Problematic gaming and sleep: A systematic review and meta-analysis

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Abstract

Problematic gaming is described as a pattern of playing digital (video/computer) games that could negatively influence physical and mental health and/or interference with daily activities. An increasing number of studies have shown that problematic gaming is negatively related to sleep. Due to the ongoing debate surrounding the conceptualization of problematic gaming and gains in empirical evidence on the topic over the last years, there is a need for an updated consolidation of the current knowledge on health outcomes associated with problematic gaming. Thus, a systematic review and meta-analysis was conducted in correspondence with the PRISMA guidelines to consolidate the available data on sleep characteristics in problematic gamers, and to quantify the strength of the potential association between problematic gaming and sleep problems. The primary search was conducted in January 2020 in Medline, Embase, Web of Science, PsycINFO, and Google Scholar databases, yielding a total of 21 empirical quantitative studies that met the specified inclusion criteria. Overall, the results from the review and meta-analyses suggest that problematic gaming is inversely associated with sleep duration and sleep quality, and that problematic gamers have increased odds of reporting sleep problems. The results are discussed in terms of limitations and implications for further research.

Keywords: Problematic gaming, Gaming, Gaming addiction, Sleep, Sleep problems Systematic review, Meta-analysis

Sammendrag

Problematisk bruk av dataspill kan defineres som et mønster av spillatferd som kan negativt påvirke fysisk og mental helse og/eller forstyrre daglige aktiviteter og gjøremål. Et stigende antall studier har pekt på at problematisk bruk av dataspill er negativt knyttet til søvn. Grunnet de pågående debattene om konseptualiseringen av problemspilling, samt en økning i empirisk data de siste årene, er det behov for en oppdatert forening av kunnskapen om helseutfallene assosiert med problematisk bruk av dataspill. I lys av dette, ble det i denne studien gjennomført en systematisk litteraturgjennomgang og metaanalyse i tråd med PRISMA-retningslinjene, for å samle den tilgjengelige kunnskapen om søvnkarakteristikkene hos problemspillere og for å kvantifisere styrken i det potensielle forholdet mellom problematisk bruk av dataspill og søvnproblemer. Primærsøket ble gjennomført i januar 2020 i databasene Medline, Embase, Web of Science, PsycINFO, and Google Scholar, og resulterte i 21 studier som møtte inklusjonskritteriene. Samlet sett viser resultatene fra litteraturgjennomgangen og meta-analysene at problematisk bruk av dataspill er negativt assosiert med søvnlengde og søvnkvalitet, og at problemspillere har økt sannsynlighet til å rapportere søvnproblemer. Resultatene er diskutert i lys av deres begrensninger og deres implikasjoner for videre forskning.

Nøkkelord: Dataspill, Gaming, Dataspillavhengighet, Søvn, Søvnproblemer, Systematisk litteraturgjennomgang, Metaanalyse

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Introduction

Over the last decades the world has witnessed an explosive rate of technological advances which have had a significant impact on many aspects of our lives, including how we work, interact with others, and importantly; the way we recreate. Today, gaming is a popular leisure activity world-wide, and for many individuals an integral aspect of everyday life. Gaming is the activity of playing video games which can be facilitated through a variety of digital devices such as personal computers (PC), TV-consoles (i.e. PlayStation or Xbox), handheld gaming consoles (i.e. Game Boy or Nintendo Switch) and gaming applications on smartphones or tablets. Gaming distinguish itself from traditional media (e.g. television) by its inherent interactive features where the user is controlling the actions of the game, thus shaping the narrative (Granic, Lobel, & Engels, 2014). The video game market offers a wide range of different games, ranging from simple but salient card games such as Solitaire, to complex and never-ending role-play games, such as World of Warcraft, which are played simultaneously by millions of people over the internet.

Results from a national representative survey of Norwegian children and adolescents aged 9-18 showed that 96% of the boys and 63% of the girls played video games. Further 45% of the boys and 22% of the girls reported playing more than two hours the day before sampling (The Norwegian Media Authority [Medietilsynet], 2018). High prevalence rates of video gaming amongst children and adolescents were also found in an European survey, where 76% of children age 6-10 years, 84% of children age 11-14 years, and 74% of adolescents and young adults age 15-24 years, reported to play video games (Interactive Software Federation of Europe [ISFE], 2019). Though it is a common conception that video games are mostly enjoyed by children and adolescents, gaming is also a common leisure activity for adults. The findings from the ISFE-survey suggest that the average European gamer is 31 years and that 67% of 25-35-year-olds, 49% of 35-44-year-olds, and 34% of 45-64-year-olds play video games (ISFE, 2018).

Problematic Gaming

Parallel with video games' increasing popularity, concerns have risen that heavy investment in video games may be harmful and that some individuals may develop an addiction-like relationship to video games. Correspondently, several recent studies have aimed to investigate the potential detrimental effects of gaming (Granic et al., 2014). The available empirical evidence suggest that playing video games is unproblematic for most people and that gaming could involve several potential beneficial effects in many domains including cognitive processing, problem-solving, emotional regulation, and development of social skills (Granic et al., 2014; Adachi & Willoughby, 2013; Griffiths, 2002). However, a minority of players seem to experience gaming-related impairments in health and daily life functioning (Griffiths, Davies, & Chappell, 2004; Kuss & Griffiths, 2012). Of particular concern is reports suggesting that some gamers display maladaptive patterns of recurrent video game use despite negative consequences, a behavioral pattern which resembles the pattern observed with addictive disorders (Kuss & Griffiths, 2012; Mannikko, Billieux, & Kaariainen, 2015). Consequently, problematic gaming and gaming addiction have become a topic of interest amongst both researchers and clinicians who have investigated many aspects of the phenomenon including the nature of the pathology (i.e. classification/assessment, epidemiology and phenomenology), risk factors (i.e. etiology), and ramifications (i.e. consequences and treatment) (Kuss & Griffiths, 2012).

Conceptualizing problematic gaming. There has been a wide range of conceptualizations describing the state where video gaming becomes problematic for an individual. Some researchers have considered the video games themselves to be the starting point for examining the characteristics of the specific behavior (e.g. Griffiths, 2005; Charlton & Danforth, 2007; Mentzoni et al., 2011), whereas others (e.g. Van Rooij, Schoenmakers, Vermulst, Van Den Eijnden, & Van De Mheen, 2011; Young, 1998; Block, 2008) have considered the Internet as the source of the pathology (Király, Nagygyörgy, Griffiths, & Demetrovics, 2014b). Regarding the latter view, problematic gaming has been considered to be a variant of generalized Internet addiction, where it is primarily online games and especially the “Massively Multiplayer Online Games” -genre that are thought to have the potential to cause problems for the gamer (MMOGs) (Király et al., 2014b). However, the Internet addiction construct has been criticized to be too heterogeneous for addressing problematic involvement in video games specifically, as online gaming is only viewed as one of many addictive online behaviors such as, chatting, watching films, shopping, gambling and surfing the web (Király et al., 2014b; Pontes & Griffiths, 2014b). Correspondently, empirical research has shown that internet addiction and online gaming addiction are two separate constructs (Király et al., 2014a). More integrative approaches have also been suggested, viewing both the games and internet as equally contributing factors for problematic involvement in online games (Demetrovics et al., 2012; Kim & Kim, 2010), while some (e.g. Billieux et al., 2015b) have addressed problematic online gaming as a separate entity distinct from both problematic offline gaming and Internet addiction; referring to the research suggesting that online games may have a greater addictive potential that other game types (e.g. Porter, Starcevic, Berle, & Fenech, 2010; Lemmens & Hendriks, 2016).

Correspondent with different views on source of the behavior, there have been a lack of consensus on what specific components comprise problematic or addictive use of video games (Ferguson, Coulson, & Barnett, 2011; Griffiths, Király, Pontes, & Demetrovics, 2015). Some researchers have operationally defined problematic gaming based on the time spent playing games. For example, Messias, Castro, Saini, Usman, and Peeples (2011) defined "excessive gaming" as gaming more than five hours a day, and Huang (2006) defined "dependent video-gaming" as gaming more than ten hours a week. Although this approach may provide valuable insight regarding the potential beneficial or negative effects of video gaming in general, limiting the classification of problematic gaming to time spent gaming only may be unreliable as research have shown that much time spent gaming is not necessarily an indicator of problematic behavior and that the context is essential when using time spent as a criterion of problem gaming (Griffiths, 2005, 2010; Ferguson et al., 2011). Thus, most researchers have conceptualized problematic gaming by the harms it may cause to the individual.

Problematic gaming has largely been viewed as a behavioral addiction and classified based on the presence of addiction symptoms. One of the most influential conceptualizations of behavioral addictions is *the component model of addiction* proposed by (Griffiths, 2005). By adapting the framework outlined by Brown (1993), Griffiths (2005) operationally defines addictive behavior as any behavior that feature all of the six core components of addiction: *salience, mood modification, tolerance, withdrawal, conflict and relapse*. In terms of video game addiction: Salience refers to when gaming becomes the most important activity in life. This is characterized as preoccupation in the activity, where the individual's thoughts are dominated by thinking of previous and future gaming events. Mood modification is the subjective experience of pleasure as a result of video game engagement. This is often described as a "high" or a "buzz" or a feeling of "escape" from real life. Tolerance is the process where the individual must increase the amount of time spent gaming to achieve the same mood modifying effects as the gamer previously obtained by less time spent gaming. Withdrawal symptoms is described as unpleasant feeling states and/or physical effects when the individual is prevented from gaming. The withdrawal symptoms associated with behavioral addictions usually take form as psychological stress such as irritability, anxiety or sadness (Grant, Potenza, Weinstein, & Gorelick, 2010). Conflict is when the gaming causes conflicts either between the addict and people around them (i.e. interpersonal conflict) or within the individual (i.e. intrapsychic conflict). The conflict may arise because the individual continues to choose the short-term pleasure and relief of gaming over social obligations or in despite of experiencing adverse long-term negative effects. Escalation of conflict could fuel the addiction as they may use the activity as a coping strategy to avoid dealing with the conflicts. Lastly, relapse refers to the tendency to repeatedly fall back to earlier patterns of the activity after periods of abstinence or control (Griffiths, 2010a).

While the component model of addiction as a framework for identifying problematic/addicted gamers have been approached by many scholars (e.g. Lemmens, Valkenburg, & Peter, 2009; Gentile, 2009), concerns have been made that these proposed symptoms may overidentify pathology in non-problematic gamers (Wood, 2008). Specifically, it have been argued that the criteria of salience, mood modification, and tolerance may erroneously tap into engagement in video games rather than actual pathological behavior (Charlton & Danforth, 2007; Ferguson et al., 2011). Further, it has been argued that gaming is different from several other behaviors that may be addictive such as substance use and gambling as high video game engagement (i.e. heavy video game use) is not necessarily problematic in itself as it will not necessarily involve negative consequences/harm as opposed to for instance excessive alcohol use (Gentile, 2009). Conversely, while addiction usually involves a high frequency of use, it is possible to be addicted to video games without being highly engaged (Charlton & Danforth, 2007; Brunborg et al., 2013). Charlton (2002), and later Brunborg, Hanss, Mentzoni, and Pallesen (2015), have investigated with factor analyses whether the proposed addiction criteria by Brown (1993; Brown's terminology in brackets) and Griffiths (2005) (i.e. [cognitive/behavioral] salience, mood modification [euphoria], tolerance, withdrawal, conflict, and relapse [and reinstatement]) constitute a unitary and distinct set of criteria. Both studies concluded that a two-factor structure had better fit than a one-factor structure, with factor loadings suggesting that salience [cognitive salience], mood modification [euphoria], and tolerance shared underlying properties distinct from the items tapping conflict, withdrawal, relapse and problems [and behavioral salience]. As such, it was suggested that these two factors represent *peripheral* and *core criteria* of video game addiction, respectively (Charlton, 2002; Brunborg et al., 2015). The validity of two dimensions is strengthened by a meta-analysis which showed that studies investigating the core criteria of addiction report stronger correlations with negative outcomes compared to studies including both core and peripheral criteria in assessing problematic gaming (Ferguson et al., 2011). As such, it have been argued that core criteria of addiction (i.e. withdrawal, relapse, conflict, and problems) should either be used exclusively or that they should at least be given greater weight as they are more unambiguously indicative of gaming addiction (Charlton & Danforth, 2007).

In an alternative approach, some researchers have operationally defined problematic gaming referring to the interfering nature of the gaming behavior, rather than drawing direct parallels with the traditional addiction criteria. For example, Porter et al. (2010) have defined problematic gaming as excessive use of video games in a manner that result in preoccupation with, loss of control, and various negative psychosocial and/or physical consequences. However, they do not apply other traditional addiction criteria (i.e. tolerance and symptoms of withdrawal) as they do not recognize such phenomena to be associated with excessive video gaming.

Building upon a growth in empirical studies showing that some individuals display addiction-like behaviors towards gaming, *Internet Gaming Disorder* (IGD) was in 2013 included in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders as a tentative condition for further study (DSM-5; APA, 2013). IGD is characterized as "persistent and recurrent use of the internet to engage in games, often with other players, leading to clinically significant impairment or distress…" (APA, 2013, p. 795). To be diagnosed with IGD, the individual must endorse five or more of the following criteria over a 12-month period: (1) Preoccupation with internet games (i.e. the individual spends a significant amount of time thinking about previous or future gaming activities; internet gaming becomes the dominant activity of life). (2) Withdrawal symptoms when internet gaming is taken away (e.g. irritability, anxiety, or sadness) (3) Tolerance (i.e. a need to spend an increasing amount of time engaging in internet games). (4) Unsuccessful attempts to control the participation in internet games. (5) Loss of interest in previous hobbies and entertainment as a result of, and with the exception of, internet games. (6) Continued excessive use of internet games despite knowledge of psychosocial problems. (7) Has deceived family members, therapists, or others regarding the amount of internet gaming. (8) Use of internet games to escape or relieve a negative mood (e.g. feelings of helplessness, guilt, anxiety). (9) Has jeopardized or lost a significant relationship, job, or educational or career opportunity because of participation in internet games (APA, 2013, p. 795).

More recently, problematic gaming received formal recognition as a mental/behavioral disorder by the World Health Organization (WHO) with the inclusion of *Gaming Disorder* in the 11th edition of the International Classification of Diseases (ICD-11; World Health Organization, 2018). Gaming disorder (GD) is in the ICD-11 defined as "a pattern of gaming behavior ("digital-gaming" or "video-gaming"), that is characterized by impaired control over gaming, increasing priority given to gaming over other activities to the extent that gaming takes precedence over other interest and daily activities, and continuation or escalation of gaming despite the occurrence of negative consequences" (World Health Organization, 2018). To diagnose GD, the behavioral pattern must be in such severity that it results in impairments in personal, family, social, educational, occupational or other important areas of functioning over a 12-month period (World Health Organization, 2018).

Current terminology. Given the wide range of constructs, there have been several terms and definitions suggested to describe what seems to be the same or related phenomenon. This includes, but are not limited to "video game addiction", "pathological gaming", "video game dependency", "excessive gaming", "problematic gaming", "problematic online game use", "online gaming addiction", "internet game addiction", "internet gaming disorder" and "gaming disorder" (Griffiths et al., 2015; Pontes & Griffiths, 2014a). In an effort to consolidate the knowledge on the phenomenon the current study will use *problematic gaming* as an umbrella term for the wide range of related constructs. As such, problematic gaming is defined as a pattern of playing digital (video/computer) games that could negatively influence physical and mental health and/or interfere with daily activities. It entails both online and offline gaming behavior that is played via all types of digital gaming devices.

Measurement and classification of problematic gamers. In line with the diversity of conceptualizations there have been several different approaches to assess and to differentiate problematic from non-problematic gamers. Problematic gaming behavior has primarily been assessed using self-report questionnaires or parental report. Some studies have simply relied on single items asking whether the participants would consider themselves addicted to video games (e.g. King, Delfabbro, & Griffiths, 2012). Despite shortcomings of self-diagnostic methods, a study conducted by Widyanto, Griffiths, and Brunsden (2011) reported that a person's self-diagnosis of whether they were addicted to the Internet or not correlated highly with more standardized measures of Internet addiction. Thus, self-diagnosis could function as a good indicator of problematic gaming. However, the vast majority of studies have employed some form of self-report questionnaire consisting of a set of criteria based on the different conceptualizations.

