Insert Table 3 here!

The average USG value for this sample was 1.020 (SD = 0.007) g/cm^3 and according to the scale developed by Casa et al. (2000),[30] only 10.2% were well hydrated, while 25.5% had minimal dehydration, 60.2% significant dehydration, and 4.1% presented serious dehydration. For the assessment performed through comparison with the Armstrong (2000) Ucol,[30] the mean value was 5.5 (SD = 1.1). 16.3% of the total sample was categorized as minimal dehydration, 65.3% as significant dehydration, and 18.4% as serious dehydration.

The results of the two methods of assessing hydration status (USG and Ucol) presented a positive, moderate, and statistically significant correlation ($r = 0.711$, $p < 0.001$). The agreement between the two classifications was 56.1%, with Cohen's kappa showing a weak agreement ($k = 0.213$, $p < 0.001$) even if with linear ($k = 0.330$, $p < 0.001$) or quadratic ($k = 0.471$, $p < 0.001$) weighting.

The binary logistic regression model used to predict significant/serious dehydration by the USG method was not significant ($p = 0.816$, Nagelkerke's $R^2 = 0.081$) and none of the independent variables presented a significant association with that classification. The ANCOVA model was also not significant ($p = 0.651$, $\eta p^2 = 0.082$) and no variable was significantly associated with the USG values.

4. Discussion

Our study revealed that about two-thirds of esports players who participated in a live esports tournament were dehydrated (64.3%), and a quarter (25.5%) presented minimal dehydration in a period around each player's competitive game. These values are much higher than the 18.8% of dehydrated individuals reported by the European Hydration Research Study (EHRS) [26], which assessed the 24 h urine osmolality of 573 healthy individuals (51.1% male) aged 20 to 60 years living in Spain, Germany, and Greece.

In the EHRS study, the average USG values for males was 1.018 (SD = 0.005) g/cm³ for both winter and summer seasons [26]. In comparison, the average USG value obtained in our study, of 1.020 (SD = 0.007) g/cm³, is slightly higher.

Our results are more alike those reported by Volpe et al. (2009) [32], which assessed the USG of 263 male and female collegiate athletes from 14 different sports ~1 hour before team practice and found that only 34% were well hydrated (< 1.020 g/cm³), while 53% presented significant dehydration (1.020 to 1.029 g/cm³) and 13% serious dehydration (USG ≥ 1.030 g/cm³).

Although higher environmental temperatures promote greater water loss, especially through sweat [21], the EHRS study did not find significant differences between the average USG values recorded in winter and summer, which can be explained by greater consumption of fluids during the summer [26]. Furthermore, the ambient temperature on the days in which the competitive events took place was within the typical values recorded for the season (spring), in the district of Porto, in Portugal, during which average temperatures historically varied between 8.7 °C (minimal) and 22,6 °C (maximal) [33].

We theorize that the higher prevalence of dehydration in our sample could be due to:

- The competitors were not aware of the influence of hydration status on health and cognitive performance and neglected adequate fluid consumption.
- A higher commitment to esports or increased focus on the upcoming competitions on tournament day led to lesser concern with proper hydration intake.
- The esports players may have minimized fluid intake to avoid trips to the bathroom during the competitions.
- In the three competitions, the availability of liquids was low, difficult to spot, and consisted mainly of energy drinks.
- Sleep disturbances, including insufficient sleep, have been documented among esports professionals [34] and are associated with increased hypohydration risk [17].

- Higher levels of psychological stress may have induced hyperthermia [13], hyperhidrosis [14], polyuria [15], or gastrointestinal disorders such as diarrhea [16].
- The sample was predominantly male, who typically are more physically active [22], and typically exhibit higher prevalence of dehydration than females [26, 32].

As our statistical analysis did not reveal significant associations between hydration status and age, BMI, number of hours of sleep and video game play per day, professionalism level, esports title, and physical activity level, we assume that dehydration in Portuguese esports players is generalized and not restricted to certain subgroups. This implies that future intervention strategies should target esports players as a whole.

