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The impact of eSports and online video gaming on lifestyle behaviours in youth: A systematic review

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ABSTRACT

Background: ESports has evolved into a hyper-competitive genre of video gaming. Emerging evidence has linked its intense engagement with mental health problems, with implications on youth development. We aim to summarise the impact of eSports and online video gaming on lifestyle outcomes.
Method: We conducted a systematic review and meta-analysis of studies in journals published in the English language since 2011. We searched PubMed, Web of Science (WoS) and Bielefeld Academic Search Engine (BASE) using search strings related to eSports or video-gaming and lifestyle behaviours.
Results: We identified 3694 studies, 36 of which met the inclusion criteria. The studies reported associations between online video gaming (including eSports participation and consumption) and poor lifestyle outcomes: physical activity-related (decreased levels of physical activity, increased body mass index (BMI) and sedentary behaviour)nutrition-related (poorer diet, sweetened beverage consumption) and sleep-related outcomes (decreased quality/duration, increased sleepiness/sleep deprivation). One study investigated physical lifestyle-related outcomes (eye strain, wrist pain, neck pain) Results indicate a widening breadth of research investigating associations between lifestyle outcomes and online video gaming.
Conclusion: Lifestyle outcomes associated with engagement in eSports and video gaming are important to consider. This emphasizes the need for longitudinal studies which examine characteristics of gaming that may increase young people's risk of practicing unhealthy lifestyle behaviours. The accessibility of eSports to a wide digital audience highlights the need for this sector to promote healthy lifestyle behaviours among consumers and gamers.

Electronic sports or "eSports" is known as a professional sport competition using video games as platforms for competition between two or more individuals (Scholz & Barlow, 2019). Modern eSports have been defined as "a form of sports where the primary aspects of the activity are facilitated by electronic systems; the input of players and teams as well as the output of the eSports system are mediated by human-computer interfaces" (Hamari & Sjöblom, 2017). In 2020, the eSports industry's global revenue has been estimated to value up to $1.1 billion and has been drawing attention from 495 million people across the world (Newzoo, 2019). Though contentious (Scholz & Barlow, 2019) these estimates have highlighted the rapid evolution and growth of the eSports industry. This growth has been attributed to the accelerated popularity of digital communication which has boosted the consumption of eSports and also paved the way for potential investment opportunities and sponsorship (Lee & Schoenstedt, 2011). With the increase of endemic and non-endemic sponsors and the diversification of numerous sports into eSports, commercialization of the sector saw rapid development. While individuals initially engaged in recreational video gaming, competitive play within gaming communities has led to officially sponsored tournament (Jin, 2010). The national and international level of these competitive tournaments have catalysed the sponsorship of teams and the professionalisation of eSports. With this professionalisation came a myriad of residual impacts on the gaming sector such as professional players gaining contracted salaries within professional teams (Scholz & Barlow, 2019). Esports consist of a plethora of gaming types and genres, each attracting distinct audiences, with genres

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including Multiplayer Online Battle Arena (MOBA), Real Time Strategy, First Person Shooter, Fighting and Sports. Games can be player versus player or player versus environment (PVP or PVE), and traditional research examining video gaming impacts does not account for these nuanced and complex distinctions, suggesting that a systematic review of the current field is warranted.

In 2020, the global pandemic COVID-19 has caused severe global economic, educational, and social repercussions, but in direct relevance to our interest, it also has led to a disruption of traditional sport which negatively impacted the billion dollar sports industry (Goldman & Hedlund, 2020). With traditional sports being postponed, there has been a rapid increase of spectators moving towards digitally delivered sports. In particular, they saw eSports as a potential avenue of filling the void of traditional live sports (Ke & Wagner, 2020). Online gaming simulations were streamed by some organizations as a proxy to live sports, including prominent sporting organizations such as the National Basketball Association (NBA), National Hockey League (NHL) and Federation Internationale de Football Association (FIFA; Middler, 2020; Owen, 2020).

While eSports research has so far focused predominantly on businesses, media studies, and sociology paradigms, academic research on eSports phenomena has also recently begun to emerge. Special attention has been given to how participation in eSports can lead to problematic gaming (Chung, Sum, Chan, Lai, & Cheng, 2019). With the recent exponential rise of eSports, it is important to consider the problematic behaviours associated with eSports consumption. Health concerns associated with gaming are highlighted by the American Psychiatric Association (APA) and the World Health Organization (WHO) who have recognised 'Internet Gaming Disorder' as part of a diagnosis within the 11th revision of the International Classification of Diseases (Jo et al., 2019). Due to the social nature of eSports and gaming, recognising associated problematic behaviours can be difficult (Ayenigbara, 2018). When compared with traditional sport settings, eSports lack the educational nature and organic promotion of healthy lifestyle choices that may emerge from informal social guidance. By nature, eSports require extended periods of sedentary behaviour (sitting infront of the computer) which have been extensively associated with greater risks for numerous chronic disease outcomes (Bailey, Hewson, Champion, & Sayegh, 2019; Patterson et al., 2018). However, less is known about the impact of eSports on dietary behaviours (Yin et al., 2020). While previous literature has investigated the association between video gaming and dietary behaviours, there is insufficient evidence to determine whether a link exists (Pelletier, Lessard, Piche, Tetreau, & Descarreaux, 2020). With healthy and active lifestyle choices playing an important role in the reduction of sitting time and unhealthy dietary behaviour (Rezende et al., 2016), the importance of promoting balanced consumption and engagement with eSports is highlighted (Shi, Renwick, Turner, & Kirsh, 2019).

While less research has been done on the impact of eSports on mental health outcomes, research has suggested that video-gaming may lead to negative impacts on psychological functioning (von Der Heiden, Braun, Müller, & Egloff, 2019) such as increased stress, maladaptive coping (Milani et al., 2018) clinical symptoms of depression and anxiety (Wang, Cho, & Kim, 2018). However, whether these negative associations with poor mental health are consequences or causes of video-gaming still requires further investigation. Our review therefore encompasses both esports and video gaming, given that esports represents a particular subset of video gaming (i.e. electronic gaming), and that both are likely to be captured in research.

Previous systematic reviews on video-gaming have focused on recreational video-gaming populations, however no current review has investigated the unique impacts on individuals who participate in eSports and online competitive gaming. Esports is a newly evolved, hyper-competitive landscape which contains a unique and under-researched population. The majority of research investigating video-gaming has focused primarily on the adverse effects of gaming while neglecting to investigate the possible benefits associated with eSports activity. Taking a balanced approach to fully understanding the impacts of this under-researched population may reveal a side to human behaviour which has not been previously addressed.

A recent review of health and social impacts of gaming undertaken by the authors revealed a dearth of research on lifestyle impacts of gaming, particularly in relation to diet and sedentary habituation. The aim of this study is to identify these specific health impacts through a systematic review, with the goal to guide future research agenda. Our study is therefore novel, in that it examines 1. The health impacts of gaming across both recreational and heavy users, and 2. Both positive and adverse impacts upon health and wellbeing, in a departure from prior research. It is also a timely synopsis to inform future research, given the evolving nature of gaming into global and highly commercialized activity. Specifically, through a systematic review and informed by a recent meta scoping review of the state of the field (Kelly and Leung 2021), we aim to gain insights into the following research questions:

1. What are the lifestyle behaviours, including physical, nutrition and sleep, associated with gaming and esports?
2. How might these behaviours and impacts inform a future research agenda on video gaming wellbeing impacts?

1. Method

1.1. Design and protocol

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; see Supplementary material S1 for checklist and Supplementary material S2 for protocol).

1.2. Eligibility criteria

To be included, studies had to meet the pre-determined Population, Exposure, Comparison, and Outcome (PECO) selection criteria. Population: Studies must contain samples involved in video gaming participation. Exposure: Participants in the studies must engage in video gaming participation, this can include players, spectators, and live streams audiences. A comparison group was not required. Outcome: Studies must report quantitative information about lifestyle behaviours, which was included but not limited to dieting, physical activity, sleep duration, screen time, and sedentary behaviour. The lifestyle outcomes defined in this review are physical activity-related outcomes (e.g., body mass index (BMI), physical activity, sedentary behaviour, body weight), nutrition/consumption-related outcomes (e.g., diet, alcohol drinking, and smoking), direct lifestyle-related physical outcomes (e.g., eye strain, injury, pain, posture, and screen time), and sleep-related outcomes (e.g., bedtime and sleep).

Additionally, eligible studies included in this review were restricted to articles written in the English language and published over a ten year period from January 2011. We excluded clinical trials, protocols, reliability or validity studies, abstracts only with no full-text (e.g. conference abstract), perspectives or theories with no empirical data, qualitative studies with no quantifiable data, and case studies of one patient.

1.3. Information sources and searches

We searched from peer-reviewed articles and unpublished studies. We conducted search on PubMed and Web of Science (WoS) to identify potential peer-reviewed articles. We also searched on Bielefeld Academic Search Engine (BASE) to capture eligible unpublished studies and grey literature. The search strategies were developed in close consultation with a research librarian with expertise in the three chosen databases.