In a review of sixty studies conducted between 2000 and 2012, King, Haagsma, Delfabbro, Gradisar, and Griffiths (2013b) identified 18 distinct instruments pre-dating the IGD and GD conceptualizations. The review highlights the inconsistencies in definition of the core addiction indicators, as well as the inconsistencies in the use of cutoff levels to separate normal from pathological involvement in games (King et al., 2013b). A central question is whether a monothetic or a polythetic diagnosis system better captures addiction. A monothetic approach entails that all of the criteria must be endorsed to be categorized as addicted. Conversely, a polythetic approach, as employed by the DSM-5, entail an endorsement of only a certain number of criteria such as least half of the criteria is needed for a positive diagnosis (Lemmens et al., 2009). Adopting different approaches have consequences for estimating the prevalence in research setting as well in performing correct diagnosis in clinical settings. The former was demonstrated by Charlton and Danforth (2007) who estimated prevalence rates ranging from 1.8 to 37.8 percent in the same sample by tweaking the criteria and cutoff levels based on these different conceptualizations. Consequently, some studies have categorized subgroups of problematic gamers based on the severity of symptoms (i.e. number of endorsed criteria), such as using a polythetic approach to indicate less severe "problem gaming" (or *at risk*) and a monothetic approach to identify those who were "addicted" (e.g. Lemmens et al., 2009; Mentzoni et al., 2011). Others have completely worked around the issue as they embrace a dimensional conceptualization, investigating problematic gaming on a continuum from "non-problematic" to "full blown addiction", using mean scores to indicate the severity of problematic gaming symptoms (e.g. Pontes & Griffiths, 2015; Stavropoulos et al., 2019).

Another issue is whether peripheral criteria (i.e. salience, mood modification, and tolerance) should be implemented in categorizing problematic gamers. Inclusion of the peripheral criteria can offer problems in both monothetic and polythetic diagnose systems as a monothetic approach might fail to include addictive gamers that display low engagement, and a polythetic approach it might overestimate the prevalence of problem gamers as it misdiagnose individuals that are highly engaged rather than addicted video games (Charlton & Danforth, 2007; Ferguson et al., 2011). Consequently, some studies have adapted a "core-criteria" approach, classifying problem gamers exclusively on the core addiction criteria (i.e. conflict, withdrawal, relapse and problems; e.g. Brunborg et al., 2013; Wittek et al., 2016).

Lastly, some authors have separated normal from disordered gamers using statistical procedures such as latent class analysis (LCA) (e.g. Van Rooij et al., 2011; Lin et al., 2019). LCA is a mixture of modeling technique that can be used to identify meaningful groups of people (i.e. classes) that are similar in their responses to the measured variables (Nylund, Asparouhov, & Muthén, 2007). Using this rather sophisticated diagnostic approach has the advantage that it does not rely on cutoff points. As such, it can identify problematic gamers and provide evidence of the existence of disordered gaming independent from any theoretical assumptions (Saunders et al., 2017). The field is yet to reach consensus on a "gold standard" in the measurement and classification of problematic gaming.

Prevalence and characteristics of problematic gamers. The prevalence rates of problematic gaming have varied greatly across studies ranging from 0.2 to 34 percent (Griffiths et al., 2015). The wide spread in estimates is are largely caused by differences in definitions, measuring tools, cutoff values, and the characteristics of the populations investigated (Griffiths et al., 2015). Using a meta-analytic approach, Ferguson et al. (2011) synthesized an average prevalence rate of problematic gaming from 17 independent estimates attained from 33 studies of adolescents and young adults between 2001-2011. The authors found that the average prevalence rate of problematic gaming to be 6 percent. However, when excluding engaged gamers that might have been misclassified as problematic gamers (i.e. only pooled the prevalence rates from studies with instruments especially focusing on interferences; e.g. Porter et al., 2010) the estimate dropped to 3.1 percent (Ferguson et al., 2011). Similarly, Fam (2018) estimated a pooled prevalence of 4.6 percent in a meta-analysis which included 61.737 participants derived from 16 studies between 1998-2015 with samples from four continents (Asia, Australia, Europe, North America); suggesting that problematic gaming is a global phenomenon. These meta-analyses, however, were limited to only include samples consisting of adolescents and young adults. In a representative sample of 816 Norwegians aged 15-40, Mentzoni et al. (2011) used a monothetic approach in defining video game addiction (i.e., endorsement of all seven items) and the less strict polythetic approach in defining problematic gamers (i.e. endorsement of four or more items). In this study, 0.6 percent of the sample met the criteria for gaming addiction while 4.1 percent of the sample where categorized as problematic users (Mentzoni et al., 2011). These results are comparable to a more recent national representative study of 10.081 Norwegians aged 16–74 years which reported that 0.33 percent of the sample were addicted to video games and 3 percent were problematic gamers (Wittek et al., 2016). Adapting the same diagnostic approach, a representative study of 4382 German gamers aged 14-40 found that 0.2 percent were addicted to video games whereas 3.7 percent could be classified as problematic gamers (Festl, Scharkow, & Quandt, 2013). The results from the national representative samples indicate that problematic gaming behavior is relatively rare on a societal level. Higher prevalence rates of problematic and addictive gaming behavior have, however, been found amongst studies with participants recruited through gaming communities and especially in studies specifically investigating Massively Multiplayer Online Role-Playing Games (MMORPGs). For example, Dauriat et al. (2011) found that amongst 696 MMORPG-players 36.8 percent of the sample could be categorized as problematic gamers and 11.2 percent were considered to display more severe addiction to MMORPG games. Correspondently, (Achab et al., 2011) found that 27.5 percent of 516 MMORPG-gamers recruited through gaming forums could be categorized as addicted. However, the latter high percentage may in part be explained by the researchers adapting a polythetic approach.

While the prevalence rates have varied greatly across studies, the empirical data have been more consistent regarding the characteristics of problem gamers. Especially is the finding that boys and men are experiencing more problems related to video gaming compared to girls and women consistent (Mihara & Higuchi, 2017; Wittek et al., 2016; Festl et al., 2013). Studies have also been rather consistent in reporting that problematic gaming is associated with younger age (Mihara & Higuchi, 2017; Mentzoni et al., 2011; Griffiths et al., 2015). Thus, it appears that adolescents and young adulthood is a risk factor in developing gaming related problems. This is consistent with the literature suggesting that emerging adulthood seems to be a critical period for the development of addictions and other mental disorders more generally (Stone, Becker, Huber, & Catalano, 2012; Kessler et al., 2005; Adams et al., 2019).

Associated negative outcomes of problematic gaming. Epistemological studies have found associations between problematic gaming and a variety of adverse psychological, physiological and functional outcomes. A great number of studies have reported associations between problematic gaming and higher levels of depression, anxiety, and loneliness (e.g. Starcevic, Berle, Porter, & Fenech, 2011; Gentile et al., 2011; Lehenbauer-Baum et al., 2015; Caplan, Williams, & Yee, 2009; Lemmens, Valkenburg, & Peter, 2011). Also, problematic gaming has been linked to symptoms of attention-deficit hyperactive disorder (ADHD; Andreassen et al., 2016; Weinstein & Weizman, 2012), psychoticism (Starcevic et al., 2011), obsessive-compulsive disorder (OCD; Starcevic et al., 2011; Andreassen et al., 2016; Kim et al., 2016b), general psychiatric stress (Király et al., 2015; Rikkers, Lawrence, Hafekost, & Zubrick, 2016), , somatization (i.e. psychological stress expressed through somatic symptoms; Starcevic et al., 2011; Kim et al., 2016b), and decreased levels of physical activity (Montag et al., 2011; Henchoz et al., 2016). Additionally, one study found that problematic and normal gamers differed in resting state plasma catecholamine levels, suggesting that problematic gamers were experiencing higher levels physiological stress compared to non-problematic gamers (Kim, Hughes, Park, Quinn, & Kong, 2016a).

Moreover, problematic gaming have been linked to psychosocial and functional problems such as lower levels of quality of life and life satisfaction (Montag et al., 2011; Mentzoni et al., 2011; Festl et al., 2013; Lemmens, Valkenburg, & Gentile, 2015; Lehenbauer-Baum et al., 2015), lowered psychosocial well-being and self-esteem (Lemmens et al., 2011; Festl et al., 2013; Lemmens et al., 2015; Van Rooij, Schoenmakers, van den Eijnden, Vermulst,

& van de Mheen, 2012), problems in interpersonal relationships (Kim, Namkoong, Ku, & Kim, 2008; Festl et al., 2013; Strittmatter et al., 2015), poorer academic achievement (Toker & Baturay, 2016; Brunborg, Mentzoni, & Frøyland, 2014), school phobia (Batthyány, Müller, Benker, & Wölfling, 2009) and low school well-being (Rehbein & Baier, 2013). Additionally, a recent study showed that elevated symptoms of Hikikomori; a relatively new condition described as an extreme form of social real-life withdrawal, where individuals isolate themselves from society; was associated with higher scores on a measure of internet gaming disorder (Stavropoulos et al., 2019).

A limitation of these investigations, however, is that the research has mostly adapted cross-sectional designs which makes it impossible to draw inferences on the causality between problem gaming and adverse outcomes. In the case of depression, it is possible that depression could cause problem gaming as gaming could be a coping strategy to deal with depression and to escape real-life stress. Visa versa, depression could be a result of problematic gaming due to the social- and health-related impairments problem gaming may involve. It could also be a reciprocal relationship, as depressed individuals may retreat into gaming where gaming could further fuel the depression, or the other way around. There have been some longitudinal studies which makes it possible to draw some inferences. In a two year longitudinal study of Singaporean youths, Gentile et al. (2011) found that depression, anxiety and social phobias scores increased after the youth become a problematic gamer, and decreased if the individual stopped being a problematic gamer. Similar results were found in two longitudinal studies who both identified depression as a consequence of problematic gaming after one (Van Rooij et al., 2011) and two years (Liau et al., 2015), respectively. Furthermore, Lemmens et al. (2011) found in a longitudinal study of Dutch adolescents that diminished social competence and lower self-esteem predicted an increase in pathological gaming behaviors. In addition, the authors found both a reciprocal, directional relationship between pathological gaming and loneliness, suggesting that loneliness was both a cause and consequence of problem gaming (Lemmens et al., 2011). Lastly, in a recent longitudinal study among a representative sample of Norwegian adolescents, depression and loneliness was found to be reciprocal associated with problematic gaming, while anxiety was found to be a consequence of addictive gaming (Krossbakken et al., 2018).

The controversies of problematic gaming. It should be noted that problematic gaming has been a concept of much controversy and debate. A central issue in is whether problematic gaming behavior could actually constitute a distinct mental disorder, rather than a consequence of another disorder, as the directionality between problematic gaming and associated negative consequences seems somewhat unclear or not sufficiently established at the present (Van Rooij et al., 2018). Given the consistently shown associations between gaming and depression and anxiety, as well as other comorbidities, some scholars have argued that problematic gaming should be considered as a coping mechanism of depression/anxiety or other underlying problems rather than an own clinical entity (Kardefelt-Winther, 2014, 2017). Others have questioned the stability of the construct, referring to findings from longitudinal studies showing that few of the classified problem gamers at the first time point remain in this category at the second time point (Scharkow, Festl, & Quandt, 2014; King et al., 2012; Bean, Nielsen, Van Rooij, & Ferguson, 2017). However, these findings stand in contrast to other longitudinal studies have which have reported that problem gaming status at baseline was a strong predictor of future problem gaming; suggesting stability in the construct (Gentile et al., 2011; Krossbakken et al., 2018). Also, the notion of disordered gaming is supported by neuroscientific studies which have found that when exposed to gaming relevant cues, gaming addicts (diagnosed by self-report) show similar neural processes as those observed with cue exposure among individuals with chemical addictions and other behavioral addictions such as pathological gambling; including a deficiency in the neuronal reward system (Kuss & Griffiths, 2012; Kuss, Pontes, & Griffiths, 2018). However, these findings could reflect problematic gaming as an expression of an underlying addiction syndrome which could have multiple possible expressive opportunities (cf. Shaffer et al., 2004). Following this model, the etiology as well as treatment should focus on the underlying addiction syndrome rather than paying attention at object of addiction (i.e. gaming), since the object of addiction could just as be engagement in any other rewarding objects or activities such as alcohol consumption, gambling or exercising, and more. Consequently, these neurological findings do not necessarily support that problematic gaming constitute a separate addiction, but they indicate that gaming may become an addiction for some individuals.

Other criticisms have been directed more specifically on the suggested IGD and GD conceptualizations. In particular, the current official conceptualizations have been criticized to be too heavily based on of traditional addiction symptoms and especially pathological gambling, and concerns have been stated that these symptoms might have been misapplied to problematic gaming. For instance, Carras and Kardefelt-Winther (2018) argued that the symptom of preoccupation may in the context of gaming reflect investment rather than pathological behavior – as spending quite some time thinking about past and planning future gaming events could be an unproblematic and positive way to optimize the gaming experience. This argument is in line with the empirical findings of Charlton (2002) and Brunborg et al.

(2015) which suggests that the inclusion of peripheral criteria might over-pathologize non-problematic gaming behavior. Accordingly, the current diagnostic conceptualizations have been criticized to be of too poor specificity, and concerns have been stated from an large group of researchers that the inclusion of GD in the formal diagnosis classifications system is premature and could lock the research into a confirmatory approach rather than exploring the boundaries of what comprises problematic and normal gaming behavior (Aarseth et al., 2017).

In summary, the range of different views on problematic gaming as displayed in this and previous sections reflects a topic of much debate and controversy. These debates have important practical implications extending further than theoretical considerations, as invalid or unreliable conceptualizations of problematic gaming could risk pathologizing healthy gamers and misidentify treatment goals from underlying disorders such as depression or anxiety (Bean et al., 2017). Yet, there are some areas that most researchers agree. A recent survey amongst scholars in the field of problematic gaming conducted by Ferguson and Colwell (2019) found that most of the researchers believed that some form of problematic gaming exists and that it can be classified as a mental illness. Also – with a slight preference of the ICD-11 criteria – the majority of researchers thought that the current DSM and ICD-11 criteria are valid and reliable, and that these official video game addiction diagnoses will likely result in better research. However, while the survey suggested that a majority supported the official IGD and GD conceptualizations, it also noted that a substantial amount of the researchers did not support these conceptualizations; reflecting that problematic gaming still remain a topic without a clear cut consensus which have been suggested by some scholars (e.g. Petry et al., 2014).

Sleep

It has been suggested that gaming – and especially problematic gaming – may disturb sleep (Peracchia & Curcio, 2018; Lam, 2014). Further, as the levels of gaming has increased the past years so has the prevalence rates of sleep problems (Pallesen, Sivertsen, Nordhus, & Bjorvatn, 2014). Understanding the key mechanisms of sleep is useful to get an understanding about how problem gaming and sleep may be connected.

What is sleep? Sleep can be defined as a reversible state of inactivity and perceptual disengagement from the environment; a phenomenon that can be observed in all known species (Lockley & Foster, 2012; Carskadon & Dement, 2017). We humans spend about a third of our lives sleeping. Yet, there is to date no consensus on the etiology of sleep. Several theories have been proposed based on the various roles sleep play in many physical and mental processes including metabolic functioning and energy restoration (Maquet, 1995; Berger & Phillips, 1995; Benington & Heller, 1995; Scharf, Naidoo, Zimmerman, & Pack, 2008), cellular maintenance (Vyazovskiy & Harris, 2013), immune system (Marshall & Born, 2002; Krueger & Opp, 2016), synaptic plasticity and memory processing (Abel, Havekes, Saletin, & Walker, 2013; Rasch & Born, 2013), and removal of metabolic waste products of neural activity in the brain (Xie et al., 2013). The diversity of the abovementioned theories testifies the complexity of sleep, and while none of these singular theories might capture the whole truth about sleep, they emphasize the importance of sleep for optimal functioning and general good health. Accordingly, lack of sleep has been found to have several detrimental effects both short term- and long-term. Sleep deprivation studies show that acute sleep shortage can negatively impact mood and higher cognitive functions such as memory, executive attention, and alertness; decreasing optimal functioning and increasing the risk for accidents (Banks, 2007; Uehli et al., 2014). Moreover, long-term sleep shortage may negatively affect our daytime functioning, subjective-wellbeing and quality of life, and is associated with serious health conditions such as, hypertension (Gangwisch et al., 2006), weight gain (Patel & Hu, 2008), diabetes and impaired glucose tolerance (Gottlieb et al., 2005), and increased vulnerability to alcohol and drug abuse (Carskadon, 1990) development of psychiatric disorders (Sateia, 2009), and increased mortality in general (Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002).

The average sleep duration in adults has been estimated to be around seven hours, however, the sufficient amount of sleep varies strongly between individuals and normally ranges between six and nine hours a day (Ursin, Bjorvatn, & Holsten, 2005). The literature attribute some of this variation to sex and age, as women generally sleep longer than men, as well as the fact that sleep duration and architecture changes throughout the lifespan (Carskadon & Dement, 2017; Lockley & Foster, 2012). Also, people differ in when they prefer to sleep and the timing of which it is easiest to sleep, referred to as chronotype. Morningness-types typically prefer to wake up and go to bed earlier than eveningness-types who preferer later waketimes and bedtimes (Horne & Östberg, 1977). These preferences are viewed to be endogenous (i.e. internally originated) controlled, and research have shown that the chronotype tend to change with age, displaying more eveningness in adolescence whereas morningness increases with age (Kerkhof & Van Dongen, 1996; Randler, Bilger, & Díaz-Morales, 2009; Paine, Gander, & Travier, 2006; Fabbian et al., 2016).