Ucol is considered an economical, non-invasive method to assess hydration status that does not require a high level of expertise [31]. Nonetheless, in our study, the two methods of hydration assessment (USG and Ucol) presented a moderate correlation, and their classifications had a weak agreement. This suggests that hydration assessment exclusively through Ucol doesn´t provide reliable results.

Our study's key strengths include the relatively large sample and the fact that we collected data from three live esports events during a period close to and around each player's competitive game. Additionally, we applied the USG method to assess hydration status which may be more sensitive than blood indices [36].

Despite our findings, research in this area is still lacking, and future investigations should: a) assess the hydration status of esports players over various consecutive days, both in competitive and non-competitive periods; b) test the influence of dehydration and rehydration on cognitive and video game performance of esports players; c) develop and evaluate the effectiveness of strategies to improve literacy regarding the influence of hydration status on health and cognitive performance in esports players.

5. Limitations

The results here presented were collected on a competitive day from a sample of Portuguese esports players, mainly male and university students. They may not apply to esports players in other countries or other populations and non-competitive days.

To avoid the Hawthorn effect and to minimize interfering with the normal course of the competition and the usual performance of players, volunteers were not inquired about their dietary habits and fluid intake. However, that information could have provided valuable insights regarding their typical fluid intake into how esports players differ in their hydration habits. Some participants may have ingested large volumes of fluids in a short period before the evaluation. Various players may have failed to report health conditions, the consumption of dietary supplements, or drugs that could affect hydration status. The urine samples were collected at different points in time, despite possible circadian variations in urine concentration.

6. Conclusion

This observational study revealed that about two-thirds (64.3%) of Portuguese esports players were dehydrated at a live competition event, which is much higher than the value registered in a reference population and relatively like that observed in college athletes. Our findings highlight the importance of regularly assessing esports players' hydration status and call for the development and implementation of strategies for, in close collaboration with esports organizations, educate esports players on the importance of water balance for optimal health and cognitive function. In the absence of significant relationships between the hydration status and lifestyle-related variables, we conclude that hypohydration is generalized, and not concentrated in specific subgroups. Therefore, intervention strategies should be comprehensive, not sub-group targeted. Future investigations should assess the fluid intake and hydration status of these individuals over several consecutive days, including in non-competitive periods.

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Table 1. Socio-demographic characteristics.

	n	*%*	*Mean*	*SD*	*min-max*
Sex					
Male	95	96.9			
Female	3	3.1			
Nationality					
Portuguese	92	93.9			
Brazilian	5	5.1			
Other (Honduran)	1	1.0			
Age, years			21.3	2.1	18-28
BMI, kg/m^2			23.5	3.3	17,9-31,9
Underweight (< 18.5 kg/m^2)	5	5.1			
Normal range ([18.5; 25.0[kg/m^2)	61	62.2			
Pre-obesity ([25.0; 30.0[kg/m^2)	28	28.6			
Obesity class I ([30.0; 35.0[kg/m^2)	4	4.1			
Education, years			12.7	1.5	
12 y	80	81.6			
≥ 16 y	18	18.4			

Table 2. esports related characteristics.

	n	*%*	*Mean*	*SD*	*min-max*
Professionalism level					
Amateur	74	75.5			
Semi-professional	21	21.4			
Professional	3	3.1			
Video game practice, hours/day			3.3	2.1	0,0-12,0
Sleep, hours/day			7.1	1.1	4,0-10,0
Physical Activity Level					
Insufficiently active	33	33.7			
Sufficiently active	65	66.3			

Table 3. Hydration status.

	USG		**Ucol**	
Mean (SD)	1.020 (0.007)		5.5 (1.1)	
	n	%	***n***	***%***
Well hydrated	10	10.2	0	0.0
Minimal dehydration	25	25.5	16	16.3
Significant dehydration	59	60.2	64	65.3
Serious dehydration	4	4.1	18	18.4

5. Discussion

This thesis includes six complete articles, each with a discussion section. Four articles had already been published at the time this thesis was submitted, one had been accepted for publication, and one had been submitted but not yet approved. All articles have been published or submitted to international peer-reviewed scientific journals.

This section has six discussion subcategories, one for each of the six articles included in this thesis. The content presented here adds to and further develops the content presented in each article.