The search strings consisted of two main components: (1) eSports or video-gaming search string and (2) lifestyle behaviour search string. This search strategy was developed in PubMed and then adapted for the other databases (see Supplementary material S3).

1.4. Data extraction process

Studies sourced from the initial search were stored and checked for duplicates in a reference management program EndNote. Subsequently, one reviewer conducted screening based on study title. Two reviewers then undertook abstract and full-text screening independently. Any disagreements were resolved between the reviewers through discussions in reference to the study eligibility criteria.

Data was extracted into a Microsoft Excel spreadsheet by one reviewer and independently checked by a second reviewer. A third reviewer was consulted for any discrepancies in data extraction. Extracted information included study details such as year of publication, location of study, sample size, participant's demographics (e.g., age and sex), sampling strategy, response rate, measurement, definition of video games, definition of outcome, quantitative results.

1.5. Risk of bias

Quality assessment was undertaken using the Newcastle Ottawa Quality Assessment Scale (NOS) with three major criteria (i.e., selection, comparability, and outcome) for observational studies (see Supplementary material S5). Two independent reviewers assessed the included studies.

1.6. Synthesis of results

Findings of the included studies were first descriptively summarized. For outcomes with comparable data for pooling, meta-analyses were performed using the Metafor package in R for each of the lifestyle outcome factors. Given that the effect size measures were different across studies, random-effects meta-analyses were used. The estimates were converted into log odds ratio before analysis.

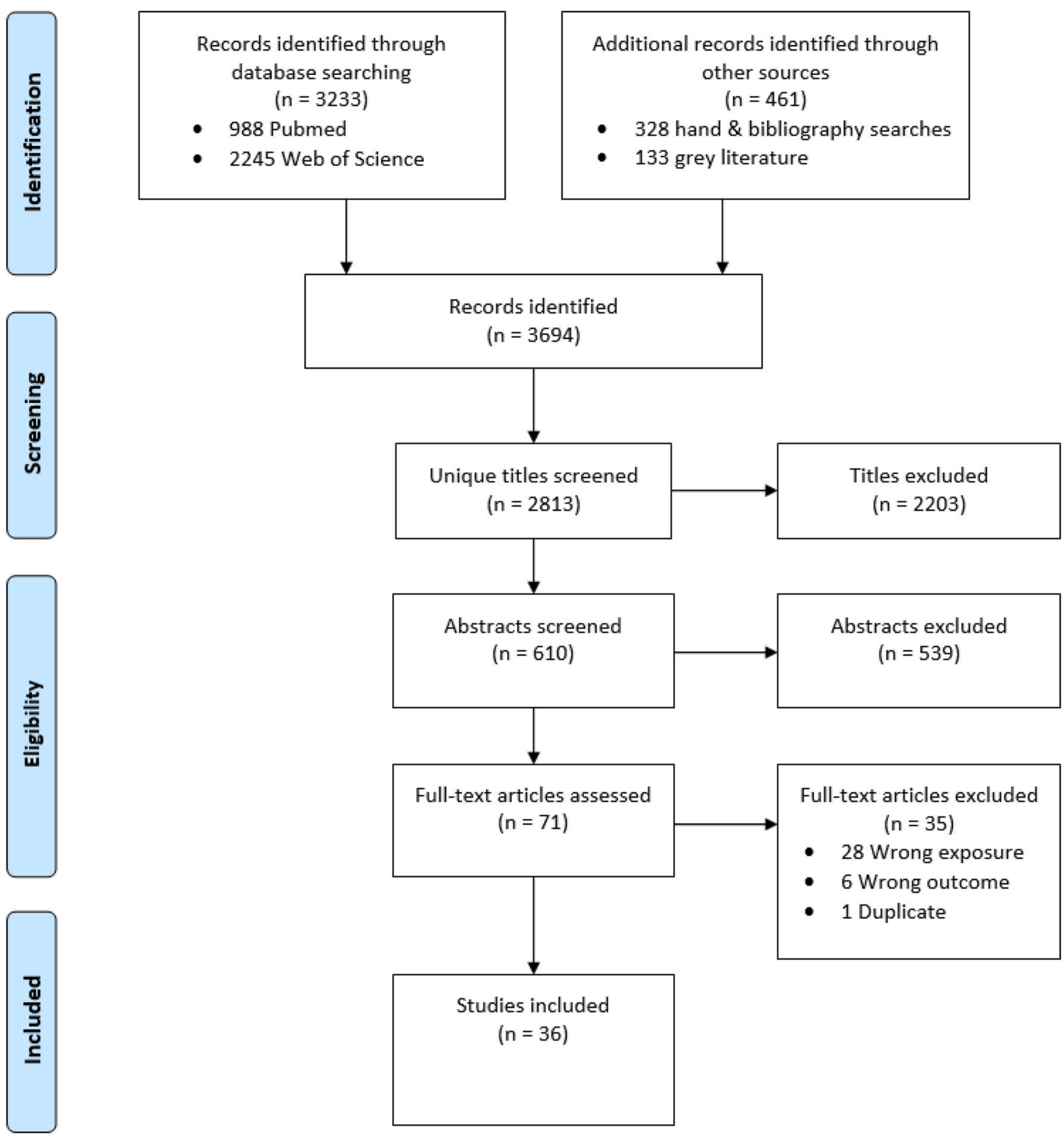

Fig. 1. PRISMA flowchart for the study identification process.

2. Results

2.1. Study selection

From the 3694 articles identified, screening was conducted for 2813 unique titles then 610 abstracts, leaving 71 articles for full-text assessments. Thirty-five full-text articles were excluded due to not meeting our inclusion criteria for the exposure variable, such as studies that examined the effect on lifestyle outcomes due to screen time or computer use in general (e.g. included internet surfing or social media use), or on video gaming genres specified as not eSports/competitive online gaming type of games (e.g. exergames/educational games). A final number of 36 studies were included (see Supplementary material S4), involving data from 54,950 participants (see Fig. 1).

2.2. Study characteristics

Study characteristics and definition of eSports, online competitive gaming, or broader category of video gaming exposure examined are presented in Table 1 (see S4 for full citations). There were three studies that specifically examined eSports/online competitive games (Achab et al., 2011; DiFrancisco-Donoghue, Balentine, Schmidt, & Zwibel, 2019; Dindar & Akbulut, 2014), while the other studies included a broad category of video gaming behaviours.

There were four studies with relatively smaller sample sizes of n < 100 (DiFrancisco-Donoghue et al., 2019; Keenan & Greer, 2015; Mario, Hannah, Jonathan, & Jose, 2014; Turel, Romashkin, & Morrison, 2016), 10 studies with large sample sizes of n > 1000 (Brooks, Chester, Smeeton, & Spencer, 2016; Brunborg, Mentzoni, & Froyland, 2014; Busch, Manders, & de Leeuw, 2013; Coleman, Wileyto, Lenhart, & Patterson, 2014; Cranwell, Whittamore, Britton, & Leonardi-Bee, 2016; Delfino et al., 2018; Lange et al., 2017; Mwaikambo, Leyna, Killewo, Simba, & Puoane, 2015; Santaliestra-Pasias et al., 2012; Tomlin et al., 2014), and one study with a very large sample size of n > 20,000 (Merelle et al., 2017).

There were more studies from the UK (11 %) and USA (22 %), with other studies from a diversity of geographical regions including European and Asian countries, but also from South Africa and a study from Saudi Arabia and one from Brazil. There was one case-control study (Japutra, Fadlyana, & Alam, 2015), three cohort studies (Straatmann et al., 2019; Turel et al., 2016, 2017) among which the two by Turel and colleagues were from the same larger study but examined a slightly different age groups and research questions, and the rest were cross-sectional studies.

Among studies that reported the sex distribution, 57 % of these studies have predominantly more male participants. For age of the samples, most were adolescent to young adult samples, four studies were on children samples (Amidu et al., 2013; Japutra et al., 2015; Mwaikambo et al., 2015; Tomlin et al., 2014), and four included participants across all age groups (Achab et al., 2011; Arnaez, Frey, Cothran, Lion, & Chomistek, 2018; Exelmans & Van den Bulck, 2015; Keenan & Greer, 2015).

2.3. Risk of bias

Overall quality assessment ratings of each study ranged from 1 to 7 (see Table 1), with an average of M = 4.53. Quality assessment ratings within and across studies for each item is available in Supplementary material S6. Across studies, the best ratings were for the confound consideration, outcome assessment and analysis, but low for the selection component. Many studies have controlled for age and sex in their analyses, and also measures of socio-economic profiles of participants (see Supplementary material S7). Within the selection component, while high ratings across studies were achieved for the ascertainment of the exposure variables obtained by using a validated and/or clearly describing the measurement tool, the key fallback of the studies were not providing sample size and response rate justifications and analyses.

2.4. Lifestyle outcomes of eSports/Online competitive gaming

Among the three studies that specifically examined eSports/online competitive gaming, the lifestyle outcomes which were examined were BMI (Dindar & Akbulut, 2014), sleep (Achab et al., 2011), eye strain and bodily pain (DiFrancisco-Donoghue et al., 2019; see Table 2). Two of the studies found that higher engagement in eSports/online competitive gaming was significantly associated with unhealthy lifestyle outcomes (Achab et al., 2011; Dindar & Akbulut, 2014), while studies examining eye strain and bodily pain only provided descriptive results and did not conduct a test of associations.