Sleep regulation. According to Borbely (1982)'s two process model, sleep is regulated by the interaction between a homeostatic factor (S) and a circadian factor (C). Process S refers to the need to sleep, or sleep pressure, which is accumulated during wakefulness and affects the likelihood of falling asleep. The sleep pressure increases with increasing time spent awake and decreases during sleep (Lockley & Foster, 2012). Individuals who are sleep deprived experience a greater homeostatic drive, typically resulting in shorter sleep latency, longer sleep length, and a greater amount of slow wave sleep in the following sleep episode (Exelmans & Van den Bulck, 2019; Grønli & Ursin, 2009).

Process C refers to circadian rhythm which is a cycle with a time frame of about a day (circa = about, dia = day). Circadian rhythms are found in several bodily processes and play an important role in the sleep-wake cycle (Lockley & Foster, 2012). The circadian rhythm is regulated by both intrinsic and extrinsic factors which is synchronized by a brain structure located at the tip of the hypothalamus called the suprachiasmatic nucleus (SCN). The SCN – which is often referred to as our "biological clock" – produce an endogenous close-to-24-hour rhythm which synchronize a chain of bodily functions, such as metabolic functioning, body temperature, and the secretion of hormones (Lockley & Foster, 2012). However, as the endogenous circadian rhythm is usually not precisely 24 hours, the biological clock is dependent on external ques termed zeitgebers (time givers) in order to synchronize the internal biological clock with the external world; a process called entrainment. The most important zeitgeber is the natural dark-light cycle, as the SCN receives a direct projection of light from the eyes through the retinohypothalamic tract (Dijk & Lockley, 2002; Lockley & Foster, 2012). SCN is also stimulated by light trough a subgroup of ganglion cells in the retina which provide a functional link between the eyes and the brain (Berson, Dunn, & Takao, 2002; Hattar, Liao, Takao, Berson, & Yau, 2002). These photosensitive retinal ganglion cells (pRGCs) contain a light-sensing pigment called melanopsin which is particularly sensitive to the exposure of short-wavelength blue light (Dijk & Archer, 2009). The signals received by the SCN are relayed to various regions of the brain, including the pineal gland which secretes the hormone melatonin. When stimulated by light, the SCN sends inhibitory signals to the pineal gland which suppress the secretion of melatonin. When the light dims, the pineal gland secretes increasing amounts of melatonin into the blood stream. As such, the presence of melatonin in the blood stream functions as a chemical representation of darkness (or night) in the external world, while absence of melatonin indicates daytime. Correspondently, sleep usually takes place while the plasma melatonin levels are high, while low plasma melatonin levels are associated with wakefulness (Bjorvatn & Pallesen, 2009). Normally, the onset of melatonin secretion is initiated approximately two hours before the individual's habitual bedtime and peeks around the middle of the sleep period before it gradually declines towards awakening (usually in the morning) (Pandi-Perumal, Zisapel, Srinivasan, & Cardinali, 2005). Thus, one's circadian phase (i.e. timing of the circadian rhythm) can be objectively estimated by measuring levels of melatonin attained from blood plasma, saliva or urine (Bjorvatn & Pallesen, 2009). The circadian rhythm can also be registered by following the core body temperature. Normally, the core temperature reaches its highest point, termed *acrophase*, in the later afternoon normally around 4-5 pm and declines during the night before it reaches its lowest point, termed *nadir*, usually around 4-5 am (Grønli & Ursin, 2009). Sleep normally occurs when the core body temperature rhythm is declining and ends approximately two hours after nadir. Thus, nadir can be used as a reference point when assessing one's circadian rhythm (Bjorvatn & Pallesen, 2009; Grønli & Ursin, 2009). Moreover, acrophase and nadir are closely related to the entrainment process. Accordingly, exposure to lights after acrophase (and before nadir) may delay the sleep phase, whereas light exposure after nadir (and before acrophase) may advance the sleep phase.

The interplay between process S and process C affects the timing, duration and structure of sleep. The two processes work in opposition in order to maintain wakefulness during the day and to promote a consolidated period of sleep during night (Lockley & Foster, 2012). During wake, the homeostatic drive rises but sleep is suppressed by the circadian drive until the appropriate time of day (Bjorvatn & Pallesen, 2009). Visa versa, the circadian drive for sleep – which increases throughout the night – is opposed by the reduction of sleep pressure during sleep (Lockley & Foster, 2012). A third factor of sleep regulation is behavior. Sleep promoting habits (i.e. sleep hygiene) such as regular bedtimes and restricting sources of arousal before bedtime is important in order to promote efficient sleep. Moreover, our behavior may override both the homeostatic and circadian factors as we may engage in behaviors that causes alertness such as consuming stimulants or engaging in arousing activities. It is our ability to override process C and S that makes us able attend to a late-night party or work a nightshift although the homeostatic and circadian factors favor sleep in during night-time (Bjorvatn & Pallesen, 2009).

Sleep problems. Suboptimal habits and behaviors, physiological disturbances of the C or S processes and/or having C or S processes that do not match the external environment could result in sleep problems of varying severity. Sleep problems are among the most common health concerns with several studies from western countries suggests that about one of three adults experience sleep problems weekly (Singleton, Bumpstead, O'Brien, Lee, & Meltzer, 2003; Ohayon, 2002). The problems can be oriented around struggling to fall asleep, failing to stay asleep, or experiencing sleep of too poor quality. For some, the sleep interference is transient – such as experiencing trouble falling asleep after a traumatic experience – while others experience chronic life-long sleep interferences. Some problems may be brought by the individual's own behavior suppressing the homeostatic and circadian factors, such as poor sleep hygiene (e.g. late-time caffeine consumption or exposure to artificial bright light) or working at night, while other individuals experience inferences to these factors due to an underlying illness. Regardless of the nature and cause, sleep problems may affect the quality of life and long-term sleep problems may cause serious detrimental effects on the individual's health. Moreover, sleep problems are costly on a societal level due to the associated burden on health-care services, increased risk of accidents, sleep-related work absences, and reduced productivity (Daley, Morin, LeBlanc, Grégoire, & Savard, 2009; Uehli et al., 2014).

For some individuals the experienced sleep problems are of such severity and persistence that it classifies as a disorder. The most common sleep disorder is *insomnia*. Insomnia is characterized by impairments in daytime function as result of too little sleep or poor sleep quality. Insomnia can be both acute and chronic and may relate to difficulties falling asleep at bedtime (i.e. sleep onset insomnia), experiencing nocturnal awakenings (i.e. sleep-maintenance insomnia), waking up to early and not being able to get back to sleep (i.e. early-morning insomnia) (Wilson & Nutt, 2013; Morin & Benca, 2012). According to both the International Classification of Sleep Disorders (ICSD-3; American Academy of Sleep Medicine, 2014) and the DSM-5, to be diagnosed with clinical insomnia disorder the individual must experience sleep disturbances at least three times a week for at least three months and experience daytime impairments as a function of the sleep disturbances (APA, 2013; American Academy of Sleep Medicine, 2014). Due to the lack of sufficient sleep, insomniacs typically experience negative consequences such as fatigue, impaired cognitive and social functioning, mood alterations, and physical discomfort (Wilson & Nutt, 2013). Insomnia may present as an independent condition (often referred to as primary insomnia) or could be a symptom of another underlying illness. Accordingly, insomnia has been found to correlate with hypertension, neurologic disease, breathing problems, urinary problems, and gastrointestinal problems, chronic painful physical conditions, and drug abuse; all conditions that have been shown to interfere with sleep (Taylor et al., 2007; Sivertsen, Krokstad, Øverland, & Mykletun, 2009; Ohayon, 2005). Moreover, insomnia have consistently been shown to be strongly associated with psychiatric disorders such as depression and anxiety. In a meta-analysis by Baglioni et al. (2011) it was found that insomnia predicted depression, with an overall effect size suggesting that non-depressed people with insomnia have a twofold risk of developing depression. Other studies have shown sleep problems to be reciprocal associated with depression, indicating that depression may also predict sleep problems (Sivertsen et al., 2012). Epistemological studies have shown the prevalence of insomnia to wary greatly, which is most likely due to different definitions and methodological inconsistencies (Lichstein, Taylor, McCrae, & Petrov, 2017). In a review, Ohayon (2002) found that the prevalence rates varied from 30-48 percent in studies that based the estimation on difficulty initiating, maintaining or non-restorative sleep, making no regard to the duration of difficulties or experienced consequences. In contrast, prevalence rates on studies adapting the more rigid DSM or ICSD criteria yielded prevalence rates between 4.4 to 6.4 percent in the general public (Ohayon, 2002). A more consistent finding is that insomnia complaints are associated with increasing age and are up to twice as prevalent in females compared to males (Ohayon, 2002; Johnson, Roth, Schultz, & Breslau, 2006).

Another frequent sleep disorder is delayed sleep phase disorder (DSPD). DSPD is characterized as a "…delay by the phase of the major sleep period in relation to the desired sleep time and wake-up time…" (American Academy of Sleep Medicine, 2014, p. 191). The DSPD is classified as a circadian rhythm sleep disorder, which are thought of as disturbances of the sleep-wake cycle caused by changes in the endogenous circadian regulating system or a misalignment between the endogenous circadian rhythm and the external 24-hour environment (Bjorvatn & Pallesen, 2009; World Health Organization, 2018). In individuals with DSPD, the sleep is stable and of normal duration and quality when sleep is allowed to occur on the delayed schedule. However, they typically experience sleep shortage because they fail to fall asleep at the desired or required time needed to acquire sufficient amounts of sleep before attending obligations such as early school or work times the following day; resulting in insomnia-like symptoms such as the subjective feeling of excessive daytime sleepiness. DSPD can over time cause significant mental, physical and functional impairments (Sivertsen, Harvey, Pallesen, & Hysing, 2015; American Academy of Sleep Medicine, 2014). DSPD is thought to be influenced by both genetic and environmental factors, where bad sleep promoting habits such as exposure to artificial light after acrophase and a lack of light in the morning (after nadir) may intensify the delayed sleep schedule. The prevalence of DSPD has been estimated to be 0.1-0.2 percent in the general population, but is most often occurs in adolescence with a prevalence of 7-16 percent (Monderer, Harris, & Thorpy, 2014; Wilson & Nutt, 2013).

Measuring sleep and sleep problems. Sleep and sleep problems can be measured both objectively and subjectively. The "gold standard" of sleep assessment is considered to be the *polysomnography* (PSG). The PSG provides objective measurements of multiple parameters, including the electrical activity in the brain using an EEG, eye movements recorded by electrooculogram (EOG), and muscle tonus captured by an electromyogram (EMG) (Carskadon & Dement, 2017). In clinical settings it is usually extended by adding other physiological parameters such as heart and respiration rate. The EEG, EOG and EMG records can be used to investigate several sleep parameters, including total sleep time, sleep efficacy, sleep latency, sleep events (e.g. apnea or limb movements), and the sleep architecture (i.e. the distribution of sleep stages NREM 1-3 and REM). As such, the PSG allows for the most detailed and comprehensive data collection on sleep (Stone & Ancoli-Israel, 2017). Another objective sleep measurement tool is the *actigraphy*. The actigraphy is a wrist- or leg worn device that records the user's limb movements. Given the fact that little bodily movements occur during sleep, the actigraphy-data can indicate total sleep length and the timing of sleep and wakefulness (hence circadian rhythm) (Stone & Ancoli-Israel, 2017). The PSG and actigraphy has both its advantages and disadvantages. The PSG provides with the most accurate and reliable data, and is by such necessary for assessing certain sleep disorders (Exelmans & Van den Bulck, 2019). However, the recording process may interfere with the subjects sleep as the equipment may be rather uncomfortable to wear, as well as the fact that the PSG-recordings most often takes place in an artificial setting such as a sleep laboratory (Lockley, Skene, & Arendt, 1999). Consequently, using PSG-data in research settings may compromise the external validity of the study (Exelmans & Van den Bulck, 2019). Also, both the equipment and scoring process are rather expensive and time-consuming, which may limit the number of study subjects one could afford to include (Stone & Ancoli-Israel, 2017). In contrast, the actigraphy is less expensive, less invasive, and more effortless to use. Thus, it can be administered to a greater pool of subjects and allow for assessment in a more natural sleep environment. Moreover, it opens up the possibility for longitudinal research designs as the participants can casually wear the actigraphy for longer periods of time. A limitation of the actigraphy, however, is that it only indirectly measures sleep and the indication of sleep onset latency is particularly unprecise with actigraphy. Yet, comparisons between actigraphy and PSG show that actigraphy in general yields acceptable levels of accuracy, especially when complemented by a self-reported sleep log (Marino et al., 2013; Kosmadopoulos, Sargent, Darwent, Zhou, & Roach, 2014; Landry, Best, & Liu-Ambrose, 2015)

Subjective sleep assessments record data on the subject's self-perceived sleep, which can be collected by sleep diaries, self-reported questionnaires, or interviews. Sleep diaries, or sleep logs, provides a detailed recording of a subject's sleep experience over a period of time. It usually collects information about time of wake and sleep initiation, sleep onset latency, number and duration of nightly awakenings, subjective sleep quality, naps during the day, and the use of medications or substances to promote sleep (Monk et al., 1994; Carney et al., 2012). In contrast, self-reported sleep questionnaires are typically administered at a single point in time, recording various aspects of the subject's sleep experience, including symptoms of sleep disorders, retrospectively in a given time frame (Libman, Fichten, Bailes, & Amsel, 2000). Lastly, sleep interviews are mostly used in clinical contexts and are typically structured, paying attention to sleep history, sleep problems, specific symptoms, impairments, sleep habits, general health, and more (e.g. the Duke Structured Interview for Sleep Disorders; Edinger et al., 2004). Subjective sleep assessment too has both its up- and downsides. Firstly, subjective assessments provides valuable insight on the subsect's own experience of sleep, which may not necessarily correspondent to objective measurements (Perlis, Giles, Mendelson, Bootzin, & Wyatt, 1997). Also, research have suggested that sleep diary data is superior to actigraphy in predicting fatigue (Short, Gradisar, Lack, Wright, & Carskadon, 2012). Moreover, self-report questionnaire assessments are low cost and easily distributed, which makes them convenient to implement in large scale surveys. The downside of subjective measurements is that they are vulnerable to for inaccurate reporting and recall bias, which making the data less reliable than objective measurements (Exelmans & Van den Bulck, 2019). Yet, studies have shown high levels of correspondence between subjective and objective assessments, suggesting that self-reports provide a valid method to assess both normal and abnormal sleep (Signal, Gale, & Gander, 2005; Lockley et al., 1999).

Problematic gaming and sleep. Several researchers have proposed that exposure to video games may cause sleep problems (Peracchia & Curcio, 2018). There are number of possible mechanisms by which both normal and problematic gaming behavior may influence sleep. Firstly, as proposed by the media displacement hypothesis (Van den Bulck, 2000; Cain & Gradisar, 2010; Exelmans & Van den Bulck, 2017a), gaming could displace sleep directly as the individual choose to engage in games over sleep, or indirectly by disregarding behaviors that are essential for good sleep hygiene (e.g. physical activity). Consequently, the gaming behavior could result in delayed sleep onset and indirectly to difficulties falling or staying asleep. For problematic gamers the displacement may not be by choice but rather driven by an inability to stop playing. Furthermore, problematic gamers typically experience high levels of flow (i.e. a state of intense enjoyment of immersion in the game) which may distort the individual's sense of time and lead to unintended prolonged gaming delaying bed-time (Chou & Ting, 2003; Csikszentmihalyi, 2013; Hull, Williams, & Griffiths, 2013). In addition, research have shown that problematic gamers often have a preference for games with online social content (Billieux, Deleuze, Griffiths, & Kuss, 2015a). In these games, such as World of Warcraft, players can (and are often expected to) collaborate with other players in order to reach higher and more complex goals. Consequently, some gamers might have to stay up late in order to play simultaneously with gamers in other time zones, thus delaying their sleep schedule and possibly sleep duration due to social obligations forcing them to get up early the following day.

Furthermore, playing the video game content can be arousing which may interfere with sleep. Consequently, gaming during the evenings and/or close to bedtimes may cause excessive arousal which in turn could make it difficult to fall asleep or impair sleep quality (Exelmans & Van den Bulck, 2019). One other possible arousing aspects of gaming relates to the artificial blue-spectrum light emitted by the screens projecting the visual gaming content, as light exposure may directly enhance alertness (Lockley & Foster, 2012). Moreover, the bright (blue) light from the gaming devices could disturb the circadian rhythm. As previously presented, the onset of nighttime melatonin secretion is usually initiated approximately two hours before the individual's habitual bedtime. However, the bright (blue) light emitted from the screens emulate the SCN's primary circadian signal of daytime, thus suppressing melatonin secretion. Consequently, using gaming devices with bright screens during the late afternoon or night (after acrophase) may delay the sleep phase. Lastly, sleep may also be interfered by electromagnetic fields that are emitted by wireless gaming devices such as laptop computers and mobile phones – as research have shown that such exposure can alter the total sleep time, sleep efficiency, sleep architecture, as well as inhibit the secretion of melatonin (Loughran et al., 2005; Lowden et al., 2011; Karasek, Woldanska-Okonska, Czernicki, Zylinska, & Swietoslawski, 1998).