Although this doctorate project had originally planned to test the effects of DS) (e.g., caffeine) on the mental performance of esports players, they were not carried out for the following reasons:

1) The COVID-19 pandemic and consequent restrictions on circulation made it difficult or impossible to apply these studies.
2) Difficulties in obtaining approval from the ethics committee.
3) It proved difficult to obtain an adequate sample size of professional or semi-professional esports players.
4) Several studies evaluating the effects of DS on esports players (e.g., caffeine) have been published, thus eliminating the "innovative" factor, and diminishing the possible contribution to the advancement of scientific knowledge in this area.

Given that other research teams have been publishing articles regarding the dietary habits of esports players, and the effects of DS on the performance of video game players, it was pertinent to encompass and summarize this information in the form of review articles.

Despite the esports-related articles that had been published, it became evident that there were no studies that characterized the hydration status of esports players and given the influence of hydration status on health and cognitive performance, we conducted such a study on competition days.

Paper I: The Emergence of eSports Nutrition: A Review

From this review, which intended to gather information on nutritional aspects that influence cognitive performance in adolescents and young adults, it follows that the dietary guidelines typically recommended to promote overall good health also optimize cognition. Unsurprisingly, a healthy body is required to sustain a healthy and highly performing brain. While it did not allow for establishing specific recommendations for esports players due to the lack of studies conducted on this population, it was possible to assemble a set of recommendations to optimize cognitive performance in adolescents and young adults.

This review also revealed a variety of nutritional-related variables that influence the cognitive performance of healthy individuals and which could also be investigated explicitly in esports players, including the influence of the Body Mass Index (BMI) and body fat composition, carbohydrates manipulation, including low versus high glycemic index, breakfast omission versus intake, low versus high protein intake (i.e., ~3g/kg body weight), the effect of diet quality improvement (e.g., Mediterranean diet), the effects of dehydration, modulation of fatty acids composition (unsaturated vs saturated fat), supplementation with ~20 g of glucose, tyrosine, caffeine, and multivitamin-minerals, and the influence of the placebo effect.

Paper II: Nootropic Supplements for esports: A Scoping Review

Despite the absence of research papers relating to nutrition and esports at the inception of this doctorate program, over time, various papers have been published by different research teams. As its information is of interest to researchers and health professionals working in esports, an additional review was carried out to identify studies that have assessed the effects of DS on the cognitive performance of video gamers.

From the literature identified in the context of this review, it was difficult to reach firm conclusions as the various studies tested different DS, at varying doses, with different methodologies, in different genres of esports, and esports players with different degrees of experience and competitive level. However, it can be stated that the literature published so far has focused on the effects of caffeine, which seems especially relevant for those who play shooter games (e.g., First-person shooter). The reported improvements included improved inhibitory control, cognitive flexibility, working memory, attention, time on target tracking, hit accuracy, and reaction speed. However, caffeine may also impair gaming performance by increasing anxiety, impulsivity, jitteriness, and sleep perturbations.

As some esports players resort to drugs to enhance their game performance,[64] whose effectiveness has not been tested in esports, with the notorious exception of chess, in which methylphenidate and modafinil were tested,[65] it is important that nutritionists are adequately informed and able to advise on legal alternatives (i.e., DS) that do not imply a health risk and that have some degree of scientific evidence of effectiveness in esports players.

This review also highlights the interest of supplement companies in the esports industry, as 9 of the 16 included studies were funded by companies that commercialize DS.

Surprisingly, some DS with the highest supporting evidence for boosting cognitive performance in young adults, such as tyrosine[66] and Bacopa monnieri,[67] have not yet been tested in esports players, and only one study tested glucose.[68] Additional studies should assess the effectiveness of these DS in esports players of varying levels of expertise.

As in "classical" sports nutrition, where it is necessary to acknowledge the characteristics of the sport practiced by the athlete,[69] in esports it is also required to distinguish the genre of the game played (e.g., strategy, shooter), the key features of the competitions (e.g., duration), and the characteristics of the player when establishing recommendations regarding DS or nutritional strategies.