Dindar and colleagues (2014) conducted a cross-sectional survey of predominantly male gamers (mean age = 19) from an online MMORPG website to examine the characteristics and gaming motivations of Turkish MMORPG players. Correlational analyses showed that playing time was significantly associated with higher BMI, r = 0.17, $p < 0.01$.

Based in France, Achab et al. (2011) ran an internet-based survey in 2010 sampling MMORPG gamers from a World of Warcraft online discussion forum. The main aim of the study was to validate a screening tool for online gaming addiction and examine the characteristics of adult gamers, among which sleep characteristics were investigated as one of the outcomes. Using the scale under validation, the DSM-IV-TR substance Dependence Adapted Scale (DAS) for gaming addiction, participants were categorized as yes or no for MMORPG addiction. Adjusting for age and sex, results showed that gamers categorized into the MMORPG addiction positive group had significantly less hours slept (OR = 0.78 (0.66–0.93)) and lower odds of obtaining a restful sleep (OR = 0.23 (0.14–0.38)) than the group without MMORPG addiction. In addition, the MMORPG addiction positive group had higher odds of reporting deprivation of sleep due to play (OR = 2.83 (1.83–4.38)) and more daytime sleepiness (OR = 3.10 (1.92–5.00)).

The third study, DiFrancisco and colleagues (2019) surveyed collegiate eSports athletes recruited from nine universities from the US and Canada to investigate their lifestyle habits with the aim to propose a healthcare model for eSport athletes. They found that among eSports players, 52 % reported eye fatigue, 30 % reported hand pain, 41 % reported neck pain, and 36 % reported wrist pain. In addition, the study found that 40 % of eSport athletes are physically inactive. Although there were no comparison groups of corresponding university students not participating in eSports, the authors concluded that the high prevalence of physical strains, especially for eye and neck and back, implies that a health management model involving medical teams for eSport athletes are needed.

2.5. Lifestyle outcomes of a broader category of video gaming behaviour that includes eSports/Online competitive gaming genres

The lifestyle outcomes of video gaming behaviour studied the most were BMI (n = 12 studies; and n = 2 on body weight) and physical activity (n = 10; and n = 3 on sedentary behaviour), followed by diet (n = 8), sleep (n = 8), consumption of alcohol and smoking (n = 5; see Table 3).

2.5.1. Metabolic/physical activity-related outcomes

In studies that examined metabolic-related outcomes, there were mixed findings of negative impacts and non-significant conclusions. Four studies reported that video gaming was associated with higher BMI and being overweight (Amidu et al., 2013; Arora et al., 2013; Mario et al., 2014; Melchior, Chollet, Fombonne, Surkan, & Dray-Spira, 2014), while eight studies reported non-significant results (Arnaez et al., 2018; Awadalla, Hadram, Alshahrani, & Hadram, 2017; Byun, Dowda, & Pate, 2012; Cemelli, Burris, & Woolf, 2016; Jackson, von Eye, Fitzgerald, Witt, & Zhao, 2011; Japutra et al., 2015; Mwaikambo et al., 2015; Turel et al., 2016).

Table 1
Study characteristics and definitions of eSports online competitive gaming, or broader category of video gaming exposure examined.

Study	Location; year of data collection	Study design; Sampling strategy and context	Study aims/Research questions	Sample size (percent males)	Age range; mean (SD)	eSports/online competitive gaming/broader category of video gaming examined	NOS
Achab (2011)	France; 2010	Cross-sectional; MMORPG gamers who often visited a World of Warcraft (WoW) online discussion forum; Internet-based survey	To test substance dependence DSM-IV-TR criteria to screen for online gaming addiction and examine the characteristics of adults gamers	448 (82.7)	18-54; M = 26.6 (7.1)	MMORPG	5
Altintas (2019)	France; nr	Cross-sectional; Online video game players who were active members of several online gaming forums; Internet-based survey	To test the hypothesis that intensity of play should be a better predictor than game duration for sleep quality, which in turn should be associated with better health indicators	217 (81.0)	nr; M = 24.4 (6.98)	Online video games in general, no specific description	3
Amidu (2013)	Ghana; 2013	Cross-sectional; Students selected from 4 schools within the Tamale metropolis; School-based survey	To assess the prevalence of childhood obesity and its association with the type of school and other lifestyle factors	400 (nr)	6-12; M = 10.1 (1.7)	Computer games in general, not specified	4
Arnaez (2018)	United States of America; 2014	Cross-sectional; Video game players who reported less than 35 h of recreational physical activity per week, and attended a large Midwestern gaming convention; Internet-based survey	To elucidate how gaming correlates with health in an adult gaming population using multiple measures of gaming behaviour	292 (68.6)	18-99; M = 34.2 (10.6)	Video games played via different platforms (i.e., computer, console, handheld, tabletop, live action role-play (LARP), phone, and tablet platforms)	5
Arora (2013)	United Kingdom; 2009	Cross-sectional; Students of six schools across the UK Midlands region; School-based survey	To examine the independent associations between the use of four technology types (TV viewing, internet use, video gaming, and mobile telephone use) and sleep duration as well as the relationship between sleep duration and BMI in UK adolescents	632 (36.1)	11-18; M = 13.9 (2)	Online video games in general, no specific description	7
Awadalla (2017)	Saudi Arabia; 2016	Cross-sectional; Students from 12 secondary schools; School-based survey	To describe the patterns of video gaming among secondary school adolescents and to investigate their association with risky behaviours such as smoking, violence, traffic rules violation and crashes, social isolation and weight problems	336 (nr)	15-21; M = 17.2 (1.03)	Video games in general including fighting games, racing, sports, and strategy war games	5
Brooks (2016)	United Kingdom; 2010	Cross-sectional; Students from secondary schools; School-based survey	To investigate factors associated with video gaming behaviour of boys and girls among a large representative sample of young people in England	4404 (90.0)	11-15; nr	Video gaming is defined as the playing of any video games for entertainment purposes during self-directed leisure time on either a computer or console, excluding game playing in other contexts such as educational or therapeutic settings	6
Brunborg (2014)	Norway; 2010	Cross-sectional; Students from 89 schools; School-based survey	To investigate the relationship between video game use and several depression, poor academic achievement, alcohol intoxication and conduct problems	1928 (44.5)	13-17; nr	Video games in general, not specified	6
Busch (2013)	Netherlands; nr	Cross-sectional; Students from 5 Dutch high schools; School-based survey	To investigate how unhealthy behaviours are associated with screentime behaviours	2425 (45.0)	11-18; nr	Online video games on a game console	5
Byun (2012)	South Korea; 2005	Cross-sectional; Korean adolescents; Multi-stage national sample (Korean National Health and Nutrition Examination Surveys [KNHANES])	To: 1) describe the patterns of screen-based sedentary behaviours, specifically watching TV and playing PC/video games in Korean adolescents and 2) examine the association between screen-based sedentary behaviour and CVD risk factors	577 (54.8)	12-18; M = 14.4 (0.1)	PC/video games	6
Cemelli (2016)	United States of America; 2015	Cross-sectional; General population from social media sites by convenience sampling strategy; Internet-based survey	To study lifestyle behaviours in gamers who currently play games online, gamers who participate in more traditional	292 (52.1)	18-35; M = 23.1 (4)	Video games including online and offline games	3

(continued on next page)

Table 1 (*continued*)