Several studies support the notion that gaming may disturb sleep. An experimental PSG-study of 12-14 year old males, found that a singular exposure to 60 minutes of computer gaming in the afternoon yielded prolonged sleep onset latency and reduced amounts of SWS in the subsequent sleep episode compared to the control condition (i.e. no media exposure) (Dworak, Schierl, Bruns, & Strüder, 2007). This was distinct from when the same group were exposed to television for the same amount of time at another timepoint; a finding which might reflect that video games may induce higher levels of arousal compared to other type of media, possibly due to its inherent interactive features. Video games' arousing capabilities has been well demonstrated in experimental settings showing that gaming can cause higher heart rate (Wang & Perry, 2006), and increased blood pressure (Markovitz, Raczynski, Wallace, Chettur, & Chesney, 1998) and cortisol levels (Hébert, Béland, Dionne-Fournelle, Crête, & Lupien, 2005).

Another PSG-study found that adults playing exciting games with a bright display at night (between 11 pm and 1.45 am) displayed increased heart rate, lower levels of subjective and objective sleepiness, prolonged sleep latency, and shorter amounts of REM-sleep compared to the control conditions (Higuchi, Motohashi, Liu, & Maeda, 2005). Similar findings were found in a study by (King et al., 2013a) who assessed the impact of “prolonged” (i.e. 150 min) versus “normal” (i.e. 50 min) gaming engagement directly before bedtime. The results showed that prolonged gaming, as compared to normal gaming, led to a 27-minute decrease in total sleep time, increased sleep onset latency (3.5 min), and a reduced sleep efficiency to under the clinical threshold of <85% used to indicate sleep disruption (cf. Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Finally, the alerting effects of exposure to screen-emitted blue light have been consistently shown in several studies. For instance, Chang, Aeschbach, Duffy, and Czeisler (2015) found that participants reading a e-book from an tablet in the hours before bedtime, reduced evening sleepiness, reduces melatonin secretion, had longer sleep onset latency, delayed circadian phase, and reduced next-morning alertness compared to when they read from a printed book.

Taken together, problematic gaming behavior may lead to shorter sleep duration, poorer sleep quality, delayed sleep phase, and problems initiating or maintaining sleep compared to individuals not displaying such behavior. However, the direction of the relationship could also be reverse. It is possible that insomniacs and others experiencing sleep difficulties may use gaming to cope with their sleeplessness and as such develop problematic gaming patterns. Also, there could be a mutual (reciprocal) relationship, meaning that problematic gaming could cause sleep problems which in turn could further fuel further maladaptive gaming, and the other way around. Moreover, the relationship might be mediated through the consequences of problematic gaming such as musculoskeletal pain or somatization, or emotional distress caused by negative psychosocial outcomes such as academical failure; making it hard to fall or to maintain asleep (Männikkö, Ruotsalainen, Miettunen, Pontes, & Kääriäinen, 2017). Alternatively, it is possible that both problematic gaming and the experienced sleep problems are caused by common third variables. For example, both problematic gaming and insomnia have been shown to be strongly associated with depression (Baglioni et al., 2011; Männikkö et al., 2017). Thus, depression could be the underlying cause for both conditions. The relationship between problematic gaming and sleep problems might also be explained by personality factors. Research have consistently shown that individuals displaying higher levels neuroticism (i.e. the tendency of being nervous and anxiety prone) may be more vulnerable of developing problematic gaming behavior, experience insomnia symptoms, as well more at risk for developing depression (Kuss

& Griffiths, 2012; Gervasi et al., 2017; Şalvarlı & Griffiths, 2019; Van de Laar, Verbeek, Pevernagie, Aldenkamp, & Overeem, 2010; Harvey, Gehrman, & Espie, 2014). Lastly, age might also play a role. Adolescence and young adulthood have been shown to be closely associated with both problematic gaming and delayed sleep phase (Mentzoni et al., 2011; Monderer et al., 2014; Wilson & Nutt, 2013). As adolescents typically experience a natural biological delay in the sleep phase, the delayed sleep phase might, hypothetically, promote untimely gaming engagement due to the individual's inability to sleep during the desired or required bedtime; resulting in engagement in video games as a means to pass time which could further delay the sleep schedule and result in sleep shortage.

Study Objectives

An increasing amount of evidence have shown associations between problem gaming and several adverse psychological, physiological and functional outcomes; including an association with sleep problems (Lam, 2014). Despite well-established associations between psychiatric disorders and sleep interference, there has only been a few attempts of investigating the sleep characteristics of problematic gamers. Moreover, there is to date no available meta-analysis quantifying the strength of the relationship between problematic gaming and sleep problems across studies. Given a growth in empirical evidence on the topic, and the ongoing debate regarding the directionality between problematic gaming and associated harms, there is a need for an updated consolidation of the current knowledge on health outcomes associated with problematic gaming. Against this backdrop, the current study aims to review the existing literature on sleep characteristics in problematic gamers, and to provide a quantitative meta-analysis of the strength of the association between problematic gaming and sleep problems.

Methods

Search Strategy and Inclusion Criteria

A systematic literature review and meta-analysis were conducted in correspondence with the PRISMA guidelines (Moher, Liberati, Tetzlaff, Altman, & The, 2009; see appendix A). The meta-analysis was pre-registered at the PROSPERO International prospective register of systematic reviews (https://www.crd.york.ac.uk/PROSPERO/; record ID CRD42020158955). The primary search was conducted in January 2020 using relevant keywords in four of the largest databases for medicine, health, and psychology; Medline,

Table 1.

Search items

Keywords/terms Problematic gaming	**Operand**	**Keywords/terms** Sleep
OR "Problem* gaming" "Gaming addiction" "Game addiction" "Gaming disorder*" "Internet gaming" "Internet game" "Online gaming" "Online game*" "Video gaming" "Video game*" "Computer gaming" "Computer game*" "Excessive computer use" "Risk* gaming" "Pathological gaming" "Pathological internet"	AND	OR Sleep* Insomnia Circadian "Morningness-eveningness" "Delayed sleep" "Social jet-lag" "Wake after sleep onset" Snoring Hypersomnia

Embase, Web of Science, and PsycINFO. Search words are displayed in table 1. An additional search was conducted in Google Scholar. Lastly, the reference lists in relevant studies were examined searching for possible relevant material that was not detected by database search engines. The search strategy yielded a total of 1078 results with the following result in each database: Web of Science (471 results), Medline (326 results), Embase (93 results), and PsychINFO (188 results). Due to a large number of results provided by Google Scholar (more than 18,800 hits), only the first 30 pages of results were reviewed; identifying four additional manuscripts.

For inclusion in the present review and meta-analysis the studies had to fulfill the following eligibility criteria: (1) The full manuscript was available in a European language (e.g. English, Scandinavian, German, Spanish, French etc.). (2) The manuscript addressed problematic gaming specifically. (3) The manuscript contained empirical original quantitative data on the relationship between problematic gaming and least one sleep parameter, and (4) the manuscript reported estimates of, or sufficient data to calculate an effect size, the strength of this potential relationship. No further restrictions in terms publication time or design were implemented. In instances where studies reported insufficient data, the corresponding authors were contacted in an effort to acquire them. Studies not reporting data on gaming but rather on problematic screen or internet behaviors were excluded.

Data Extraction and Coding Procedures

The data was extracted and coded using a coding schema made for the purpose of the present review before compiling the data into a database. The coding scheme was designed to extract information about the study's characteristics, study setting, sample, methodology, and results (see appendix B). The effect sizes were either extracted directly from the original publications or calculated using the data of the respective publications when available. The extraction procedure was conducted by JHK and EKE who coded the studies independently and blinded to the process of each other. Potential discrepancies between the two reviewers were resolved by a discussion between them. If the two reviewers did not reach consensus, a third reviewer (SP) was to be consulted.

In studies categorizing subgroups of problematic involvement in games based on the severity of symptoms (e.g. a polythetic approach to indicate less severe "problematic gamer" and a monothetic approach to identify those who were "addicted"), the effect sizes of all/both groups were collapsed by calculating the mean effect size using a fixed effect-model. In order to not count the control/contrast group twice in these cases, only the mean effect size was included in the final meta-analysis and the correct sample size of the control/contrast group was then entered, and by such not underestimating the standard error and consequently the corresponding confidence interval (Giang et al., 2019; Borenstein, Hedges, Higgins, & Rothstein, 2011). One study (Wenzel, Bakken, Johansson, Gotestam, & Oren, 2009) assessed excessive gaming referring to hours spent playing per day and categorized the individuals into four distinct groups (i.e. "<1h", "≥1-2h", "≥ 2-4h", and "≥ 4h a day"). In this case, groups separating excessive and non-excessive players were created using the study's original cutoff value (i.e. more than 4 hours a day). Lastly, one study (Ko, Lin, Lin, & Yen, 2019) assessed problematic gaming using both the DSM-5 IGD and ICD GD criteria. In this instance, only the data based on the IGD criteria were included in the current review and meta-analysis, as these data were deemed to be more comparable with the other studies included in the review.

Quality assessment

Two reviewers (JHK and EKE) independently assessed the quality of the included studies using the Newcastle-Ottawa Quality Assessment Scale (NOS) adapted for cross-sectional studies (Wells et al., 2014; Modesti et al., 2016; Appendix C). The NOS works as a "star rewarding system" which assesses a study's quality in three broad categories; 1) the sample selection process; 2) comparability between groups; and 3) the ascertainment of the results. To determine the level of inter-reviewer reliability in the quality assessment procedure, Cohen's Kappa statistic was conducted using SPSS for Mac, Version 25 (IBM Corp., Armonk, NY). The Kappa was found to be .759 ($p < .001$), indicating substantial agreement between the two reviewers. In the cases of disagreement between reviewers consensus was sought through discussions.

Meta-analyses

Meta-analyses were conducted to calculate overall effect sizes for each sleep parameter separately. Based on previous reviews of the literature we expected a considerable variance in both terminology and the instruments used to measure problematic gaming as well as sleep parameters, as well as divergence in terms of study populations. As such, the meta-analyses were a priori planned to use random-effects models for any sleep parameter that yielded five or more effect sizes. If less than five specific studies could be identified for a given sleep parameter, the parameter was not included for meta-analysis as the results were judged to be too unstable and since random-effects models in such cases could yield an inappropriate estimation of tau (the between study variance). In contrast to the fixed-effect model – which assumes that all studies share a common true effect and where differences in estimates are solely assumed to be caused by within-study measurement error (sampling error) – the random-effects model assumes the true effect sizes to vary between studies, in addition to taking within-study measurement error into account. The studies included in the analysis were clearly deemed to represent a random sample of effect sizes from a theoretically unlimited number of studies. Thus, the computed overall effect size is an extrapolation of the mean of a distribution of effect sizes (Borenstein et al., 2011). In an effort to quantify between-study variance, tests of heterogeneity were calculated using the Q and I^2-statistics. The Q-statistic is a measure of the total observed study-to-study variation, and a significant Q ($p. < .05$) indicates presence of heterogeneity between the studies. The I^2-statistic is a measure of percentage which quantify the total amount of variability in a set of effect sizes that is a result of true differences between the studies rather than chance. The I^2 percentages of 25, 50, and 75 can roughly be interpreted as low, medium, and high levels of true heterogeneity, respectively (Higgins, Thompson, Deeks, & Altman, 2003). The extrapolated overall effect sizes are reported with Hedges' g for continuous means and odds ratio (OR) for binary outcomes. The Hedges' g is an estimation of the standardized mean difference between groups, which have the advantage over Cohen's d

that it corrects for bias that is caused by small sample sizes. Hedges' g are interpreted using Cohen's (1988) convention of small (0.2), medium (0.5), and large (0.8) effects.

If presence of heterogeneity, subgroup meta-analyses were conducted in an effort to explain the between-study variance. The impact of participant age was explored by creating a dichotomous moderator variable that separated studies that specifically targeted adolescent populations and studies that targeted adults or no specific age groups. The weighted mean age was 15.14 and 25.31 for the two subgroups, respectively. In addition, a second dichotomous moderator variable separating studies that investigated sleep with a multiple-item questionnaire and studies using a single item assessment was created in order to assess the impact this methodical discrepancy on the overall effect size. The subgroup analyses were based on mixed-effects models, using a random effects model within subgroups (pooling within-group estimates of tau-squared) and a fixed-effect model across subgroups (Borenstein et al., 2011).

Publication bias was assessed for each sleep parameter by visual inspection of funnel plots and statistically by Orwin's fail-safe N (Orwin, 1983) and Duval and Tweedie's trim and fill procedure (Duval & Tweedie, 2000a, 2000b). The funnel plot provides a visual representation of the study size (standard error) on the vertical axis as a function of effect sizes which are placed on the horizontal axis. Larger studies – which provide more precise estimates – will appear towards the top of the graph and tend to cluster near the overall effect size. Smaller studies tend to appear toward the bottom of the graph, and because such studies contain more sampling variation in terms of effect sizes, smaller studies will be dispersed more widely across the horizontal axis. In absence of publication bias, the studies should be symmetrically distributed around the overall effect size in a shape that resembles a funnel. In the presence of bias, the bottom of the plot would have higher concentration of studies on one side of the overall effect than the other. This would suggest that smaller studies are more likely to be published if they have larger than average effects, thus indicating publication bias (Borenstein et al., 2011). The Orwin's fail-safe N is an estimate on how many missing studies with a specified effect is needed to bring the overall effect statistically to a pre-set level. If the *N* is low, there is concern that the whole overall effect is an artifact of publication bias as it is likely that some studies are missing due to publication bias. Orwin's fail-safe *N* have the advantage over Rosenthal's fail-safe *N* (Rosenthal, 1979) in that it focuses on substantive rather than statistical significance by allowing the researcher to set a value that would represent the smallest effect deemed to be of substantive importance (i.e. a criterion that would deemed the overall effect to be "trivial"), as well as the possibility to set the mean of the missing studies other than zero (Borenstein et al., 2011). In the current study, $g = 0.2$ and $OR = 1.2$ was set as criterion for "trivial" effects, and *g*

= 0.0 and *OR* = 1.0 was set as the mean of the missing studies. Lastly, Duval and Tweedie's trim and fill procedure was used to assess the magnitude of bias on the overall effect. It complements the funnel plot by imputing the theoretically missing studies and adjust the overall effect size to the best estimate of an unbiased effect size. All statistical analyses were conducted using Comprehensive Meta Analysis, version 3.3.070 (Biostat, Inc., 2014).

Results

After removing duplicates (n = 448), the remaining (n = 630) titles and abstracts were independently screened by two reviewers (JHK and a research assistant), resulting in 65 studies for full-text eligibility evaluation (see flow diagram Figure 1). From this evaluation, forty-four records were excluded as (n = 29) did not target problematic gaming specifically, (n = 13) did not contain sleep parameter data, (n = 1) manuscript was a conference abstract that did not contain sufficient data, and (n = 1) manuscript was not accessible. As a result, a total of 21 studies met the eligibility criteria and were included in the review. From this pool it was found a total of 37 estimates (or results) on the relationship between problematic gaming and ten different sleep parameters. Eight studies reported sleep duration, five reported sleep quality, one reported sleep loss, ten reported sleep problems, one reported morningness-eveningness, four reported daytime sleepiness, one reported delayed sleep phase disorder, and four studies reported other sleep related outcomes.