Paper III: Dietary Habits of esports Competitors: A Scoping Review

An additional scoping review was conducted to outline and summarize published information regarding the dietary habits of esports players. This review identified seventeen relevant publications, which surveyed a total of 8760 esports players. It proved difficult to summarize, generalize, and draw conclusions as the studies were conducted in a variety of different countries, on esports players with different levels of professionalization, and from different esports genres. Moreover, the methodologies applied were diverse and various studies produced contradictory findings.

However, in most cases, the quality of the esports players' diet presented a significant degree of inadequacy, at least at the same level as a reference population, and in some cases at an even higher degree, including lower consumption of fruit and vegetables. Some studies have also reported an association between a higher degree of internet addiction and regular alcohol consumption, and between time playing video games and higher consumption of energy, fast food, soft drinks, energy drinks, and caffeine.

There is a margin to improve the dietary habits of esports players. These competitors would benefit from the application of education strategies and training regarding adequate nutrition, including through the intervention of nutritionists. This reinforces the need to include these health professionals in esports organizations and teams.

Paper IV: Sociodemographics, Playing Habits, Adherence to the Mediterranean Dietary Pattern, Dietary Supplements Intake, Physical Activity Level, and Degree of Internet Gaming Disorder of Portuguese Chess Players

In the context of the increasing popularity of esports one has to include chess, which has been expanding its player and fan base in recent years, in part due to the restrictions on circulation imposed during the covid-19 pandemic, which resulted in a higher number of online competitions, held mainly on platforms such as chess.com.[3] Justified by the lack of scientific publications, this manuscript aimed to characterize Portuguese chess players' lifestyles, including chess playing habits, physical activity level, internet gaming disorder (IGD), DS consumption, adherence to the mediterranean diet (MD), and its predictors of adherence.

The main findings were that despite adhesion to the MD being slightly higher, red or processed meat intake was notoriously higher, soft drink consumption was slightly higher and conformity to the World Health Organization recommendations for fruit and vegetable consumption was lower compared to a reference population.[70] We theorize that the most dedicated chess players may be less concerned with maintaining a balanced diet as a higher number of hours of chess play per week associated with a greater consumption of pastries and sweets, higher Elo scores correlated with higher red and processed meat intake, a trend for lower vegetable ingestion, and higher IGD scores correlated with lower adhesion to the MD and lower fish or shellfish consumption.

Although our sample remained seated for slightly longer periods (6.4 vs 5.3 h/day), it displayed a higher prevalence of high (45.8% vs 27.1%) and moderate (33.3% vs 30.6%) levels of physical activity.[70] Differing from the widespread misconception, the majority of top-level esports competitors of various esports titles are not sedentary. Higher percentages for "high" levels of physical activity (84.5%) were recorded in a Portuguese study that applied the International Physical Activity Questionnaire on 433 players of a football simulator (Electronic Arts Sports™ FIFA), whereas "moderate" and "low" levels of physical activity were reported at 12.9% and 2.5%, respectively.[71] In another study that applied the International Physical Activity Questionnaire to 260 male professional esports players from 7 countries, namely Chile, Argentina, Brazil, Mexico, Spain, Germany, and Sweden, the majority reported high

(48.5%) and moderate (44.2%) levels of physical activity, with only 7.3% presenting a low level.[72]

Chess players can use a variety of tactics to get an edge over opponents and increase their chances of victory. They may resort to “smart drugs” and stimulating DS such as caffeine to boost their cognitive abilities and minimize fatigue.[73] This practice has been considered a menace to the fair play policy in chess.[65] Not surprisingly, companies that operate in the DS market have been launching products that cater to chess players, ensuring their customers that their products are effective nootropics.[74] The formulations of these DS include caffeine, choline, theanine, tyrosine, and herb-based extracts such as Bacopa monnieri, Ginkgo biloba, and Rhodiola rosea.[74] However, for most variables related to the consumption of DS, the behaviors of Portuguese chess players do not differ significantly from those recorded in the Portuguese population.[70]

Regarding the frequency of DS consumption, another investigation (IAN-AF 2015-2016) reported similar values, with 29.2% of Portuguese adults (18 to 64 years) admitting the use of DS in the preceding year.[70] In comparison, the consumption prevalence of DS seems to vary significantly in the European Union, with lower values for southern countries such as Greece (6.7%), and Spain (12.1%) and higher values in the Nordic countries, such as Norway (60.6%) and Denmark (65.8%).[75]

Nevertheless, a higher number of chess players reported taking DS to increase energy/decrease fatigue (44.8%), while 26% of Portuguese reported using them to lower fatigue or increase focus (26%).[70] Thus, our sample may be more concerned with maintaining a high cognitive or chess performance.