Study	Location; year of data collection	Study design; Sampling strategy and context	Study aims/Research questions	Sample size (percent males)	Age range; mean (SD)	eSports/online competitive gaming/broader category of video gaming examined	NOS
			games offline, and non–video game players as controls				
Chan (2014)	China; nr	Cross-sectional; cohort of children born in 2002 recruited for a developmental research study; Hospital-based survey	To understand video gaming's associations with sleep quality in children	143 (47.6)	12	Video games including action, adventure, role-playing, simulation, and strategy games	3
Coleman (2014)	United States of America; 2011	Cross-sectional; Students in grades 9–12; School-based survey	To examine the co-occurrence of a broad array of risk behaviours in an adolescent population	1354 (47.0)	15-18; nr	Video or computer games	3
Cranwell (2016)	United Kingdom; 2014	Cross-sectional; Using YouGov, an internet-based market research service, to sample British adolescents aged 11–17 years; Internet-based survey	To quantify and characterize alcohol and tobacco content in the most popular UK video games, and to assess the relationship between exposure to tobacco or alcohol content and smoking or drinking behaviours in British adolescents	1082 (50.0)	12-17; M = 14 (1.9)	17 games: Call of Duty: Black Ops II, Hitman: Absolution, Far Cry 3, Borderlands 2, Mass Effect 3, Battlefield 3, Call of Duty: Modern Warfare 3, Max Payne 3, Sleeping Dogs, Tom Clancy's Ghost Recon: Future Soldier, Grand Theft Auto V, Grand Theft Auto Episodes: Liberty City, Grand Theft Auto IV, Assassin's Creed IV: Black Flag, Batman: Arkham Origins, BioShock Infinite, Assassin's Creed III	4
Delfino (2018)	Brazil; nr	Cross-sectional; Students from six public and private schools; School-based survey	To estimate the prevalence of sedentary behaviour based on screen time (TV, computer, video games, mobile phone/tablet) and the association with physical activity and eating habits	1101 (44.9)	10-17; M = 13.5 (2.3)	Video games in general, not specified	6
DiFrancisco (2019)	United States of America; nr	Cross-sectional; eSports athletes from eight universities; University-based survey	To investigate the lifestyle habits of collegiate eSport players and a proposed healthcare model for eSport athletes	65 (nr)	18-22; nr	–	1
Dindar (2014)	Turkey; nr	Cross-sectional; MMORPG gamers from a online MMORPG website; Internet-based survey	To examine the characteristics and gaming motivations of Turkish MMORPG players	307 (98.1)	nr; M = 19.36 (6.789)	–	2
Exelmans (2015)	Belgium; nr	Cross-sectional; Adults living in Flanders, Belgium; Computer-assisted telephone and personal interviews	To investigate the association of video gaming volume with sleep quality in adults	844 (43.8)	18-94; M = 46 (17.76)	Video games played on a computer or console, and games played on the internet or social media	6
Gilbert (2018)	United States of America; nr	Cross-sectional; Male college students from one Midwestern university; University-based survey	To investigate the relationship between video game play and participation in risk-taking behaviours	273 (100.0)	17-26; M = 18.99 (1.17)	Video games including Legend of Zelda, Grand Theft Auto, and Madden NFL	3
Ivory (2017)	United States of America; nr	Cross-sectional; Full-time students enrolled in colleges and universities; University-based online survey	To examine the role video games may have in the health risk environment of college and university campuses	533 (57.3)	nr; M = 25.02 (5.67)	Video games including action, role-playing, simulation, strategy, sports, racing, puzzle, and trivia games	4
Jackson (2011)	United States of America; nr	Cross-sectional; Children from 20 middle schools distributed throughout the southern lower peninsula of Michigan; School-based survey	To examine the prediction of children's body mass index (BMI), body weight, academic performance, social self-esteem and overall self-esteem from their information technology use, specifically, their Internet use, cell phone use and videogame playing	482 (47.1)	nr; M = 12.19 (0.72)	Video games in general, not specified	5
Japutra (2015)	Indonesia; 2013	Case-control; Children with either overweight/obese (case), or normal BMI (control); School-based survey	To assess for relationships between obesity in 6 to 12-year-old children and maternal nutritional status, maternal education, eating breakfast, eating fast food, physical activity, TV watching, and playing video games	120 (57.5)	6-12; M = 9 (1.7)	Video games in general, not specified	3
Keenan (2015)	United States of America; 2014	Cross-sectional; Full-time liberal arts faculty members from a North-eastern university; University-based survey	To describe sedentary behaviour, examine the relationship with demographic, physical activity, and environmental factors	72 (36.1)	18-99; M = 51 (11.2)	Video games in general, not specified	3

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Table 1 (*continued*)

Study	Location; year of data collection	Study design; Sampling strategy and context	Study aims/Research questions	Sample size (percent males)	Age range; mean (SD)	eSports/online competitive gaming/broader category of video gaming examined	NOS
Lange (2017)	German; 2006	Cross-sectional; General population from the German Health Interview and Examination Survey for Children and Adolescents; Interviews and Examinations	To examine associations of time spent per day using different electronic media devices and the occurrence of insomnia complaints in adolescents	7533 (51.3)	11-17; M = 14.2 (0.01)	Video games in general, not specified	6
Mario (2014)	United Kingdom; nr	Cross-sectional; Male college students from the Newcastle University; University-based survey	To investigated the relationship between video game playing with nutritional, behavioural and lifestyle factors including diet and macronutrient intake, eating behaviour, body composition and physical activity in young male adults	45 (100.0)	18-27; nr	Video games on computer and console	4
Melchior (2014)	France; 2009	Cross-sectional; Young adults in the Trajectories Epidémiologiques en Population (TEMPO) study that comprises offsprings of employees from a national gas and electricity company	To examine the association between interactive media use and being overweight in young adults	674 (39.8)	22-35; M = 28.9 (3.7)	Video games in general, not specified	6
Mentzoni (2011)	Norway; 2009	Cross-sectional; Norway citizens selected from the Norwegian National Registry; General population	1) To investigate the use of video games in a representative sample of young Norwegian adults; 2) To assess how video game-related problems or addiction might be associated with physical and psychological health	816 (nr)	15-40; nr	Video games including MMORPG in general, not specified	5
Merelle (2017)	Netherlands; 2014	Cross-sectional; Second- and fourth graders in secondary schools were invited to complete a web-based questionnaire; School-based survey	To identify which health-related problems are most important for adolescents that are at risk of problematic video-gaming or social media use	20,741 (49.4)	nr; M = 14.4 (1.3)	Video games on devices such as computer, tablet, smartphone or game console (e.g., Playstation, Wii, Xbox, DS)	7
Mwaikambo (2015)	Tanzania; nr	Cross-sectional; Students from six public and four private schools; School-based survey	To identify behavioural and dietary factors that are related to overweight and obesity in children.	1722 (45.2)	7-14; M = 10.9 (1.74)	Video games in general, not specified	7
Peracchia (2017)	Italy; nr	Cross-sectional; Adolescents who had low or high video gaming frequency from an existing study investigating habits of video gaming and sleep quality (sampling method not reported); Self-report survey	To examine sleep quality and sleep-related variables in a group of hard and casual gamers	300 (38.0)	nr; M = 14.76 (1.08)	Video games in general, not specified	3
Polski (2016)	Poland; 2014	Cross-sectional; Students from Lublin's universities; University-based survey	To evaluate the relationship between physical activity and gaming	138 (33.3)	18–25	Computer games in general, not specified	1
Scholz and Barlow (2019)	Ten European countries; 2007	Cross-sectional; Students from schools in 10 European cities including Athens, Heraklion, Dortmund, Ghent, Lille, Pecs, Rome, Stockholm, Vienna, and Zaragoza; School-based survey	To examine the association between time spent on different (mainly screen-based) sedentary behaviours and the dietary consumption behaviours in a sample of European adolescents	2202 (46.9)	12-17; M = 14.74 (0.07)	Video games in general, not specified	6
Straatmann (2019)	Brazil; 2012	Cohort; Students from two public and four private schools from the metropolitan area of Rio de Janeiro, Brazil; Data from a population-based survey: The Adolescent Nutritional Assessment Longitudinal Study (ELANA)	To investigated the correlates of physical activities, television viewing and video game/ computer use	810 (53.8)	nr; M = 10.95 (0.82)	Video games in general, not specified	4
Tomlin (2014)	Canada; 2005	Cross-sectional; Grade four and five students from 30 schools; School-based survey	To examine the hypothesis that unhealthy dietary behaviour would be more strongly associated with television viewing than with computer use and video gaming	1423 (48.2)	9-10; M = 9.9 (0.58)	Video games in general, not specified	4
Turel (2016)	Canada; 2015	Cohort; Adolescents who play online video games recruited from two clinics (paediatric lipid and weight management outpatients) at a large research hospital; Hospital-based survey	To examine the hypothesis that video gaming addiction is linked to obesity, and that this association is partially mediated through reduction in sleep time	94 (67.0)	10-17; M = 13.02 (2.24)	Video games in general, not specified	6

(continued on next page)

Table 1 (*continued*)

Study	Location; year of data collection	Study design; Sampling strategy and context	Study aims/Research questions	Sample size (percent males)	Age range; mean (SD)	eSports/online competitive gaming/broader category of video gaming examined	NOS
Turel (2017)	Canada; 2015	Cohort; Adolescents who play online video games recruited from two clinics (paediatric lipid and weight management outpatients) at a large research hospital; Hospital-based survey	To examine the association between duration of video gaming and sleep quality	125 (67.0)	9-17; M = 13.06 (2.22)	Video games in general, not specified	6

nr: not reported; MMORPG: Massively Multiplayer Online Role-Playing Games; PC: personal computer.
NOS: Newcastle-Ottawa Quality Assessment Scale, max score of 10.

Table 2
Summary of findings in studies examining eSports or online competitive gaming exposure on lifestyle outcomes.