Descriptive Characteristics of the Included Studies

A table of study characteristics and associations can be found in appendix D. Of all the 21 studies who met the eligibility criteria, 20 manuscripts were peer-reviewed research papers while one manuscript comprised an unpublished master-thesis (Arnesen, 2010). Regarding the study designs, one study used a longitudinal design (Turel, Romashkin, & Morrison, 2016), while the vast majority of studies (*n* = 19) were cross-sectional. Additionally, one study was a cohort study (Lin et al., 2019), but the sleep data was only collected at the first wave – making the data included in the present meta-analysis cross-sectional. The studies were published in the time frame of 2009-2019. The included studies yielded a summarized pool of 42,717 participants, with sample sizes ranging from 60-15,168 participants. One study population came from Australia (King, Delfabbro, Zwaans, & Kaptsis, 2014; 1287 participants), three from Asia (Kim et al., 2016a; Ko et al., 2019; Satghare et al., 2016; 1522 participants), two from North America (Stockdale & Coyne, 2018; Turel et al., 2016; 299 participants), four from

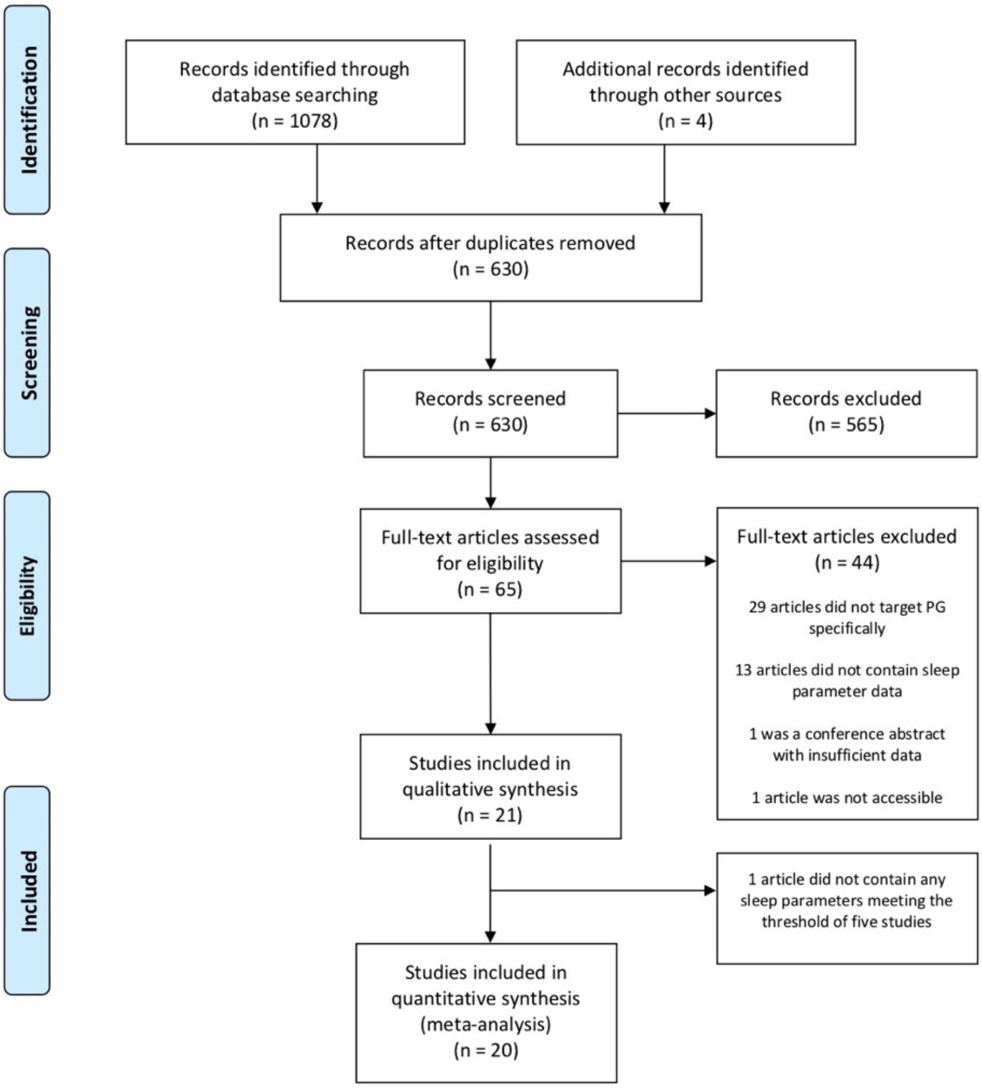


Figure 1. PRISMA flow diagram of the study screening and selection process

the Middle East (Al Gammal, Ali Elsheikh, & Abozahra, 2019; Hawi, Samaha, & Griffiths, 2018; Lin et al., 2019; Vollmer, Randler, Horzum, & Ayas, 2014; 5497 participants), and the remaining eleven study populations came from Europe (Achab et al., 2011; Arnesen, 2010; Bonnaire & Phan, 2017; Brunborg et al., 2013; Mannikko et al., 2015; Männikkö, Ruotsalainen, Tolvanen, & Kääriäinen, 2019; Nogueira, Faria, Vitorino, Silva, & Neto, 2019; Peracchia, Triberti, & Curcio, 2017; Rehbein, Kleimann, & Mossle, 2010; Rehbein, Kliem, Baier, Mosle, & Petry, 2015; Wenzel et al., 2009; 33,664 participants).

The participants' age ranged from 10-74 years with a weighted grand mean of 15.8. The majority of studies (n = 12) specifically targeted adolescents (i.e. 10-19 years old), two studies specifically targeted young adults (i.e. 18-34 years old) (Al Gammal et al., 2019; Stockdale &

Coyne, 2018), two studies targeted adolescents and young adults (Mannikko et al., 2015; Männikkö et al., 2019), two studies targeted adults over 18 years old (Achab et al., 2011; Ko et al., 2019), and three studies did not target any specific age group (Arnesen, 2010; Satghare et al., 2016; Wenzel et al., 2009). With regard to sex, the proportion of female participation ranged from 0-62.8 percent, with one study only including boys/men (Kim et al., 2016a), and one study only including boys/men in the analysis (Rehbein et al., 2010). The weighted overall sex distribution was 34.9 percent girls/women for all the included studies.

The majority of populations (*n* = 13) were recruited from primary- / high schools, while three populations were recruited from college / universities (Al Gammal et al., 2019; Ko et al., 2019; Stockdale & Coyne, 2018), two populations were recruited from gaming communities (Achab et al., 2011; Satghare et al., 2016), two populations were recruited using random population sampling (Arnesen, 2010; Wenzel et al., 2009), and one population were recruited from two pediatric lipid and obesity treatment clinics (Turel et al., 2016). After merging subgroups of problematic gamers (e.g. "problem" / "at risk" and "addicted" / "disordered"), the included samples yielded a total of 5,152 individuals that were categorized as problem gamers. Prevalence rates of problematic gamers varied widely in the samples ranging from 1.2 - 73.9 (weighted mean = 16.2 percent), while three studies had comparison groups of similar sample size (Ko et al., 2019; Peracchia et al., 2017; Stockdale & Coyne, 2018).

Problematic Gaming Assessment

The majority (*n* = 20) of studies assessed problematic gaming using self-report questionnaires, while one study (Ko et al., 2019) collected the data through diagnostic interviews. Twenty studies adapted an addiction framework, of which five studies used the GASA, seven studies used instruments based on the DSM-5's IGD criteria (i.e. IGDS, IGD-20, PTU, IGDT-10, IGDQ; for full references see appendix D) one study adapted the criteria of pathological gambling (Nogueira et al., 2019), three studies adapted the DSM-IV-TR or the ICD-10 substance dependence criteria (i.e. DAS, AICA-S, KFN-CSAS-II; see appendix D), whereas three studies used instruments that were based on general addiction symptoms (i.e. OGASA, OVGA, CGA; see appendix D).

A total of 17 studies identified problematic gamers using a categorical approach, while four studies employed a continuous measure. Regarding the categorical approach, one study identified problematic gamers using latent class analysis (LCA) (Lin et al., 2019), one study used a core addiction criteria approach (Brunborg et al., 2013), whereas the remaining used a variety of cutoff values which mainly reflected a polythetic approach. In addition, one study assessed problematic gaming exclusively based on time spent playing, with four hours or more playing per day defined as excessive gaming (Wenzel et al., 2009). Finally, one study selected a group of 300 participants balanced by high or extremely low scores on the AICA-S, and further created two comparison groups of 150 “hard gamers” (4-6 hours) and 150 “casual gamers” (less than 1 hour) based on time reported playing a day (Peracchia et al., 2017).

Sleep Assessment

The majority of studies (n = 19) investigated sleep using self-report questionnaires, while one study collected data through diagnostic interviews (Ko et al., 2019), and one study used an objective tool; *Fitbit*- actigraphy (Turel et al., 2016). Concerning sleep duration, eight studies assessed this by a single item, and one study used *Fitbit*- actigraphy to measure rest/activity cycles (Turel et al., 2016). One study used a cutoff of more or less than six hours of sleep (Kim et al., 2016a), while the remaining reported sleep duration as a continuous measure. Regarding sleep quality, the most utilized instrument was the Pittsburgh Sleep Quality Index (n = 3), whereas two studies used single items (Achab et al., 2011; King et al., 2014). Of the ten studies reporting sleep problems, two studies assessed insomnia using standardized self-report instruments (Arnesen, 2010; Satghare et al., 2016), one study assessed insomnia by clinical interviews (Ko et al., 2019) while the remaining seven studies used single items assessing generic/general sleep problems. Morningness-eveningness was assessed in one study using a standardized questionnaire (Vollmer et al., 2014). Daytime sleepiness was assessed by standardized instruments in two studies (Nogueira et al., 2019; Peracchia et al., 2017), while two studies used a single item (Achab et al., 2011; Brunborg et al., 2013). Delayed sleep phase was in one study examined by clinical interviews (Ko et al., 2019). The remaining sleep-related outcomes were assessed during clinical interviews and various single items (see appendix D)

Quality Assessment

The quality scores of the single included studies ranged from two to nine stars, with a mean quality score of 5.66 and a standard deviation of 1.71 (see table 2 for further details).

Table 2.

Results from the Newcastle-Ottawa Quality Assessment Scale (NOS)

	Selection				Comparison	Outcome	
Study ID	**Representativeness** (Max:★)	**Sample size** (Max:★)	**Non-respondents** (Max:★)	**Ascertainment of the exposure** (Max:★★)	**Comparable outcome groups / Controlled for confounding factors** (Max:★★)	**Assessment of outcome** (Max:★★)	**Statistical test** (Max:★)
Achab, 2011	–	★	–	★	★★	★	★
Al Gammal, 2019	–	–	–	★★	–	★	–
Arnesen, 2010	★	★	★	★★	–	★	–
Bonnaire, 2017	–	★	★	★★	–	★	–
Brunborg, 2013	★	★	★	★★	★★	★	★
Hawi, 2018	★	★	–	★★	★★	★	–
Kim, 2016	★	★	–	★★	–	★	–
King, 2014	★	★	–	★★	–	★	–
Ko, 2019	–	★	–	★★	★	★	–
Lin, 2019	★	★	★	★★	★★	★	★
Männikkö, 2015	★	–	–	★★	–	★	–
Männikkö, 2019	★	★	–	★★	–	★	–
Nogueira, 2019	–	–	–	★	–	★	–
Peracchia, 2017	–	★	–	★★	–	★	–
Rehbein, 2010	★	★	★	★★	–	★	–
Rehbein, 2015	★	★	★	★★	–	★	–
Satghare, 2016	★	★	–	★★	–	★	★
Stockdale, 2018	★	★	–	★★	★★	★	–
Turel, 2016	–	★	–	★★	–	★★	–
Vollmer, 2014	–	★	–	★★	★★	★	★
Wenzel, 2009	★	★	★	★	–	★	–

Meta-analyses

Of all 21 studies and sleep parameters reviewed, sleep duration, sleep quality, and sleep problems comprised the parameters that reach the threshold of five different effect sizes. Thus, a total of 20 studies were included in the quantitative meta-analysis.

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Achab, 2011	-0,317	0,106	0,011	-0,526	-0,109	-2,989	0,003
Hawi, 2018	-0,415	0,082	0,007	-0,576	-0,254	-5,061	0,000
Kim, 2016	-0,315	0,134	0,018	-0,578	-0,053	-2,354	0,019
King, 2014	-0,262	0,056	0,003	-0,372	-0,152	-4,658	0,000
Männikkö, 2019	-0,193	0,072	0,005	-0,334	-0,051	-2,664	0,008
Nogueira, 2019	-0,526	0,175	0,031	-0,869	-0,183	-3,005	0,003
Rehbein, 2010	-0,163	0,045	0,002	-0,251	-0,075	-3,622	0,000
Turel, 2016	-0,580	0,187	0,035	-0,947	-0,212	-3,093	0,002
Overall	-0,291	0,045	0,002	-0,379	-0,203	-6,480	0,000

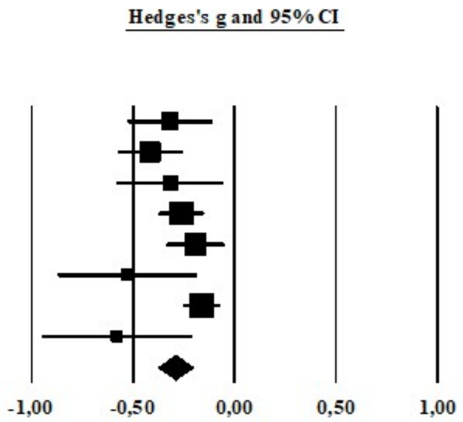


Figure 2. Forest plot showing the association (Hedges's *g*) between problematic gaming and sleep duration.

Sleep Duration. The forest plot regarding sleep duration is displayed in figure 2. The results from the random-effects model showed a significant overall negative association between problematic gaming and sleep duration (*g* = -.291, 95% CI [-.203, -.379]), suggesting that problematic gamers report shorter sleep duration than non-problematic gamers. The Q-statistic was significant ($Q = 14.7$, $df = 7$, p = .040) indicating heterogeneity between the studies. The I^{2}-statistic showed a moderate percentage of true between-study variance ($I^2 = 52.3\%$). In order to ease interpretation of this finding, an additional fixed effect model was run for those studies (*k* = 4) providing data on sleep duration in terms of hours and minutes. This amounted to a difference between conditions of -21.51 minutes (95%, CI = [-15.16, -27.86 min.]). Concerning publication bias, the funnel plot (appendix E) was somewhat asymmetric. The trim and fill procedure suggested that 2 studies were missing and when imputing these the overall effect size was adjusted to *g* = -.262, 95% CI [-.172**,** -.352]. Orwin's fail-safe *N* showed that 3 missing studies with zero effect are needed to reduce the overall effect to the set trivial effect criterion (*g* = -.20). A subgroup analysis comparing studies targeting adolescent populations (*k* = 7, weighted mean age = 15.2) and studies targeting adult or non-targeted age populations (*k* = 1, weighted mean age = 26.5) was conducted. The difference between the subgroups was not significant $Q_{bet} = 0.03$, $df = 1$, $p = .862$. There was still significant heterogeneity within the adolescent subgroup ($Q = 14.27$ df = 6, p < .05, $I^2 = 57.6\%$) without inclusion of the adult/non-specific population.

Study name	Statistics for each study				
	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Achab, 2011	4,313	2,633	7,064	5,804	0,000
Al Gammal, 2019	0,538	0,085	3,395	-0,660	0,510
King, 2014	1,290	1,057	1,574	2,508	0,012
Lin, 2019	3,471	3,229	3,732	33,695	0,000
Peracchia, 2017	1,445	0,957	2,180	1,752	0,080
Overall	2,039	1,095	3,798	2,245	0,025

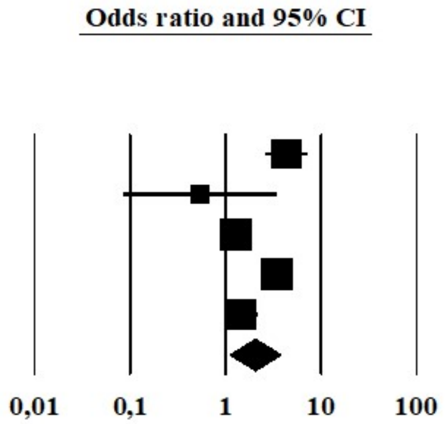


Figure 3. Forest plot showing the association (odds ratio) between problematic gaming and sleep quality.

Note. Increased odds indicate poorer sleep quality

Sleep Quality. The forest plot for sleep quality is displayed in figure 3. The overall results from the random-effects model showed that problematic gamers had increased odds of reporting poorer sleep quality compared to non-problematic gamers (*OR* = 2.039, 95% CI [1.10, 3.80]). The *Q*-statistic was significant (Q = 102.12, df = 4, p < .0001), indicating significant heterogeneity between studies and the I^{2}-statistic showed a high percentage of true between-study variance (I^2 = 96.1%). The funnel plot (appendix F) was symmetric and the Trim and Fill procedure did not adjust the overall effect size, suggesting low risk of publication bias. The Orwin's fail-safe *N* showed that 26 missing studies with zero effect are needed to reduce the overall effect to the trivial effect criterion (*OR* =1.2). The subgroup analysis comparing studies targeting adolescent populations (k = 3, weighted mean age = 15.2) and studies targeting adult/non-specific age populations (k = 2, weighted mean age = 26.5) did not yield any significant differences between subgroups (Q_{bet} = 0.11, df = 1, p = .738). There was significant heterogeneity within both the adolescent subgroup (Q = 96,79, df = 2, p < .001, I^2 = 97.9%) and within the adult/non-specific group (Q = 4.57, df = 1, p = .032, I^2 = 78.1%). A second subgroup analysis comparing studies that used a single item sleep assessment (k = 1) and studies using multi-item sleep questionnaires (k = 4) was conducted. The difference between the subgroups was not significant Q_{bet} = 1.39, df = 1, p = .237. There was still significant heterogeneity within the sleep questionnaire subgroup (Q = 14.27 df = 6, p < .05, I^2 = 57.6%) without inclusion of the single item study.