Perhaps surprisingly, the most commonly consumed DS (multivitamin/mineral complexes: 41.4%, and whey protein: 31.0%) were not caffeine-based, such as caffeine (19.0%), energy drinks (13.8%), and guarana (3.4%), which has some evidence for enhancing chess-playing performance.[65] Moreover, none reported the consumption of tyrosine[66] or Bacopa monnieri,[67] two of the DS with the highest nootropic potential in young adults. In comparison, caffeine use seems higher in poker, another “mind game”. In an online survey that included 198 players, 56.6% of respondents acknowledged using caffeine, and 40.9% acknowledged the consumption of energy drinks.[76]

However, this extensive usage of vitamin and mineral-based food supplements might be justifiable. The Portuguese population presents high proportion of deficiency in several micronutrients, mainly vitamins A, B2, B6, B9, C, E, D, iodine, zinc, magnesium, and calcium, according to data gathered from two nationwide surveys.[70,77] It is known that greater adherence to healthy dietary patterns (e.g. Mediterranean diet) is associated with greater adequacy of vitamin and mineral intake,[78] and although an well-balanced diet should provide adequate amounts of all nutrients, this may not be the case. Some studies demonstrated that a food-only diet does not provide the recommended amounts of several micronutrients,[79,80] including the DASH diet,[80] a dietary pattern deemed appropriate and recommended by the US government and health authorities.[81]

In our sample, health experts, such as doctors, dietitians, and other clinical staff (63.8%), were referred to as the main source of information regarding DS. These health specialists may have recommended vitamin and minerals supplements, as advised by the Journal of the American Medical Association, which recommends that all adults supplements with a low-potency multivitamin-mineral to maintain good health.[82] These health professionals may also have sought to address clinical issues, micronutrient deficits arising from restrictive or inadequate diets,[41] or to minimize fatigue/tiredness, which our group reported as being the primary justification for taking DS.

Being the most metabolically active and energy-demanding organ,[83] the brain's performance is modulated by nutrient ingestion, including micronutrients.[53] According to Tardy et al. (2020), vitamin-mineral supplementation has positive effects on fatigue and physical and cognitive health.[84] Nonetheless, these benefits are restricted to micronutrient(s) suboptimal or deficient individuals.[84] Thus, it is important to inform chess players that micronutrient supplementation doesn´t minimize fatigue or improve performance in individuals with an adequate vitamin and mineral status,[84] and that they should work on increasing their micronutrient intake by optimizing their diet quality.

Moreover, the consumption of DS, especially when not supervised by a nutritionist or doctor, represents a potential health hazard. They may be improper for the customer's purpose, adulterated, contaminated with prohibited substances, potentially harmful to health, and even life-threatening.[85] Nevertheless, a significant percentage of the population lacks knowledge and is misinformed regarding DS.[86] When evaluating the usage of DS, one should assess their level of evidence, appropriateness for the intended goal, and consumption strategy, which should take into consideration the individual's circumstances and features.[87]

It is possible that Portuguese health professionals, namely medical doctors and nutritionists, who represent the principal the main source of information on DS for these chess players

(31.6% and 22.4%, respectively), are wary of recommending caffeine-based supplements to increase energy/minimize fatigue or improve gaming chess performance, due to their potential side effects, or are not well informed about which DS are the most effective for this purpose. It's also conceivable that, owing to their high educational level, Portuguese chess players are more concerned with potential side effects and adopt a more cautious approach to DS consumption.