Study	Lifestyle factor group	Definition of lifestyle factor	Exposure	Analysis	Effect size	Impact	Findings
Metabolic/physical activity-related outcomes							
Dindar (2014)	BMI	BMI (continuous)	Time spent playing	Correlational analyses	r = 0.17, p < 0.01	–	Playing time was significantly associated with higher BMI
Sleep-related outcomes							
Achab (2011)	Sleep	Hours slept per night	MMORPG addiction (yes vs no) measured using the DSM-IV-TR substance dependence Adapted Scale (DAS)	Multivariate logistic regression	OR[a] = 0.78 (0.66–0.93)	–	The group with MMORPG addiction had significantly less hours slept, restful sleep, and more sleep deprivation and daytime sleepiness than the group without MMORPG addiction
		Restful sleep (yes or no)			OR[a] = 0.23 (0.14–0.38)	–	
		Deprivation of sleep due to play (yes or no)			OR[a] = 2.83 (1.83–4.38)	–	
		Daytime sleepiness (yes or no)			OR[a] = 3.10 (1.92–5.00)	–	
Lifestyle-related physical outcomes							
DiFrancisco (2019)	Eye strain	Eye fatigue	Playing eSports as a professional occupation	Descriptive statistics	52 %	n/a	Among eSports players, 52 % reported eye fatigue, 30 % reported hand pain, 41 % reported neck pain, and 36 % reported wrist pain
	Bodily	Hand pain			30 %	n/a	
		Neck pain			41 %	n/a	
		Wrist pain			36 %	n/a	

BMI, body mass index; DSM, Diagnostic and Statistical Manual of Mental Disorders.
Effect size: r, correlation coefficient, OR, odds ratios.
[a] Adjusted estimates (variables adjusted for are available in S7) Impact upon health: ns, not significant; -, negative impact upon health; +, positive impact upon health; n/a, not applicable.

Impacts on physical activity and sedentary behaviour were also mixed. Four studies reported that lower levels of physical activity were associated with greater online gaming (Cemelli et al., 2016), playing for a higher number of hours (Arnaez et al., 2018; Keenan & Greer, 2015), and problematic gaming behaviour (Merelle et al., 2017), and six studies reported non-significant results (Busch et al., 2013; Delfino et al., 2018; Mario et al., 2014; Mentzoni et al., 2011; Polski, Iwaniak, Sobotka-Polska, Rogowska, & Poleszak, 2016; Straatmann et al., 2019), although estimates leaned towards a negative impact direction.

Measures on BMI and video gaming from 10 studies were similar enough for meta-analysis. Results from a random-effect meta-analytic model indicated that video gaming significantly increased risk of high BMI, log odds ratio = 0.35, 95 % CI (0.12, 0.57), $p = 0.002$ (see Fig. 2 for the forest plot). A leave-one-out sensitivity analysis was performed. The results were consistent, indicating the result was unlikely to be unduly influenced by any single study. Funnel plot of this analysis did not show any significant asymmetry, indicating the absence of strong publication bias.

2.5.2. *Dietary/consumption-related outcomes*

Multiple studies consistently reported the negative impact of increased duration of vido-games engagement with greater consumption of sugar-sweetened beverages and savory snacks (Cemelli et al., 2016; Coleman et al., 2014; Delfino et al., 2018; Santaliestra-Pasias et al., 2012; Tomlin et al., 2014). Consumption of fruits, vegetables, and sweet snacks such as cakes, pies, and cookies tend not to be associated with gaming behaviour. Two studies on whether gaming was associated with not eating breakfast reported null findings (Busch et al., 2013; Merelle et al., 2017). One study reported that boys who spent more time gaming on weekdays were significantly more likely to go to bed hungry (Brooks et al., 2016).

Evidence on the relationship between gaming with smoking and alcohol drinking reported mixed findings of negative, null, and even positive impacts. A study based in the US reported that 8.5 % of people who spent more than 3 h per day playing video games were current smokers (Coleman et al., 2014). One study reported that people who have played video games were more likely to have ever smoked (Cranwell et al., 2016), two studies reported no association (Awadalla et al., 2017; Ivory, Ivory, & Lanier, 2017), and one study reported that problematic gaming was associated with lower odds of smoking (Merelle et al., 2017). Among alcohol studies, one reported higher odds of ever trying alcohol (Cranwell et al., 2016), while another study reported a positive impact that higher frequency of playing online video games was associated with lower alcohol consumption (Gilbert, Giaccardi, & Ward, 2018), and multiple studies reported no association between video gaming intensity with heavy episodic drinking or alcohol use in the past month (Brunborg et al., 2014; Ivory et al., 2017; Merelle et al., 2017).

Measures on diet and video gaming from 3 studies were similar enough for meta-analysis. Each of the studies reported multiple dieting measures and a three-level random-effect meta-analysis model was used

Table 3
Summary of findings on studies examining lifestyle outcomes associated with a broader category of video gaming.

Study	Lifestyle factor group	Definition of lifestyle factor	Exposure	Analysis	Effect size	Impact	Findings
Metabolic/physical activity-related outcomes							
Amidu (2013)	BMI	Overweight (BMI≥85th percentile) Obese (BMI≥95th percentile)	Playing computer games (yes or no)	Logistic regression	OR = 2.35 (1.39–3.97) OR = 4.86 (2.16–10.93)	– –	Playing video games was significantly associated with the higher odds of being overweight or obese
Arora (2013)	BMI	BMI z-score	Use of video gaming at bedtime (yes or no) on weekdays	Multiple linear regression	B[a] = 0.4 (0.08), β = 0.2, p < 0.01	–	Playing video games at bedtime was significantly associated with increased BMI
Awadalla (2017)	BMI	BMI (continuous)	Heavy vs no or low amount of playing video games (scores above the median of the total weekly gaming hours)	T-test	t = 0.51, ns	ns	Heavy video gaming was not significantly associated with BMI
Byun (2012)	BMI	BMI ≥85th	Time spent playing	Logistic regression	OR[a] = 1.11 (0.97–1.26)	ns	Time spent playing PC/video games (hours/day) was not significantly associated with overweight (BMI ≥85th)
Jackson (2011)	BMI Body weight	BMI (continuous) Body weight (lb)	Playing video games (yes or no)	Hierarchical linear regression	β[a] = −0.03, ns β[a] = 0.03, ns	ns ns	Video gaming was not significantly associated with BMI nor body weight
Japutra (2015)	BMI	Overweight/obese vs normal BMI	Playing video games >8 h per week (yes or no)	Logistic regression	OR = 0.75, ns	ns	Playing games >8 h per week were not a significant risk factor for childhood obesity
Melchior (2014)	BMI	Overweight (BMI≥25)	Regular video game use more than once a week (yes or no)	Multiple logistic regression	OR[a] = 1.94 (1.15–3.28)	–	Regular video game use was significantly associated with being overweight
Mwaikambo (2015)	BMI	Overweight/Obese (BMI≥ 25)	Playing video games once a week (yes or no)	Multiple logistic regression	OR[a] = 1.2 (0.8–1.7)	ns	There was no significant association between playing games once a week and overweight or obese
Turel (2016)	BMI	Level of abdominal obesity measured using a ratio of waist circumference to height	Video game addiction measured by the Van Rooiji 14 item-scale	Multiple linear regression	β[a] = −0.01, ns	ns	Video gaming addiction was not significantly associated with higher level of abdominal obesity
Arnaez (2018)	BMI Physical activity	Obesity (BMI≥30) Performing 2.5 h/week of moderate-to-vigorous physical activity	Weekend gaming time more than 3 h per day Weekend gaming time more than 3 h per day	Logistic regression Logistic regression	OR[a] = 1.06 (0.49–2.26) OR[a] = 0.40 (0.19–0.85)	ns –	Gaming >3 h per day was not significantly associated with obesity, but was significantly associated with doing less moderate-to-vigorous physical activity
Busch (2013)	Physical activity	At least 1 h of moderately intensive physical activity per day	Excessive video gaming (>14 h/week)	Multiple logistic regression	OR[a] = nr; ns	ns	Excessive video gaming was not significantly associated with physical activity
Cemelli (2016)	BMI Sedentary behaviour	BMI (continuous) Total sedentary time (hrs/wk)	Online games vs Non-gamers	One-way between-group analysis	M = 24.9 (6.2) vs M = 23.4 (3.7), ns M = 84.7 (45.5) vs M = 68.0 (29), p < 0.01	ns –	There was no significant differences in BMI between online gamers and non-gamers, but online gamers were significantly more sedentary than non-gamers
Coleman (2014)	Body weight Sedentary behaviour	Unhealthy weight loss (vomit or take laxatives to lose weight in the past month) Zero days with 60 min of moderate-to-vigorous physical activity within the past week	Extreme video game play (more than 3 h per day in the last week)	Descriptive statistics	4.10 % 22.40 %	n/a n/a	Among people who spent more than 3 h per day to play video games, 4.1 % of them had engaged in unhealthy weight loss behaviour, and 22.4 % were physically inactive
Delfino (2018)	Physical activity	Baecke score of physical activity in school Baecke score of physical activity in sports Baecke score of physical activity in leisure time	Time spent playing	Binary logistic regression	OR[a] = 0.84 (0.59–1.2) OR[a] = 0.78 (0.53–1.15) OR[a] = 1.01 (0.73–1.41)	ns ns ns	Playing video games was not significantly associated with physical activity in school, sports, or in leisure time
Keenan (2015)	Physical activity	Minutes spent in moderate and vigorous physical activity measured by The international Physical Activity Questionnaire (IPAQ)	Time spent playing	Spearman correlation	r = −0.25, p < 0.05	–	Time spent on video games was negatively correlated with time spent in moderate and vigorous physical activity
Mario (2014)	BMI	BMI (continuous)	Video game playing (hrs/wk)	Correlational analyses	r = 0.3, p < 0.05 r = -0.24, ns	– ns	Time spent on video gaming was significantly associated

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Table 3 (*continued*)