Study name	**Statistics for each study**				
	Odds ratio	**Lower limit**	**Upper limit**	**Z-Value**	**p-Value**
Arnesen, 2010	1,808	0,411	7,956	0,783	0,433
Bonnaire, 2017	0,708	0,320	1,566	-0,852	0,394
Brunborg, 2013	2,138	1,568	2,914	4,808	0,000
Ko, 2019	4,632	1,245	17,232	2,287	0,022
Männikkö, 2015	1,871	1,229	2,848	2,923	0,003
Rehbein, 2010	2,921	2,165	3,941	7,012	0,000
Rehbein, 2015	1,448	1,056	1,986	2,295	0,022
Satghare, 2016	3,180	2,273	4,448	6,757	0,000
Stockdale, 2018	4,660	2,654	8,180	5,360	0,000
Wenzel, 2009	2,040	1,139	3,654	2,399	0,016
Overall	2,234	1,686	2,960	5,602	0,000

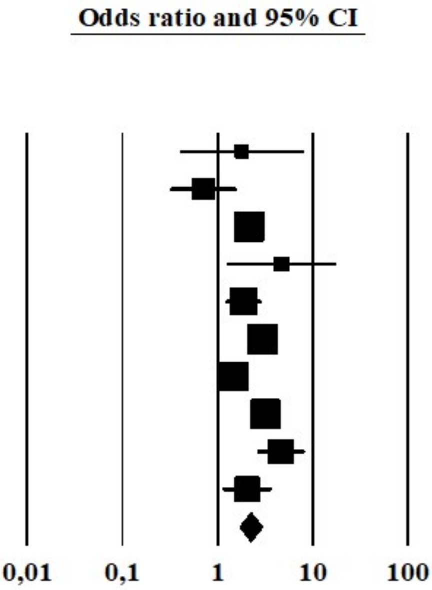


Figure 4. Forest plot showing the association (odds ratio) between problematic gaming and sleep problems

Sleep Problems. The forest plot for sleep problems is displayed in figure 4. The results from the random-effects model showed a significant overall effect size of *OR* = 2.234, 95% CI (1.68, 2.96), indicating that problematic gamers had increased odds of reporting sleep problems compared to non-problematic gamers. The *Q*-statistic was significant (Q = 31.22, df = 9, p < .0001), indicating significant heterogeneity between the studies. The I^{2}-statistic showed a high percentage of true between-study variance (I^2 = 71.2%). Concerning publication bias, the funnel plot (appendix G) showed a relatively symmetrical distribution. The Trim and Fill suggested that there are were no missing studies, resulting in no adjustment of the overall effect size. The Orwin's fail-safe *N* showed that 35 studies with zero effect are needed to bring the overall effect down to the trivial effect criterion (*OR* = 1.2). The subgroup analysis comparing studies that targeted adolescent populations (*k* = 5, weighted mean age = 15.1) and studies that targeted adult or non-specific age populations (*k* = 5, weighted mean age = 25.2) showed that the latter subgroup had a significant higher overall effect size (*OR* = 3.12, 95% CI [2.07, 4.70]) compared to the former subgroup (*OR* = 1.82, 95% CI [1.32, 2.56]), with a Q_{bet} = 4.09, df = 1, p = .043. There was still significant heterogeneity within the adolescent subgroup (Q = 16.98, df = 4, p < .01, I^2 = 76.4%) while there was no significant heterogeneity within the adult/non-specific group (Q = 4.87, df = 4, p = .30, I^2 = 17.8%). Finally, the subgroup analysis comparing studies that used a single item sleep measure (*k* = 6) and studies using multi-item sleep questionnaires (*k* = 4) showed a significant difference between groups (Q_{bet} = 5.89, df = 1, p = .015), where the latter subgroup yielded a higher overall effect size (*OR* = 3.47, 95% CI [2.63, 4.58]) compared to the former (*OR* = 1.98, 95% CI [1.70, 2.32]). There was still significant heterogeneity within the single item assessment group (Q = 16.99, df = 5, p < .01, I^2 = 70.5%) while there was no significant heterogeneity within the standardized questionnaire group (Q = 2.24, df = 3, p = .520, I^2 = 0.0%).

Discussion

Knowledge on the association between problematic gaming and sleep problems and the directionality in this relationship could contribute to a better understanding of the phenomenon of problematic gaming. A positive association between problematic gaming and sleep problems would confirm that problematic gaming is related to adverse outcomes and as such a phenomenon of potential clinical interest. Further, knowledge of the directionality in this relationship may advance our understanding of the etiology of problematic gaming by indicating whether it is a consequence or an antecedent of other problems including sleep difficulties. The aim of this study was to investigate and extend the knowledge of the relationship between problematic gaming and sleep by summarizing existing research and quantifying overall associations between problematic gaming and sleep problems. Overall, the results from the meta-analyses indicate that problematic gaming is statistical significantly associated with shorter sleep duration, poorer sleep quality, and increased odds of reporting general sleep problems. Also, the findings from the qualitative review suggests that problematic gaming is positively associated with daytime sleepiness, delayed sleep phase disorder, eveningness chronotype, sleep deprivation, and nocturnal wakeups to continue playing games (Appendix D). Most studies from the review and meta-analyses were cross-sectional which precludes conclusions regarding directionality.

Small, positive, overall associations between problematic gaming and shorter sleep duration, poorer sleep quality, and sleep problems

The meta-analysis found an inverse association between problematic gaming and sleep duration with an effect size of g = -.291, which was reduced to g = -.262 after adjusting for possible publication bias. Using Cohen's (1988) classification of effect sizes, this can be considered as a small effect. In order to ease the interpretation of this finding, an additional analysis of the four studies who reported sleep duration in terms of hours / minutes in each condition showed that problematic gamers slept on average 21.5 minutes less than non-problematic gamers. Further, the overall result from the meta-analysis on sleep quality suggests that problematic gamers had significant higher odds of reporting poorer sleep quality than non-problematic gamers with an effect size of *OR* = 2.039. Also, the meta-analysis on sleep problems found that problematic gamers had increased odds of reporting sleep problems compared to non-problematic gamers with an overall *OR* = 2.234. *OR* are slightly more difficult to interpret as the interpretation is dependent on the prevalence rates of the outcome (Chen, Cohen, & Chen, 2010; Nemes, Jonasson, Genell, & Steineck, 2009). However, following the recommendations by Ferguson (2016) an *OR* of 2.0 could be considered as a small effect.

In sum all the associations had small effect sizes which may suggest that they have limited practical significance. However, small effect sizes could still be relevant if the outcome variable is important (theoretically or practically) and when the outcome has high prevalence rates (Breaugh, 2003; Prentice & Miller, 1992). The outcome in this case (i.e. sleep problems) could be argued to be a variable of great importance due the range of adverse consequences it involves and its high and increasing prevalence rates (Pallesen et al., 2014). Identifying possible determinants of sleep problems (i.e. problematic gaming) is as such of great societal importance, even if such determinants should be rather weakly associated with sleep problems. Further, for the finding regarding sleep duration one could argue that an average, nightly sleep reduction of 21.5 minutes is not trivial, as having a chronic sleep loss of that size may have adverse consequences and is likely to be experienced as a problem by the individual (Endocrine Society, 2015).

The causal relationship between problem gaming and sleep problems are unknown. Suggested causal pathways include that problematic gaming may cause sleep problems (e.g. through difficulties with ceasing gaming to sleep and/or the emission of blue light from gaming devices disturbing the circadian rhythm), that sleep problems may cause problematic gaming if the individual engages in gaming when having difficulties sleeping, and that both problematic gaming and sleep problems are caused by the same underlying factors (e.g. depression) (King et al., 2013a; Chang et al., 2015; Baglioni et al., 2011; Männikkö et al., 2017). Due to the cross-sectional design of included studies in this review and meta-analyses it is not possible to conclude on the causal relationship between problematic gaming and sleep problems. Based on the literature on excessive media consumption one could, however, speculate that the main explanation to the associations between problematic gaming and shorter sleep duration, poorer sleep quality, and sleep problems might be that problematic gamers play games during evening/nighttime which may result in gaming both displacing sleep and delaying the circadian rhythm (Van den Bulck, 2000; Cain & Gradisar, 2010; Exelmans & Van den Bulck, 2017a, 2017b). In support of this possibility, results from the systematic review show that problematic gaming has been found to be associated with delayed sleep phase disorder and eveningness chronotype (see appendix D). Consequently, the findings from the meta-analyses might reflect that late-night gaming delays problematic gamer's sleep phase, and consequently result in shorter sleep duration because of attendance of early morning obligations the following day (e.g. school or work); experiencing poorer sleep quality because of excessive pre-sleep arousal; and experiencing problems falling asleep at the desired or required time as a result of excessive arousal and the circadian process not favoring sleep.

Heterogeneity

There was found significant heterogeneity in all meta-analyses. The observed effect sizes in a meta-analysis can be heterogeneous for two reasons, (1) within study error or (2) true variation (Borenstein et al., 2011). Given the medium to high true variance as indicated by the

I^2 -statistic, the heterogeneity in the present meta-analyses may be attributed to both sources of variance; with the high percentage of true variance indicating there are systematic differences between the studies which serve as important moderator effects. Following the recommendations of more than ten studies for each covariate (Borenstein et al., 2011) when investigating the potential moderators by meta-regression analyses, such moderator analyses were deemed not to be appropriate given the low number of studies included in the meta-analysis. As such, the investigation of the heterogeneity was limited to subgroup analyses.

The impact of participant age was investigated by creating a dichotomous variable differing adolescent and adult/non-specific population. Moreover, the impact of methodical discrepancies was assessed by creating a dichotomous moderator variable separating studies that investigated sleep with a multiple-item standardized questionnaire and studies using a single item assessment. There was not found any significant differences between the subgroups in the meta-analyses on sleep duration and sleep quality. The lack of significant difference may, however, be as a result of too low power in the analyses due to the low number of studies included in the analysis, as well in each condition, rather than implying the overall effects are not moderated by these factors. In contrast, a significant difference was found in the overall effect on sleep problems between studies targeting adult/non-specific age populations (OR = 3.12) and studies targeting adolescent populations (OR = 1.82). Given the different mean ages in the subgroups (weighted mean = 25.2 and 15.1 years, respectively) this finding could reflect that higher age is related to experiencing more sleep problems amongst problematic gamers. There are some possible explanations for this finding. First, the prevalence of problematic gaming appears to be lower in adult populations compared to adolescent populations (Griffiths et al., 2015). Followingly, adult problematic gamers might experience more gaming-related harm because adult problematic gaming is more atypical in the adult population compared to the adolescent population. Also, given that adolescence and young adulthood seem to be a critical period for the development of addictions and other mental disorders in general (Stone et al., 2012; Kessler et al., 2005; Adams et al., 2019), the problematic gaming behavior might be more established and severe in adults compared to adolescents, which could further fuel more severe impairments to the adult problematic gamer's sleep. Alternatively, the finding could be related to that adults are more autonomous than adolescents, meaning that adolescents are more likely to have caregivers that limits their gaming; resulting in reduction in the severity of the problems.

The second subgroup analysis found that for sleep problems, studies using multi-item sleep questionnaires (*OR* = 3.47) yielded higher overall effect sizes compared to the studies using a single item sleep measure (*OR* = 1.98). This finding may be attributed to the fact that multiple-item measurements have less measuring error compared to single item measurements (Diamantopoulos, Sarstedt, Fuchs, Wilczynski, & Kaiser, 2012). This have been demonstrated empirically in a study which found that a single item sleep measurement yielded relatively low sensitivity (i.e. ability to correctly identify sleep problems) compared to a multi-item sleep disturbance scale; suggesting that single item sleep measurements may lead to false positives (Lallukka, Dregan, & Armstrong, 2011). Followingly, the differences between groups may become smaller in studies using single item measurements (compared to studies using multiple item measurements) because the differences between groups are largely influenced by the measuring error possibly producing false positives. Following this line of arguments – and the fact that six of ten studies in the meta-analysis on sleep problems collected sleep parameter data with a single item – it is possible that the association between problematic gaming and sleep problems is in reality higher than indicated by the current overall effect size, but that the magnitude of the effect could be downplayed by the methodological inaccuracy from the studies implementing single item sleep measurements.

Publication bias

The risk of publication bias was investigated by funnel plots, Orwin's fail-safe *N*, and Duval and Tweedie's trim and fill. Regarding the meta-analyses on sleep quality and sleep problems, the symmetry of the funnel plots and the lack of adjustments by the trim and fill procedures, suggests that there are no obvious signs of bias influencing the overall effect sizes. This was further supported by the relatively high number of missing null-studies needed to lower the effect size to a trivial level (26 and 35, respectively) as indicated by the fail-safe *N*. Given the fact that the search strategy only identified five and ten studies on the relationship on problematic gaming and sleep quality and sleep problems, respectively, it is unlikely that such amount of studies were missing; suggesting that the results from these meta-analyses are robust and that the risk of publication bias is low. There was, however, evidence of bias in the meta-analysis on sleep duration, as shown by the somewhat unsymmetrical shape of the funnel plot (appendix E). Moreover, the fail-safe *N* showed that only three insignificant studies needed to be added to the pool of effect sizes in order to make the overall effect non-significant. The presence of publication bias implies that the smaller studies are more likely to have larger effect sizes given the fact that it is generally easier to publish smaller studies with large effects compared to small studies with small or null effect (Song, Hooper, & Loke, 2013; Borenstein et al., 2011). Consequently, the lack of published small or insignificant effects may cause bias to the overall effect. This issue was investigated using the trim and fill procedure which suggested that two studies were missing from the analysis on sleep duration. When adjusting for these two theoretical missing studies, the effect size was reduced from *g* = -.291, 95% CI (-.203, -.379) to *g* = -.262, 95% CI (-.172 -.352); suggesting that the impact of the publication bias on the overall effect was rather modest.

However, the asymmetry of effect sizes as seen in the funnel plot (appendix E) may be attributed to “small-study effects” rather than publication bias (Sterne, Egger, & Smith, 2001). The presence of small-study effects would imply that there are larger effect sizes in the smaller studies for some unknown underlying mechanism – such as the characteristics of the specific population. For instance, one of the largest effects on sleep duration in the current meta-analysis was found in one of the smallest studies (Turel et al., 2016). Given the fact that this population was recruited from two pediatric lipid and obesity treatment clinics, it is possible that problematic gaming behavior affects sleep differently in this population, thus yielding a larger effect size. Independent of the source, the presence of bias suggests that the association between problematic gaming and shorter sleep duration should be interpreted with some caution.

Limitations of the included studies

The present review identifies some key limitations in the designs of the included studies which have implications when drawing inferences of the current literature on problematic gaming and sleep. First, a major limitation of the included studies is that all except two were cross-sectional. Consequently, the paucity of longitudinal studies makes it impossible to draw inferences on the directionality between problematic gaming and sleep. Moreover, only seven of the 21 included studies adjusted their estimates for confounding factors (see table 2), leaving the residual confounding moderators to inflate the effect size and further makes it difficult to assess the direct links between the problematic gaming and sleep.

Further, most of the studies fail to provide with a detailed account regarding both the gaming behavior and sleep problems, resulting a paucity of the underlying mechanisms of the relationship. For instance, none of the studies registered the time of day the gaming took place. Consequently, we do not know whether the associated shorter sleep duration and sleep problems are simply as a result of excessive late-night gaming postponing the bed-time initiation (or making it harder to fall asleep), or whether the sleep interference is caused by other impairments associated with problematic gaming such as depression. Also, several of the included studies are rather unspecific on the nature of the sleep problem. As such, we do not currently know whether the associated sleep interference is oriented around troubles falling asleep, failing to stay asleep during the night, or experiencing sleep of poor quality. Also, few studies differentiated the sleep duration (and sleep problems) on weekdays from weekends. It is possible that the shorter sleep duration (and sleep problems) are limited to weekdays, as weekdays typically require attending early morning obligations such as school or work. Followingly, the sleep could be normal in weekends because the problematic gamer may compensate later bedtimes with later risetimes. Alternatively, sleep duration and quality could be longer and better in the weekends because the problematic gamer compensate for the gaming-related sleep shortage during the weekdays. One of the included studies, however, found the inverse association between problematic gaming and sleep duration to be of the same effect size in both weekdays and weekends (King et al., 2014). Additionally, few studies registered data on the specific game genres that were played. Consequently, little is known whether some game types are stronger associated with sleep problems than others. For instance, it is possible that problematic gamers that primarily engages in online games such as MMORPGs experience more sleep interference (as compared to problematic gamers favoring other types of games), due to their social components and their inherent variable-ratio reinforcement schedules making it more difficult to stop the late-night playing as the next reward could be “right around the corner” (Charlton & Danforth, 2007; King, Delfabbro, & Griffiths, 2010).