Paper V: Dietary Habits and Gaming Behaviors of Portuguese and Brazilian Esports Players

Another online survey was applied to Portuguese and Brazilian esports players to characterize their dietary habits, including the level of adherence to the Mediterranean diet, DS consumption, and esports-related variables, and to study the predictors of adherence to the MD. The inclusion of players of Brazilian nationality was justified by the significant number of Brazilians living in Portugal, estimated to be 276,200 in 2020,[88] and because Brazil shares many traits, such as language, historical, commercial, and cultural ties with Portugal. In addition, there weren't any publications regarding the dietary habits of Brazilian esports players despite the country having a large number of players.[7]

Our findings suggest that engagement in esports may be associated with increased adiposity as our sample of Portuguese and Brazilian players displayed a higher prevalence of obesity compared to reference populations.[70,89] This inquiry also exposed higher dietary inadequacies, namely a higher prevalence of breakfast omission, lower adherence to the MD pattern, an inferior consumption of fruit and vegetables, higher consumption of red and processed meat, fast food, soft drinks, energy drinks, confectionery, and sweets. Additionally, this sample consumed more caffeine supplements (33.2% vs 19.0%) and energy drinks (21.9% vs 13.8%) than our sample of Portuguese chess professionals did. This may be due to a desire to boost cognitive performance or minimize mental fatigue and improve performance in esports training or competitions.

It is worrying that our sample of Brazilian players presented a higher prevalence of moderate (56.8% vs 38.2%) and high risk (30.6% vs 13.5%) of IGD compared to a reference population of Brazilian young adults.[90] Interestingly, for both nationalities, a higher degree of IGD was associated with a lower adhesion to the MD, and for Portuguese players, a higher level of professionalization was associated with a lower adhesion to the MD. A greater degree of dedication to esports may translate into less concern about following a proper diet. We infer that most Portuguese and Brazilian esports players adhere to a low-quality dietary pattern, and advocate for initiatives to promote healthy eating habits in this community, preferably with the involvement of esports organizations.

Brazilian players are more vulnerable and in need of this kind of intervention as they presented significantly higher BMI values lower PREDIMED scores, lower consumption of fruit and vegetables, and higher consumption of caffeinated drinks (i.e., coffee, energy drinks), sugary drinks, and fast food than Portuguese players.

Paper VI: Hydration Status of Portuguese esports Players in a Live Competition

Given the influence of hydration status on health and cognitive performance, and given the lack of previous studies, it was important to characterize the hydration status of players in the most relevant period, more precisely on competition days. The hydration status was measured using urine-specific gravity and through comparison with Armstrong's urine color chart. In addition, a questionnaire was applied to characterize age, BMI, number of hours of sleep per day, number of hours of video game play per day, esports titles played, level of physical activity, and level of professionalism.

This study revealed that about two-thirds of 98 esports players were dehydrated during a live competition, and these values are much higher than the nearly one-fifth of dehydrated individuals reported in European adults.[91]

It seems that the intake of adequate amounts of liquids, a basic dietary behavior, is not being met by a significant percentage of the esports population, at least on competition days, which is troublesome as remaining euhydrated is critical to maintaining peak cognitive performance.[92]

If a similar scenario holds on non-competition days, a higher risk of health problems[93] and aggravation of pre-existing chronic diseases derived from hypohydration is expected, including a higher occurrence of renal lithiasis[94] and chronic kidney disease.[95] Additionally, hypohydration has been linked to a quicker pace of biological aging and a greater risk of age-related diseases later in life, such as persistent lung disease, atrial fibrillation, cardiac failure, cerebrovascular accident, cognitive impairment, and diabetes.[96]

This situation creates challenges in the present but especially in the foreseeable future. The expected increase in global temperatures and the frequency of “heat waves” should promote higher body water losses and make it difficult to maintain an adequate water status.[95] In collaboration with esports organizations, strategies should be developed to inform esports players about the importance of fluid balance for optimal health and cognitive performance. Such strategies should target all Portuguese esports players, rather than specific subgroups, as this study did not find any significant association between hydration status and the lifestyle variables characterized.

Future Directions

Despite our findings, investigation in this area is still lacking. Overall, it is necessary to carry out further high-quality research into esports nutrition, including DS, which may ultimately lead to the establishment of nutritional and supplementation recommendations that may promote health and optimize cognitive performance.