Study	Lifestyle factor group	Definition of lifestyle factor	Exposure	Analysis	Effect size	Impact	Findings
	Physical activity	Total physical activity measured by IPAQ					with higher BMI, although it was not significantly associated with levels of physical activity
Mentzoni (2011)	Physical activity	Frequency of engagement in sports or exercise ("never", "less than once per month," "1–3 days per month," "1 day per week," "2–3 days per week," "4–6 days per week," or "daily")	Problematic video gaming measured by Gaming Addiction Scale for Adolescents (GASA); respondents endorsing at least four of the items were categorized as problem gamers	MANOVA	F (2,792) = 0.50, ns	ns	Problematic video gaming was not significantly associated with the frequency of exercising
Merelle (2017)	Physical activity	Physical activity (<1 h/day)	Problematic video gaming (mean score ≥3) measured by Compulsive Internet Use Scale (CIUS)	Multiple logistic regression	OR[a] = 1.42 (1.24–1.63)	–	Problematic video gaming was significantly associated with higher odds of physical inactivity and sedentary behaviour
	Sedentary behaviour	Sedentary behaviour (≥2 h/day)			OR[a] = 4.91 (4.09–5.9)	–	
Polski (2016)	Physical activity	Frequency of doing physical activity (never, occasionally, once a week, a few times a week, everyday)	Video gaming (yes or no)	Chi-squared test	Nr	ns	There was no significant relationship between gaming and physical activity, approximately 80 % of both players and non-players were active
Straatmann (2019)	Physical activity	Light activity measured by IPAQ	Time spent playing	Autoregressive cross-lagged panel models	β[a] = 0.21, ns in males at age 11	ns	Time spent playing video games were significantly associated with physical inactivity in boys at age 13, but not in boys at age 11 or in girls at both age
					β[a] = −0.18, p < 0.001 in males at age 13	–	
					β[a]<0.01, ns in females at age 11	ns	
					β[a] = −0.05, ns in females at age 13	ns	
		Moderate and vigorous physical activity measured by IPAQ			β[a] = 0.04, ns in males at age 11	ns	
					β[a] = −0.18, p < 0.001 in males at age 13	–	
					β[a] = 0.07, ns in females at age 11	ns	
					β[a] = 0.03, ns in females at age 13	ns	
Dietary/consumption-related outcomes							
Brooks (2016)	Diet	Frequency of going to bed hungry (often vs never)	Spent 4 or more hours a day vs up to about 1 h a day	Multiple logistic regression	OR[a] = 0.178 (0.081–0.392) in boys	–	In boys, spending more time video gaming on weekdays was significantly associated with higher odds of going to bed hungry
		Frequency of going to bed hungry (sometimes vs never)			OR[a] = 0.172 (0.075–0.391) in boys	–	
Busch (2013)	Diet	Having breakfast & eating fruits and vegetables at least 5 times per week	Excessive video gaming was not significantly associated with physical activity	Multiple logistic regression	OR[a] = nr; ns	ns	Excessive video gaming was not significantly associated with nutrition intake
Cemelli (2016)	Diet	Low fat eating	Online games vs Non-gamers	One-way between-group analysis	M = 25.0 (7.1) vs M = 28.1 (6.9), p < 0.05	–	Compared to non-gamers, online gamers reported less low-fat eating and higher sugar-sweetened beverages consumption (e.g. fruit juice and soft drinks), but no significant differences were observed for other dietary behavioural groups
		Emotional eating			M = 28.5 (6.7) vs M = 30.1 (7.0), ns	ns	
		Snacking on sweets			M = 11.7 (3.8) vs M = 11.2 (3.4), ns	ns	
		Haphazard meal planning			M = 19.9 (5.2) vs M = 19.3 (5.3), ns	ns	
		Meal skipping			M = 12.2 (3.9) vs M = 11.4 (3.6), ns	ns	
		Sugar-sweetened beverages consumption (kcal)			M = 136 (210) vs M = 65 (125), p = 0.012	–	
Delfino (2018)	Diet	Fruits	Time spent playing	Binary logistic regression	OR[a] = 0.92 (0.67–1.27)	ns	Time spent playing video games was significantly associated with higher odds of snacking, but not with other eating habits
		Vegetables			OR[a] = 0.96 (0.70–1.31)	ns	
		Snacks			OR[a] = 1.65 (1.13–2.69)	–	
		Fried foods			OR[a] = 1.10 (0.79–1.53)	ns	

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Table 3 (*continued*)

Study	Lifestyle factor group	Definition of lifestyle factor	Exposure	Analysis	Effect size	Impact	Findings
		Sweets			OR[a] = 0.92 (0.67–1.27)	ns	
		Soft drinks			OR[a] = 1.24 (0.90–1.72)	ns	
		Milk and dairy			OR[a] = 0.89 (0.64–1.23)	ns	
		Grains			OR[a] = 0.95 (0.55–1.64)	ns	
Scholz and Barlow (2019)	Diet	Cakes, pies, cookies consumption above the median	Playing video games >4 h/d weekdays	Binary logistic regression	OR[a] = 0.44 (0.17–1.11) in boys	ns	Playing video games more than 4 h per day was significantly associated with higher savory snacks and sweetened beverages consumptions, but not with others dietary behaviours in boys, and was significantly associated with higher fruits and sweetened beverage consumptions, but not with others dietary behaviours in girls
					OR[a] = 0.50 (0.20–1.25) in girls	ns	
		Savory snacks consumption above the median			OR[a] = 3.10 (1.24–7.75) in boys	–	
					OR[a] = 1.82 (0.52–6.39) in girls	ns	
		Vegetables consumption above the median			OR[a] = 0.64 (0.28–1.50) in boys	ns	
					OR[a] = 0.54 (0.22–1.31) in girls	ns	
		Fruits consumption above the median			OR[a] = 0.45 (0.19–1.05) in boys	ns	
					OR[a] = 0.37 (0.14–0.94) in girls	–	
		Juices consumption above the median			OR[a] = 0.59 (0.26–1.36) in boys	ns	
					OR[a] = 0.69 (0.31–1.56) in girls	ns	
		Sweetened beverages consumption above the median			OR[a] = 7.84 (2.55–24.1) in boys	–	
					OR[a] = 7.26 (1.65–31.89) in girls	–	
Tomlin (2014)	Diet	Sugar consumption	Time spent playing	Multiple linear regression	β[a] = 0.06 (0.01–0.22), $p < 0.05$	–	Video gaming was significantly associated with higher sugar and sugar-sweetened beverages consumption
		Sugar-sweetened beverages consumption			β[a] = 0.08 (0.17–1.10), $p < 0.01$	–	
Awadalla (2017)	Smoking	Smoking (yes or no)	Heavy vs no or low playing video games (scores above the median of the total weekly gaming hours)	Chi-squared test	$\chi2 = 0.05$, ns	ns	Heavy video gaming was not significantly associated with smoking
Brunborg (2014)	Alcohol drinking	Heavy episodic drinking	Time spent gaming	Linear regression analysis	β[a] = −0.02, ns	ns	Time spent gaming and level of addiction was not significantly associated with heavy alcohol drinking
			Video game addiction (score higher than average) measured by Game Addiction Scale for Adolescents		β[a] = −0.05, ns	ns	
Cranwell (2016)	Alcohol drinking	Ever tried alcohol	Played at least one of the video games studied	Multiple logistic regression	OR[a] = 2.35 (1.70–3.23)	–	Playing one of the video games studied, and ever playing a video game rated 18+ years was significantly associated with higher odds of ever trying alcohol and smoking, with playing video games rated 18+ years at least once per week significantly associated with drinking but not smoking
			Ever played video game rated 18+ years		OR[a] = 2.68 (1.95–3.68)	–	
			Played video games rated 18+ years at least once per week		OR[a] = 1.65 (1.17–2.34)	–	
	Smoking	Ever tried smoking	Played at least one of the video games studied		OR[a] = 2.70 (1.75–4.17)	–	
			Ever played video game rated 18+ years		OR[a] = 4.08 (2.57–6.47)	–	
			Played video games rated 18+ years at least once per week		OR[a] = 1.29 (0.83–2.01)	ns	

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Table 3 (*continued*)