Another major limitation is variability in wide spread of operationalizations, measurement tools, and the inconsistent use of cutoff values to defining and measure both problematic gaming and sleep problems makes the included studies are somewhat difficult to compare. Furthermore, all except for one study assessed sleep based upon participants’ self-report, potentially introducing response bias or socially desirable responding.

Other limitations regard the sampling of participants. Of the 21 included studies only two studies used random population sampling (Arnesen, 2010; Wenzel et al., 2009), while the remaining used convenience sampling by schools/universities, online gaming forums, social media, and a treatment clinic, which may potentially cause sampling bias. Moreover, the current pool of participants is overrepresented by west-European adolescent populations. Consequently, the current findings might not be generalized beyond these populations. Lastly, only seven of the 21 studies were large scale with more than one thousand participants. Consequently, there is an issue of the representativeness of the individual samples as well as limitations the analytic power of the smaller studies; yielding estimates of poorer precision.

Taken together, the abovementioned issues suggest that the available literature is currently somewhat limited. Thus, drawing inferences of the current evidence base should be done with some caution.

Limitations and strengths of the current study

The current study contains some limitations that should be taken in mind when interpreting the results. A primary limitation of this study is the low number of studies included in the meta-analysis (due to problematic gaming being a relatively new scientific topic), causing rather imprecise estimation of the overall effect sizes as indicated by the relatively wide confidence intervals. Further, it can be argued that meta-analyses might not been appropriate given the is widespread of measurement tools and study populations; making the included studies too different to compare. This issue can be highlighted by the medium to high levels of heterogeneity found in all of the current meta-analyses. In an effort to reduce the heterogeneity, the review could have implemented more stringent inclusion criteria such as only including studies that conceptualized problematic gaming using the four “core addiction” criteria (i.e. conflict, withdrawal, relapse and problems; cf. Männikkö et al., 2017) or only included studies adapting the IGD conseptualization. This would, however, further reduce an allready sparse pool of studies on the topic in question and ultimately result in insufficient analytic power to investigate the heterogeneity. Nevertheless, a large body of heterogeneity remain unexplained as there was too few studies to perform meta-regressions. Another possible limitation is the fact that the subgroups of problematic gamers was collapsed in the meta-analyses. As indicated by several of the included studies, it is possible that problematic gamers with more severe symptoms experience more problems with sleep than those with less severe symptoms. Thus, collapsing the subgroups of may have downplayed the severity of sleep problems in the most problematic gamers. Furthermore, there are also some potential limitations in the present search strategy and inclusion criteria which could cause bias to the synthesis. While the current inclusion criteria did not exclude non-journal manuscripts, the current search strategy makes it likely that scientific work not published in scientific journals could have been overlooked – resulting in possible selection bias. Followingly, the search strategy could have been extended to include grey literature databases such as databases for doctoral and master theses (e.g. *ProQuest Dissertations & Theses*) to further reduce risk of bias. Moreover, there might be language bias to the synthesis as the current inclusion criteria excluded all manuscripts that were not in a European language. For instance, given the high attention surrounding problematic gaming in Southeast Asian countries (Griffiths et al., 2015), it is likely that there are publications on problematic gaming in Asian languages and that this empirical data were lost due to the manuscript language.

Despite these limitations, a major asset of the current study is the implementation of two independent reviewers in the study screening, data extraction, and study quality assessment processes; reducing the risk of bias and human error and consequently increasing the reliability, reproducibility and internal validity of the synthesis. Moreover, current study provides the to date most comprehensive systematic review on the topic and is the first study to quantify the relationship between problematic gaming and sleep problems with meta-analyses.

Implications for further research

The present review and meta-analyses highlight some limitations of the current literature on problematic gaming and sleep. These limitations involve some suggestions for future research. Firstly, the field is in need of more longitudinal studies in order to assess the directionality of the relationship. Moreover, more knowledge is needed on the causal pathways on the effects of problematic gaming, sleep, and associated outcomes. For instance, the physical, psychological, and functional impairments associated with problematic gaming could, hypothetically, reflect an indirect effect through sleep interference rather than a direct causal effect between problematic gaming and negative outcomes. Consequently, future research would benefit from registering more detailed data; such as the time of day the individuals are gaming, type of game played, recording in sleep weekdays and weekends, and specify the nature of the sleep problem; as this could give a better understanding of the mechanisms underlying the association between problematic gaming and sleep.

Furthermore, the review and meta-analyses notes a potential methodical issue regarding the use of single item sleep measurements which could yield unprecise estimates. Further research would benefit from assessing sleep parameters using standardized and validated questionnaires as these have less measuring error and would make for better comparisons as well as providing more information of the severity of sleep problems. Also, rather than retrospective questionnaires, further studies would benefit from using sleep diaries as it provides with a more detailed picture of the sleep and are less prone to recall bias. Moreover, there was only found one study that assessed sleep by an objective measurement. Further research should strive to measure sleep in problematic gaming objectively such as an actigraphy in order to reduce the risk of biases associated with subjective reporting. Also, the current evidence base is in need of more high-quality longitudinal, cross-cultural, and large nationally representative samples, as the current available data have some limitations in their generalizability.

Lastly, given the heterogeneity found in all of the present meta-analyses, future meta-analyses will benefit to investigate the heterogeneity using more sophisticated analyses such as meta-regressions when more empirical data becomes available. Understanding sources of heterogeneity is important as it may lead the development of new hypotheses as well have practical implications for prevention and treatment strategies (Haidich, 2010).

Conclusion

The current study contributes to the debate on problematic gaming by offering the to date most comprehensive review on problematic gaming and sleep and is the first study to quantify the strength of the association between problematic gaming and sleep problems with meta-analyses. The overall results suggest that problematic gaming is associated with shorter sleep duration, poorer sleep quality and general sleep problems. The review further highlights the currently pressing need for more high-quality studies and longitudinal investigations to address the causal nature of the relationship. Insight in sleep's role in problematic gaming behavior is important as it could contribute to gain a better grasp of the etiology of problematic gaming, and consequently better assessments and treatments.

References

Abel, T., Havekes, R., Saletin, J. M., & Walker, M. P. (2013). Sleep, plasticity and memory from molecules to whole-brain networks. *Current Biology, 23*(17), 774-788. doi:10.1016/j.cub.2013.07.025

Achab, S., Nicolier, M., Mauny, F., Monnin, J., Trojak, B., Vandel, P., . . . Haffen, E. (2011). Massively multiplayer online role-playing games: Comparing characteristics of addict vs non-addict online recruited gamers in a french adult population. *BMC Psychiatry, 11*. doi:10.1186/1471-244X-11-144

Adachi, P. J. C., & Willoughby, T. (2013). More than just fun and games: The longitudinal relationships between strategic video games, self-reported problem solving skills, and academic grades. *Journal of Youth and Adolescence, 42*(7), 1041-1052. doi:10.1007/s10964-013-9913-9

Adams, B. L. M., Stavropoulos, V., Burleigh, T. L., Liew, L. W. L., Beard, C. L., & Griffiths, M. D. (2019). Internet gaming disorder behaviors in emergent adulthood: A pilot study examining the interplay between anxiety and family cohesion. *International Journal of Mental Health and Addiction, 17*(4), 828-844. doi:10.1007/s11469-018-9873-0

Al Gammal, M. A., Ali Elsheikh, M. M., & Abozahra, A. A. (2019). Internet addiction and internet gaming disorder and associated insomnia among a sample of al-azhar university students, clinical study. *The Egyptian Journal of Hospital Medicine, 77*(5), 5718-5726. doi:10.12816/EJHM.2019.63227

American Academy of Sleep Medicine. (2014). *The international classification of sleep disorders* (3rd ed.). Darien, IL: American Academy of Sleep Medicine.

Andreassen, C. S., Billieux, J., Griffiths, M. D., Kuss, D. J., Demetrovics, Z., Mazzoni, E., & Pallesen, S. (2016). The relationship between addictive use of social media and video games and symptoms of psychiatric disorders: A large-scale cross-sectional study. *Psychology of Addictive Behaviors, 30*(2), 252. doi:10.1037/adb0000160

APA. (2013). *Diagnostic and statistical manual of mental disorders* (5 ed.). Washington, DC: American Psychiatric Publishing.

Arnesen, A. A. (2010). *Video game addiction among young adults in norway: Prevalence and health* (Master Thesis). Retrieved from http://bora.uib.no/handle/1956/4114

Baglioni, C., Battagliese, G., Feige, B., Spiegelhalder, K., Nissen, C., Voderholzer, U., . . . Riemann, D. (2011). Insomnia as a predictor of depression: A meta-analytic evaluation of longitudinal epidemiological studies. *Journal of Affective Disorders, 135*(1), 10-19. doi:10.1016/j.jad.2011.01.011

Banks, S. (2007). Behavioral and physiological consequences of sleep restriction. *Journal of Clinical Sleep Medicine, 3*(05), 519-528.

Batthyány, D., Müller, K. W., Benker, F., & Wölfling, K. (2009). Computerspielverhalten: Klinische merkmale von abhängigkeit und missbrauch bei jugendlichen. *Wiener klinische Wochenschrift, 121*(15), 502-509. doi:10.1007/s00508-009-1198-3

Bean, A. M., Nielsen, R. K. L., Van Rooij, A. J., & Ferguson, C. J. (2017). Video game addiction: The push to pathologize video games. *Professional Psychology: Research and Practice, 48*(5), 378–389. doi: 10.1037/pro0000150

Benington, J. H., & Heller, H. C. (1995). Restoration of brain energy metabolism as the function of sleep. *Progress In Neurobiology, 45*(4), 347-360. doi:10.1016/0301-0082(94)00057-O

Berger, R. J., & Phillips, N. H. (1995). Energy conservation and sleep. *Behavioural Brain Research, 69*(1), 65-73. doi:10.1016/0166-4328(95)00002-B

Berson, D. M., Dunn, F. A., & Takao, M. (2002). Phototransduction by retinal ganglion cells that set the circadian clock. *Science, 295*(5557), 1070-1073. doi:10.1126/science.1067262

Billieux, J., Deleuze, J., Griffiths, M. D., & Kuss, D. J. (2015a). Internet gaming addiction: The case of massively multiplayer online role-playing games. In N. el-Guebaly, G. Carrà & M. Galanter (Eds.), *Textbook of addiction treatment: International perspectives* (pp. 1515-1525). Milano: Springer Milan.

Billieux, J., Thorens, G., Khazaal, Y., Zullino, D., Achab, S., & Van der Linden, M. (2015b). Problematic involvement in online games: A cluster analytic approach. *Computers in Human Behavior, 43*, 242-250. doi:10.1016/j.chb.2014.10.055

Bjorvatn, B., & Pallesen, S. (2009). A practical approach to circadian rhythm sleep disorders. *Sleep Medicine Reviews, 13*(1), 47-60. doi:10.1016/j.smrv.2008.04.009

Block, J. J. (2008). Issues for dsm-v: Internet addiction. *American Journal of Psychiatry, 165*(3), 306-307. doi:10.1176/appi.ajp.2007.07101556

Bonnaire, C., & Phan, O. (2017). [negative perceptions of the risks associated with gaming in young adolescents: An exploratory study to help thinking about a prevention program]. *Archives de Pediatrie, 24*(7), 607-617. doi:10.1016/j.arcped.2017.04.006

Borbely, A. A. (1982). A two process model of sleep regulation. *Hum Neurobiol, 1*(3), 195-204.

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis*: John Wiley & Sons, Ltd.

Breaugh, J. A. (2003). Effect size estimation: Factors to consider and mistakes to avoid. *Journal of Management, 29*(1), 79-97. doi:10.1177/014920630302900106

Brown, R. I. F. (1993). Some contributions of the study of gambling to the study of other addictions. In W. R. Eadington & J. Cornelius (Eds.), *Gambling behavior and problem gambling* (pp. 341-372). Reno: University of Nevada Press.

Brunborg, G. S., Hanss, D., Mentzoni, R. A., & Pallesen, S. (2015). Core and peripheral criteria of video game addiction in the game addiction scale for adolescents. *Cyberpsychology, Behavior, and Social Networking, 18*(5), 280-285. doi:10.1089/cyber.2014.0509

Brunborg, G. S., Mentzoni, R. A., & Frøyland, L. R. (2014). Is video gaming, or video game addiction, associated with depression, academic achievement, heavy episodic drinking, or conduct problems? *Journal of Behavioral Addictions, 3*(1), 27-32. doi:10.1556/JBA.3.2014.002

Brunborg, G. S., Mentzoni, R. A., Melkevik, O. R., Torsheim, T., Samdal, O., Hetland, J., . . . Pallesen, S. (2013). Gaming addiction, gaming engagement, and psychological health complaints among norwegian adolescents. *Media Psychology, 16*(1), 115-128. doi:10.1080/15213269.2012.756374

Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Res, 28*(2), 193-213. doi:10.1016/0165-1781(89)90047-4

Cain, N., & Gradisar, M. (2010). Electronic media use and sleep in school-aged children and adolescents: A review. *Sleep Medicine, 11*(8), 735-742. doi:10.1016/j.sleep.2010.02.006

Caplan, S., Williams, D., & Yee, N. (2009). Problematic internet use and psychosocial well-being among mmo players. *Computers in Human Behavior, 25*(6), 1312-1319. doi:j.chb.2009.06.006

Carney, C. E., Buysse, D. J., Ancoli-Israel, S., Edinger, J. D., Krystal, A. D., Lichstein, K. L., & Morin, C. M. (2012). The consensus sleep diary: Standardizing prospective sleep self-monitoring. *Sleep, 35*(2), 287-302. doi:10.5665/sleep.1642

Carras, M. C., & Kardefelt-Winther, D. (2018). When addiction symptoms and life problems diverge: A latent class analysis of problematic gaming in a representative multinational sample of european adolescents. *European Child & Adolescent Psychiatry, 27*(4), 513-525. doi:10.1007/s00787-018-1108-1

Carskadon, M. A. (1990). Patterns of sleep and sleepiness in adolescents. *Pediatrician, 17*(1), 5-12.

Carskadon, M. A., & Dement, W. C. (2017). Chapter 2 - normal human sleep: An overview. In M. Kryger, T. Roth & W. C. Dement (Eds.), *Principles and practice of sleep medicine (sixth edition)* (pp. 15-24.e13): Elsevier.

Chang, A.-M., Aeschbach, D., Duffy, J. F., & Czeisler, C. A. (2015). Evening use of light-emitting ereaders negatively affects sleep, circadian timing, and next-morning alertness. *Proceedings of the National Academy of Sciences, 112*(4), 1232-1237. doi:10.1073/pnas.1418490112

Charlton, J. P. (2002). A factor-analytic investigation of computer 'addiction'and engagement. *British Journal of Psychology, 93*(3), 329-344. doi:10.1348/000712602760146242

Charlton, J. P., & Danforth, I. D. (2007). Distinguishing addiction and high engagement in the context of online game playing. *Computers In Human Behavior, 23*(3), 1531-1548. doi:10.1016/j.chb.2005.07.002

Chen, H., Cohen, P., & Chen, S. (2010). How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. *Communications in Statistics - Simulation and Computation, 39*(4), 860-864. doi:10.1080/03610911003650383

Chou, T.-J., & Ting, C.-C. (2003). The role of flow experience in cyber-game addiction. *CyberPsychology & Behavior, 6*(6), 663-675. doi:10.1089/109493103322725469

Cohen, J. (1988). Statistical power analysis for the behavioral sciences–second edition. 12 lawrence erlbaum associates inc. *Hillsdale, New Jersey, 13*.

Csikszentmihalyi, M. (2013). *Flow: The psychology of happiness*: Random House.

Daley, M., Morin, C. M., LeBlanc, M., Grégoire, J.-P., & Savard, J. (2009). The economic burden of insomnia: Direct and indirect costs for individuals with insomnia syndrome, insomnia symptoms, and good sleepers. *Sleep, 32*(1), 55-64. doi:10.5665/sleep/32.1.55

Dauriat, F. Z., Zermatten, A., Billieux, J., Thorens, G., Bondolfi, G., Zullino, D., & Khazaal, Y. (2011). Motivations to play specifically predict excessive involvement in massively multiplayer online role-playing games: Evidence from an online survey. *European Addiction Research, 17*(4), 185-189. doi:10.1159/000326070

Demetrovics, Z., Urbán, R., Nagygyörgy, K., Farkas, J., Griffiths, M. D., Pápay, O., . . . Oláh, A. (2012). The development of the problematic online gaming questionnaire (pogq). *PloS one, 7*(5), e36417-e36417. doi:10.1371/journal.pone.0036417

Diamantopoulos, A., Sarstedt, M., Fuchs, C., Wilczynski, P., & Kaiser, S. (2012). Guidelines for choosing between multi-item and single-item scales for construct measurement: A predictive validity perspective. *Journal of the Academy of Marketing Science, 40*(3), 434-449. doi:10.1007/s11747-011-0300-3

Dijk, D.-J., & Archer, S. N. (2009). Light, sleep, and circadian rhythms: Together again. *PLoS Biology, 7*(6). doi:10.1371/journal.pbio.1000145

Dijk, D.-J., & Lockley, S. W. (2002). Invited review: Integration of human sleep-wake regulation and circadian rhythmicity. *Journal of Applied Physiology, 92*(2), 852-862. doi:10.1152/japplphysiol.00924.2001

Duval, S., & Tweedie, R. (2000a). A nonparametric "trim and fill" method of accounting for publication bias in meta-analysis. *Journal of the American Statistical Association, 95*(449), 89-98. doi:10.1080/01621459.2000.10473905

Duval, S., & Tweedie, R. (2000b). Trim and fill: A simple funnel-plot–based method of testing and adjusting for publication bias in meta-analysis. *Biometrics, 56*(2), 455-463. doi:10.1111/j.0006-341X.2000.00455.x

Dworak, M., Schierl, T., Bruns, T., & Strüder, H. K. (2007). Impact of singular excessive computer game and television exposure on sleep patterns and memory performance of school-aged children. *Pediatrics, 120*(5), 978. doi:10.1542/peds.2007-0476

Edinger, J., Kirby, A., Lineberger, M., Loiselle, M., Wohlgemuth, W., & Means, M. (2004). The duke structured interview for sleep disorders. *Durham, NC: Duke University Medical Center*.