More specifically, we highlight the need to:

1) Characterize the dietary consumption of Portuguese and Brazilian esports players through a multi-day food diary, to quantify more precisely the amounts of nutrients ingested;
2) Test the hypothesis that greater adherence to a healthy dietary pattern, such as the Mediterranean diet, is associated with higher cognitive and video gaming performance in esports players;
3) Test the effect of dietary manipulations on esports players, including protein, carbohydrates, fatty acids, and healthy diets (e.g., Mediterranean diet) on their nutritional status, health, cognitive performance, and gaming performance;
4) Assess the effects of slow-release caffeine, nitrates tyrosine, Bacopa monnieri, and distinct types of carbohydrates (e.g. glucose, fructose, isomaltulose) on esports players' cognitive and gaming performance;
5) As the research regarding DS has focused on the effects of caffeine on the performance of video gamers, and anticipating that more studies will be published soon, this topic deserves to be addressed by a systematic review and meta-analysis;
6) Regarding hydration status, future investigations should: a) assess the hydration status of esports players over various consecutive days, both in competitive and non-competitive periods; b) test the influence of dehydration and rehydration on cognitive and video game performance of esports players; c) develop and evaluate the effectiveness of strategies to improve literacy regarding the influence of hydration status on health and cognitive performance in esports players;
7) Assess the efficacy of strategies to enhance food and nutrition literacy on the nutritional status, health, and cognitive performance of esports players.

Concluding Remarks

From a social impact standpoint, the scientific data produced during this doctoral project serves as a resource of knowledge for dietitians and other esports participants regarding nutrition-related issues. It also acts as a framework for health promotion programs to optimize esports players' dietary practices, health, and cognitive performance.

The growing popularity of esports represents an opportunity to promote healthy habits among teenagers and adults. As esports is a highly competitive activity that depends on mental capacity,[45-47] esports players and fans may improve their health-related behaviors if they are aware that adopting a healthy lifestyle, which includes good sleep hygiene,[97,98] physical exercise,[99] maintaining healthy body weight,[100] and eating a balanced diet, promotes optimal cognitive performance. This is a relevant topic, considering that the period between late adolescence and early adulthood is crucial for human development, and in which inadequate dietary habits can have negative cognitive consequences that are irreversible or difficult to reverse, and which tend to persist throughout adult life.[101,102]

Although we found higher obesity prevalence in specific age groups, when working with esports players, one should avoid stereotypes and assume they are typically sedentary. This doctoral thesis added evidence that esports players present higher physical activity levels than those of a reference population. Furthermore, we must be aware that several variables can affect the dietary behaviors of this population, namely nationality, level of professionalism, game genre, etc. In all cases, the nutritionist or other healthcare professional should take these and other specifics into account when working with esports players.

The main findings of this doctoral thesis were:

a) Healthy dietary regimens which are typically advocated to promote health, also optimize healthy adults' cognitive function;
b) Caffeine is the most tested DS in esports players and may improve chess and esports' cognitive and gameplay performance, mainly in shooter games, but may also have adverse effects;
c) Compared to analogous populations, Portuguese and Brazilian esports participants exhibited higher physical activity levels;
d) Portuguese and Brazilian esports players display higher degrees of internet gaming disorder (IGD), a higher prevalence of obesity in certain age groups, poorer dietary

habits, and consume higher amounts of caffeine supplements and energy drinks than the reference populations;

e) Brazilian esports players display a higher BMI, lower PREDIMED scores, lower consumption of fruit and vegetables, and higher consumption of caffeinated drinks (i.e., coffee, energy drinks), soft drinks, and fast food than Portuguese players;

f) The most committed chess players may be less concerned with maintaining a balanced diet as a higher number of hours of chess play per week is associated with greater consumption of pastries and sweets, higher Elo scores correlated with higher red and processed meat intake, a trend for lower vegetable ingestion, and higher IGD scores correlated with lower adhesion to the Mediterranean diet (MD) and lower fish or shellfish consumption;

g) A greater level of dedication to esports may translate into less concern about adhering to a proper diet, as a higher degree of IGD associated with a lower adhesion to the MD for both Brazilian and Portuguese players, and a higher level of professionalization associated with a lower adhesion to the MD on the Portuguese players;

h) More than half of Portuguese and Brazilian esports players were dehydrated on competition days and in higher prevalence than a reference population.

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