Study	Lifestyle factor group	Definition of lifestyle factor	Exposure	Analysis	Effect size	Impact	Findings
Coleman (2014)	Smoking Diet	Current smoker Daily soda consumption	Extreme video game play (more than 3 h per day in last week)	Descriptive statistics	8.50 % 27.60 %	n/a n/a	Among people who spent more than 3 h per day to play video games, 8.5 % of them were current smoker and 27.6 % had soda drinks frequently in the past 7 days
Gilbert (2018)	Alcohol drinking	Alcohol consumption (higher than average score)	Frequency online video games	Correlational analyses	r = −0.18, $p < 0.01$	+	Online games were negatively associated with alcohol use
Ivory (2017)	Smoking	Cigarette use (days per month) E-cigarette use (days per month) Chewing tobacco use (days per month)	Weekly overall video game play, action play, and sports/racing games play	Zero-inflated Poisson regression	βa = nr, ns β^a = −0.069 (0.027), $p < 0.05$ for action games β^a = −0.073 (0.024), $p < 0.01$ for action games	ns – –	Weekly game play was not significantly associated with cigarettes smoking or alcohol drinking in general, but play of action games were significantly associated with not using e-cigarettes and lower use of chewing tobacco, and that sports/racing games was associated with higher odds of binge drinking
	Alcohol drinking	Having at least 1 drink (days per month) Having at least 5 drinks in a sitting (days per month)			βa = nr, ns β^a = 0.091 (0.017), $p < 0.01$ for sports/racing games	ns –	
Merelle (2017)	Diet	Breakfast (<5 times/week)	Problematic video gaming (mean score ≥3) measured by Compulsive Internet Use Scale (CIUS)	Multiple logistic regression	OR^a = 1.14 (0.95–1.37)	ns	Problematic video gaming was not significantly associated with the odds of not having breakfast or alcohol use, but it was significantly associated with lower odds of smoking
	Alcohol drinking Smoking	Alcohol use (≥1 time past month) Smoking			OR^a = 1.04 (0.89–1.23) OR^a = 0.69 (0.55–0.88)	ns +	
Sleep-related outcomes							
Altinta (2019)	Sleep	Sleep quality measured by PSQI, cut-off score over 5 indicates poor sleep quality	Video game duration Intensity of video game playing	Logistic regression	OR = 1.02 (1.00–1.04), p = 0.08 OR = 0.97 (0.95–0.99), p = 0.01	ns	Video game players with high intensity of video game playing have lower sleep quality, while no associations were observed for video game duration
Arora (2013)	Sleep	Weekday sleep duration (hours)	Use of video gaming at bedtime (yes or no) on weekdays	Multiple linear regression	B^a = −0.39 (0.1), β = −0.15, $p < 0.01$	–	Playing video games at bedtime was significantly associated with decreased sleep duration
Chan (2014)	Sleep	Sleep onset delay measured by CSHQ Sleep duration measured by CSHQ Daytime sleepiness measured by CSHQ	Weekly gaming minutes	Correlational analyses	r = 0.1, ns r = 0.09, ns r = 0.03, ns	ns ns ns	Time spent playing video games was not significantly associated with sleep onset delay, sleep duration, and daytime sleepiness
Exelmans (2015)	Sleep	Poor sleep quality measured by PSQI Fatigue measured by FAS Symptoms of insomnia measured by BIS Later bedtime Later rise time	Gaming volume (hrs per day)	Hierarchical linear regression	β^a = 0.15, $p < 0.001$ β^a = 0.11, $p < 0.01$ β^a = 0.12, $p < 0.01$ β^a = 0.10, $p < 0.01$ β^a = 0.17, $p < 0.001$	– – – – –	More hours of video game play per day was significantly associated with poorer sleep quality.. Fatigue, insomnia, and later bedtime and rise time
Lange (2017)	Sleep	Insomnia complaints defined as participants had either difficulties initiating sleep or difficulties maintaining sleep, and indicated having felt "tired and lacking energy'' during the past week at least "often'' or "always" on a five-point Likert-scaled item with response options ranging from "never'' to "always''	video games per 0.5–2 h/d video games per >3 h/d	Binary logistic regression	OR^a = 0.60 (0.38–0.93) in boys OR^a = 1.03 (0.63–1.70) in girls OR^a = 1.44 (0.73–2.85) in boys OR^a = 1.24 (0.36–4.36) in girls	+ ns ns ns	Playing video games between 0.5 and 2 h per day significantly reduce the odds of insomnia complaints in boys, but there was no effect for playing >3 h or in girls
Peracchia (2017)	Sleep	Sleep quality measured by PSQI Sleep efficiency measured by PSQI	Hard gamers (who play for 4–6 h per day) vs Casual gamers (who played occasionally; less than 1 h)	Mean (SD)	M = 1.04 (0.95) vs M = 0.84 (0.67), $p < 0.05$	+ +	Casual gamers had significantly poorer sleep quality, poorer sleep efficiency, and higher

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Table 3 (*continued*)

Study	Lifestyle factor group	Definition of lifestyle factor	Exposure	Analysis	Effect size	Impact	Findings
					M = 0.65 (1.07) vs M = 0.43 (0.75), p < 0.06		daytime dysfunction compared to hard gamers
		Daytime dysfunction measured by PSQI			M = 0.92 (0.76) vs M = 1.13 (0.81), p < 0.05	+	
Turel (2016)	Sleep	Sleep duration measured by Fitbit devices, which categorized each minute as asleep or awake, which allows the internal calculation of accurate sleep duration	Video game addiction measured by a 14 item-scale created by Van Rooij	Multiple linear regression	β[a] = −0.24, p < 0.01	–	Video game addiction was significantly associated with lower sleep duration
Turel (2017)	Sleep	Poor sleep quality measured by PSQI	Duration of video gaming before bedtime	Multiple linear regression	β[a] = 0.32, p < 0.001	–	Duration of video gaming before bedtime was significantly associated with poorer sleep quality
Lifestyle-related physical outcomes							
Polski (2016)	Bodily pain Eye strain	Back pain Vision problems	Playing video games at least once a week	Descriptive statistics	20 % 28 %	n/a n/a	Among respondents who play computer games at least once a week, 20 % experienced regular back pain and 28 % reported vision problems

BMI: body mass index; PSQI: The Pittsburg Sleep Quality Index; CSHQ: Children's Sleep Habits Questionnaire; FAS: Fatigue Assessment Scale; BIS: Bergen Insomnia Scale; IPAQ: International Physical Activity Questionnaire; Effect size: β, standardized beta coefficient; B, beta coefficient; M (SD), mean (standard deviation); r, correlation coefficient, OR, odds ratio.

[a] Adjusted estimates (variables adjusted for are available in S7) Impact upon health: ns: not significant; -: negative impact upon health; +: positive impact upon health; n/a: not applicable.

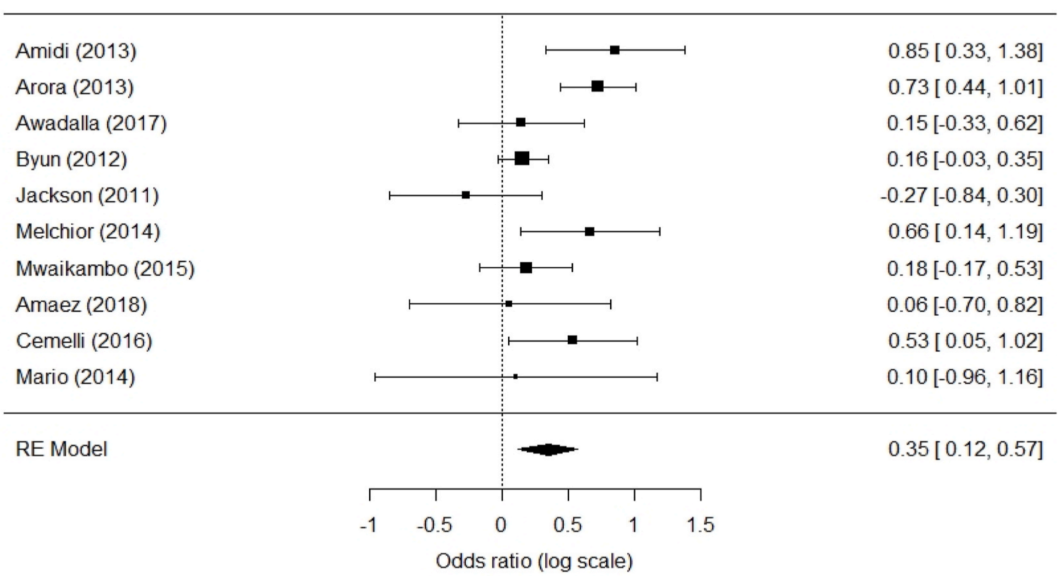

Fig. 2. Forest plot of the association between video gaming and BMI.

to account for the nested structure of the effect size (effect size nested within study). Results indicated that video gaming was significantly associated with poor diet, log odds ratio = 0.46, 95 % CI (0.10, 0.83), $p = 0.016$ (see Fig. 3 for the forest plot).

2.5.3. *Sleep-related outcomes*

Studies of the impacts of video-gaming on sleep also found mixed findings. Negative impacts of video gaming have been reported on sleep quality (Altintas, Karaca, Hullaert, & Tassi, 2019; Exelmans & Van den Bulck, 2015; Turel et al., 2017) duration (Arora et al., 2013; Turel et al., 2016), later bedtime and rise time, and symptoms of fatigue and insomnia (Exelmans & Van den Bulck, 2015). One study of a sample of 12 year-olds reported that time spent playing video games was not significantly associated with sleep onset delay, sleep duration, or day-time sleepiness (Amidu et al., 2013). A study that compared number of hours played between boys and girls found that playing video games between 0.5 and 2 h per day significantly reduced the odds of insomnia complaints in boys (positive impact), but there was no effect for playing more than 3 h among girls (Lange et al., 2017). Another study that reported a positive impact compared hard gamers (who played for 4–6 h per day) with casual gamers (who played occasionally; less than 1 h), with results showing that hard gamers had significantly better sleep

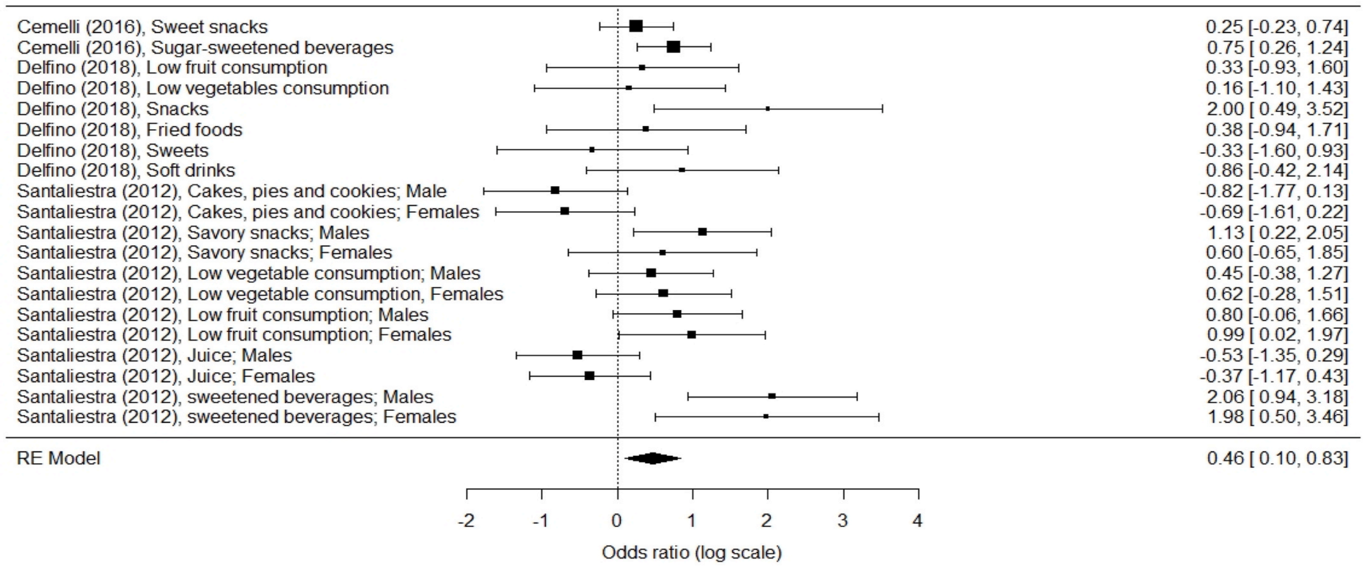

Fig. 3. Forest plot of the association between video gaming and diet.

quality, sleep efficiency, and daytime functioning (Peracchia, Triberti, & Curcio, 2017). Measures on sleep and video gaming from 3 studies were similar enough for meta-analysis. Given that the effect size measures were different across studies, they were converted into correlation coefficient (r) before analysis. Results from a random-effect meta-analytic model indicated that video gaming was not significantly associated with sleep quality, $r = 0.13$, 95 % CI (-0.05, 0.32), $p = 0.149$. Fig. 4 shows the forest plot. A leave-one-out sensitivity analysis was performed. The results were consistent, indicating the result was unlikely to be unduly influenced by any single study.

2.5.4. *Lifestyle-related physical outcomes*

Only one study examined the association between video game playing with lifestyle-related physical outcomes or injuries. The study's primary aim was to evaluate the relationship between physical activity and gaming, but also reported the effect on back pain and vision problems as secondary outcomes (Polski et al., 2016). Only descriptive statistics were available in a sample that reported playing at least once a week, with no comparison groups. The study observed that among respondents who play computer games at least once a week, 20 % experienced regular back pain and 28 % reported vision problems.

3. Discussion

The current review and meta-analysis identified associations of video gaming (including eSports) with numerous lifestyle and behavioural factors. An association between gaming and increased BMI was found as well as an association between higher rate of gaming and a poorer diet. While sleep was found to have no general association with eSports and video gaming in a number of studies. In particular, a study specifically on Massive Multiplayer Online Role Player Game ("MMORPG") addiction found that those who met addiction criteria slept less hours, had less restful sleep, and were more likely to report sleep deprivation due to play and daytime sleepiness (Achab et al., 2011).

3.1. *Implications for future research*

The consumption of eSports and online competitive gaming was found to be associated with unhealthy lifestyle outcomes and other physical impacts including eye fatigue or strain, and hand, neck, or wrist pain. Despite this, these physical measures were not compared with non-gaming populations. Increased engagement with eSports reduces the capacity for healthy and active lifestyle and promotes increased periods of sedentary behaviour. Although we found that gaming had significant association with BMI and diet, it should be noted that nearly all the

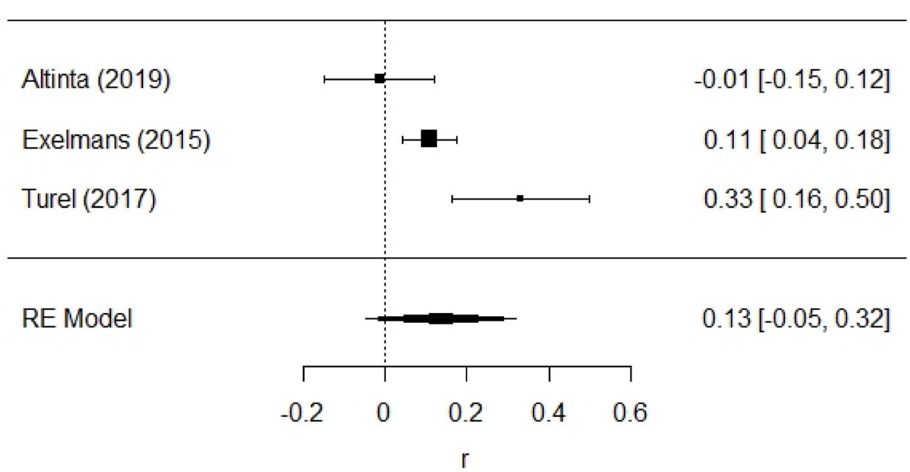

Fig. 4. Forest plot of the association between video gaming and sleep quality.

studies are cross-sectional and have limitations. Hence, future research is warranted to inform levels of eSports gaming patterns potentially associated with poor lifestyle outcomes.

3.2. Limitations

Findings need to be interpreted with the limitations of our review. The current review excluded articles that did not specifically engage in video gaming participation either as a player, spectator or live stream audience. The excluded studies were ones which investigated the impacts of computer, internet, or social media use in general rather than the unique effect of video gaming. The current review identified the impact of eSports genre of video gaming on youth, however only three studies specifically investigated the exposure of eSports, and the rest did not differentiate against recreational and non-professional players in the community. Sample sizes varied between studies with a number of studies with small sample sizes, and some that did justification for the rate of participant response which could suggest bias in the responses. We conducted sensitivity analysis whenever possible to evaluate the robustness of our key conclusions. The results from our sensitivity analyses were consistent with our conclusion. The impact of eSports is a global phenomenon and studies were from a variety of geographical regions indicating that cultural differences would not have preceded any analysis. Investigating the health impacts of the consumption of eSports is vital given the exponential growth and penetration of the sector among young consumers. Understanding the short- and long-term health impacts have public health impacts as well as implications for eSports management in practice. “

3.3. Implications for practice

Given the prevalence of youth both participating and streaming eSports, it is important that the health impacts are better understood by management within these spheres. In highly competitive eSports environments, the health impacts on individuals need to be considered as they would in traditional sport settings. Promoting health education and implementing strategies that navigate the welfare of players and spectators is a priority. The risk of participation in eSports leading to poor lifestyle behaviours is the responsibility of the industry and must be considered in the currently largely self-regulated ecosystem. It is important to work with health experts to educate players and spectators on their lifestyle choices to navigate the negative impacts eSports may have, and our research can help to guide health promotion on positive gaming participation. Likewise, there is potential for leveraging of potential benefits of epsorts, particularly when balanced with healthy lifestyle, and this systematic research provides a robust foundation for future evidence-based research designed to inform optimal governance, participation and commercial growth of the burgeoning gaming sector. A unique opportunity is presented for eSports to be leveraged as a platform for education surrounding health and activity given the accessibility and popularity of its content and its influence on younger consumers.

In conclusion, lifestyle outcomes associated with engagement in eSports video gaming such as physical and dietary behaviours are important to address when investigating risks associated with this phenomenon. The accessibility of eSports to a wide digital audience positions this sector to promote healthy lifestyle behaviours with balanced consumption to offset the potentially problematic behaviours that are associated with the raising engagement with eSports.

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Contributions

Provided funding, conceptualization, drafting of manuscript, literature review: SK. Substantial contributions to the conception or design of the work: JL, SK, GC. The acquisition of data: PH, JL. Analysis of data: JL, GC. Drafting and revising: JL, GC, CT. Revising work, positioning MG. All authors made substantial contributions to the interpretation of data for the work, drafting the work, and revising it critically for important intellectual content. All authors provided final approval of the version to be published and are accountable for all aspects of the work.

Declaration of competing interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2021.106974.

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