Endocrine Society. (2015, March 6). Losing 30 minutes of sleep per day may promote weight gain and adversely affect blood sugar control. Retrieved June 15, 2020, from www.sciencedaily.com/releases/2015/03/150306082541.htm

Exelmans, L., & Van den Bulck, J. (2017a). Bedtime, shuteye time and electronic media: Sleep displacement is a two-step process. *Journal of Sleep Research, 26*(3), 364-370. doi:10.1111/jsr.12510

Exelmans, L., & Van den Bulck, J. (2017b). Binge viewing, sleep, and the role of pre-sleep arousal. *Journal of Clinical Sleep Medicine, 13*(08), 1001-1008. doi:10.5664/jcsm.6704

Exelmans, L., & Van den Bulck, J. (2019). Sleep research: A primer for media scholars. *Health Communication, 34*(5), 519-528. doi:10.1080/10410236.2017.1422100

Fabbian, F., Zucchi, B., De Giorgi, A., Tiseo, R., Boari, B., Salmi, R., . . . Signani, F. (2016). Chronotype, gender and general health. *Chronobiology international, 33*(7), 863-882. doi:10.1080/07420528.2016.1176927

Fam, J. Y. (2018). Prevalence of internet gaming disorder in adolescents: A meta-analysis across three decades. *Scandinavian Journal of Psychology, 59*(5), 524-531. doi:10.1111/sjop.12459

Ferguson, C. J. (2016). An effect size primer: A guide for clinicians and researchers. In A. E. Kazdin (Ed.), *Methodological issues and strategies in clinical research* (4 ed., pp. 301–310): American Psychological Association.

Ferguson, C. J., & Colwell, J. (2019). Lack of consensus among scholars on the issue of video game “addiction”. *Psychology of Popular Media Culture*. doi:10.1037/ppm0000243

Ferguson, C. J., Coulson, M., & Barnett, J. (2011). A meta-analysis of pathological gaming prevalence and comorbidity with mental health, academic and social problems. *Journal of Psychiatric Research, 45*(12), 1573-1578. doi:10.1016/j.jpsychires.2011.09.005

Festl, R., Scharkow, M., & Quandt, T. (2013). Problematic computer game use among adolescents, younger and older adults. *Addiction, 108*(3), 592-599. doi:10.1111/add.12016

Gangwisch, J. E., Heymsfield, S. B., Boden-Albala, B., Buijs, R. M., Kreier, F., Pickering, T. G., . . . Malaspina, D. (2006). Short sleep duration as a risk factor for hypertension. *Hypertension, 47*(5), 833-839. doi:doi:10.1161/01.HYP.0000217362.34748.e0

Gentile, D. (2009). Pathological video-game use among youth ages 8 to 18:A national study. *Psychological Science, 20*(5), 594-602. doi:10.1111/j.1467-9280.2009.02340.x

Gentile, D. A., Choo, H., Liau, A., Sim, T., Li, D., Fung, D., & Khoo, A. (2011). Pathological video game use among youths: A two-year longitudinal study. *Pediatrics, 127*(2), e319. doi:10.1542/peds.2010-1353

Gervasi, A. M., La Marca, L., Costanzo, A., Pace, U., Guglielmucci, F., & Schimmenti, A. (2017). Personality and internet gaming disorder: A systematic review of recent literature. *Current Addiction Reports, 4*(3), 293-307. doi:10.1007/s40429-017-0159-6

Giang, H. T. N., Ahmed, A. M., Fala, R. Y., Khattab, M. M., Othman, M. H. A., Abdelrahman, S. A. M., . . . Huy, N. T. (2019). Methodological steps used by authors of systematic reviews and meta-analyses of clinical trials: A cross-sectional study. *BMC Medical Research Methodology, 19*(1), 164. doi:10.1186/s12874-019-0780-2

Gottlieb, D. J., Punjabi, N. M., Newman, A. B., Resnick, H. E., Redline, S., Baldwin, C. M., & Nieto, F. J. (2005). Association of sleep time with diabetes mellitus and impaired glucose tolerance. *Archives of Internal Medicine, 165*(8), 863-867. doi:10.1001/archinte.165.8.863

Granic, I., Lobel, A., & Engels, R. C. (2014). The benefits of playing video games. *Am Psychol, 69*(1), 66-78. doi:10.1037/a0034857

Grant, J. E., Potenza, M. N., Weinstein, A., & Gorelick, D. A. (2010). Introduction to behavioral addictions. *Am J Drug Alcohol Abuse, 36*(5), 233-241. doi:10.3109/00952990.2010.491884

Griffiths, M. (2005). A 'components' model of addiction within a biopsychosocial framework. *Journal of Substance use, 10*(4), 191-197. doi:10.1080/14659890500114359

Griffiths, M. (2010a). Online video gaming: What should educational psychologists know? *Educational Psychology in Practice, 26*(1), 35-40. doi:10.1080/02667360903522769

Griffiths, M., Király, O., Pontes, H., & Demetrovics, Z. (2015). An overview of problematic gaming. In E. Aboujaoude & V. Starcevic (Eds.), *Mental health in the digital age: Grave dangers, great promise* (pp. 27-45): Oxford University Press.

Griffiths, M. D. (2002). The educational benefits of videogames. *Education and Health, 20*(3), 47-51.

Griffiths, M. D. (2010b). The role of context in online gaming excess and addiction: Some case study evidence. *International Journal of Mental Health and Addiction, 8*(1), 119-125. doi:10.1007/s11469-009-9229-x

Griffiths, M. D., Davies, M. N., & Chappell, D. (2004). Demographic factors and playing variables in online computer gaming. *CyberPsychology & Behavior, 7*(4), 479-487. doi:10.1089/cpb.2004.7.479

Grønli, J., & Ursin, R. (2009). Basic sleep mechanisms. *Tidsskrift For Den norske Lægeforening: Tidsskrift For Praktisk Medicin, Ny Række, 129*(17), 1758-1761.

Haidich, A. B. (2010). Meta-analysis in medical research. *Hippokratia, 14*(Suppl 1), 29-37.

Harvey, C.-J., Gehrman, P., & Espie, C. A. (2014). Who is predisposed to insomnia: A review of familial aggregation, stress-reactivity, personality and coping style. *Sleep Medicine Reviews, 18*(3), 237-247. doi:10.1016/j.smrv.2013.11.004

Hattar, S., Liao, H.-W., Takao, M., Berson, D. M., & Yau, K.-W. (2002). Melanopsin-containing retinal ganglion cells: Architecture, projections, and intrinsic photosensitivity. *Science, 295*(5557), 1065-1070. doi:10.1126/science.1069609

Hawi, N. S., Samaha, M., & Griffiths, M. D. (2018). Internet gaming disorder in lebanon: Relationships with age, sleep habits, and academic achievement. *Journal of Behavioral Addictions, 7*(1), 70-78. doi:10.1556/2006.7.2018.16

Hébert, S., Béland, R., Dionne-Fournelle, O., Crête, M., & Lupien, S. J. (2005). Physiological stress response to video-game playing: The contribution of built-in music. *Life Sciences, 76*(20), 2371-2380. doi:10.1016/j.lfs.2004.11.011

Henchoz, Y., Studer, J., Deline, S., N'Goran, A. A., Baggio, S., & Gmel, G. (2016). Video gaming disorder and sport and exercise in emerging adulthood: A longitudinal study. *Behavioral Medicine, 42*(2), 105-111. doi:10.1080/08964289.2014.965127

Higgins, J. P., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *Bmj, 327*(7414), 557-560. doi:10.1136/bmj.327.7414.557

Higuchi, S., Motohashi, Y., Liu, Y., & Maeda, A. (2005). Effects of playing a computer game using a bright display on presleep physiological variables, sleep latency, slow wave sleep and rem sleep. *Journal of Sleep Research, 14*(3), 267-273. doi:10.1111/j.1365-2869.2005.00463.x

Horne, J. A., & Östberg, O. (1977). Individual differences in human circadian rhythms. *Biological psychology, 5*(3), 179-190. doi:10.1016/0301-0511(77)90001-1

Huang, Y.-R. (2006). Identity and intimacy crises and their relationship to internet dependence among college students. *CyberPsychology & Behavior, 9*(5), 571-576. doi:10.1089/cpb.2006.9.571

Hull, D. C., Williams, G. A., & Griffiths, M. D. (2013). Video game characteristics, happiness and flow as predictors of addiction among video game players: A pilot study. *Journal of Behavioral Addictions, 2*(3), 145-152. doi:10.1556/JBA.2.2013.005

Interactive Software Federation of Europe [ISFE]. (2019). Gametrack survey 2018. Retrieved 10.06, 2020, from https://www.isfe.eu/wp-content/uploads/2019/08/ISFE-Key-Facts-Brochure-FINAL.pdf

Johnson, E. O., Roth, T., Schultz, L., & Breslau, N. (2006). Epidemiology of dsm-iv insomnia in adolescence: Lifetime prevalence, chronicity, and an emergent gender difference. *Pediatrics, 117*(2), e247-e256. doi:10.1542/peds.2004-2629

Karasek, M., Woldanska-Okonska, M., Czernicki, J., Zylinska, K., & Swietoslawski, J. (1998). Chronic exposure to 2.9 mt, 40 hz magnetic field reduces melatonin concentrations in humans. *Journal of Pineal Research, 25*(4), 240-244. doi:10.1111/j.1600-079X.1998.tb00393.x

Kardefelt-Winther, D. (2014). A conceptual and methodological critique of internet addiction research: Towards a model of compensatory internet use. *Computers in Human Behavior, 31*, 351-354. doi: 10.1016/j.chb.2013.10.059

Kardefelt-Winther, D. (2017). Conceptualizing internet use disorders: Addiction or coping process? *Psychiatry and Clinical Neurosciences, 71*(7), 459-466. doi:10.1111/pcn.12413

Kerkhof, G. A., & Van Dongen, H. P. (1996). Morning-type and evening-type individuals differ in the phase position of their endogenous circadian oscillator. *Neuroscience letters, 218*(3), 153-156. doi:10.1016/S0304-3940(96)13140-2

Kessler, R. C., Berglund, P., Demler, O., Jin, R., Merikangas, K. R., & Walters, E. E. (2005). Lifetime prevalence and age-of-onset distributions of dsm-iv disorders in the national comorbidity survey replication. *Archives of General Psychiatry, 62*(6), 593-602. doi:10.1001/archpsyc.62.6.593

Kim, E. J., Namkoong, K., Ku, T., & Kim, S. J. (2008). The relationship between online game addiction and aggression, self-control and narcissistic personality traits. *European Psychiatry, 23*(3), 212-218. doi:10.1016/j.eurpsy.2007.10.010

Kim, M. G., & Kim, J. (2010). Cross-validation of reliability, convergent and discriminant validity for the problematic online game use scale. *Computers in Human Behavior, 26*(3), 389-398. doi:10.1016/j.chb.2009.11.010

Kim, N., Hughes, T. L., Park, C. G., Quinn, L., & Kong, I. D. (2016a). Resting-state peripheral catecholamine and anxiety levels in korean male adolescents with internet game addiction. *Cyberpsychology, Behavior, and Social Networking, 19*(3), 202-208.

Kim, N. R., Hwang, S. S.-H., Choi, J.-S., Kim, D.-J., Demetrovics, Z., Király, O., . . . Choi, S.-W. (2016b). Characteristics and psychiatric symptoms of internet gaming disorder among adults using self-reported dsm-5 criteria. *Psychiatry investigation, 13*(1), 58-66. doi:10.4306/pi.2016.13.1.58

King, D., Delfabbro, P., & Griffiths, M. (2010). Video game structural characteristics: A new psychological taxonomy. *International Journal of Mental Health and Addiction, 8*(1), 90-106. doi:10.1007/s11469-009-9206-4

King, D. L., Delfabbro, P. H., & Griffiths, M. D. (2012). Trajectories of problem video gaming among adult regular gamers: An 18-month longitudinal study. *Cyberpsychology, Behavior, and Social Networking, 16*(1), 72-76. doi:10.1089/cyber.2012.0062

King, D. L., Delfabbro, P. H., Zwaans, T., & Kaptsis, D. (2014). Sleep interference effects of pathological electronic media use during adolescence. *International Journal of Mental Health and Addiction, 12*(1), 21-35. doi:10.1007/s11469-013-9461-2

King, D. L., Gradisar, M., Drummond, A., Lovato, N., Wessel, J., Micic, G., . . . Delfabbro, P. (2013a). The impact of prolonged violent video-gaming on adolescent sleep: An experimental study. *Journal of Sleep Research, 22*(2), 137-143. doi:10.1111/j.1365-2869.2012.01060.x

King, D. L., Haagsma, M. C., Delfabbro, P. H., Gradisar, M., & Griffiths, M. D. (2013b). Toward a consensus definition of pathological video-gaming: A systematic review of psychometric assessment tools. *Clinical Psychology Review, 33*(3), 331-342. doi:10.1016/j.cpr.2013.01.002

Király, O., Griffiths, M. D., Urbán, R., Farkas, J., Kökönyei, G., Elekes, Z., . . . Demetrovics, Z. (2014a). Problematic internet use and problematic online gaming are not the same: Findings from a large nationally representative adolescent sample. *Cyberpsychology, Behavior, and Social Networking, 17*(12), 749-754. doi:10.1089/cyber.2014.0475

Király, O., Nagygyörgy, K., Griffiths, M. D., & Demetrovics, Z. (2014b). Problematic online gaming. In K. P. Rosenberg & L. C. Feder (Eds.), *Behavioral addictions: Criteria, evidence, and treatment* (pp. 61-97): Elsevier Inc.

Király, O., Urbán, R., Griffiths, M. D., Ágoston, C., Nagygyörgy, K., Kökönyei, G., & Demetrovics, Z. (2015). The mediating effect of gaming motivation between psychiatric symptoms and problematic online gaming: An online survey. [Original Paper]. *J Med Internet Res, 17*(4), e88. doi:10.2196/jmir.3515

Ko, C.-H., Lin, H.-C., Lin, P.-C., & Yen, J.-Y. (2019). Validity, functional impairment and complications related to internet gaming disorder in the dsm-5 and gaming disorder in the icd-11. *Australian and New Zealand Journal of Psychiatry*. doi:10.1177/0004867419881499

Kosmadopoulos, A., Sargent, C., Darwent, D., Zhou, X., & Roach, G. D. (2014). Alternatives to polysomnography (psg): A validation of wrist actigraphy and a partial-psg system. *Behavior Research Methods, 46*(4), 1032-1041. doi:10.3758/s13428-013-0438-7

Kripke, D. F., Garfinkel, L., Wingard, D. L., Klauber, M. R., & Marler, M. R. (2002). Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry, 59*(2), 131-136. doi:10.1001/archpsyc.59.2.131

Krossbakken, E., Pallesen, S., Mentzoni, R. A., King, D. L., Molde, H., Finserås, T. R., & Torsheim, T. (2018). A cross-lagged study of developmental trajectories of video game engagement, addiction, and mental health. [Original Research]. *Frontiers in Psychology, 9*(2239). doi:10.3389/fpsyg.2018.02239

Krueger, J., & Opp, M. (2016). Sleep and microbes. In J. F. Cryan & G. Clarke (Eds.), *International review of neurobiology* (Vol. 131, pp. 207-225): Academic Press.

Kuss, D. J., & Griffiths, M. D. (2012). Internet gaming addiction: A systematic review of empirical research. *International Journal of Mental Health and Addiction, 10*(2), 278-296. doi:10.1007/s11469-011-9318-5

Kuss, D. J., Pontes, H. M., & Griffiths, M. D. (2018). Neurobiological correlates in internet gaming disorder: A systematic literature review. *Frontiers in Psychiatry, 9*(166). doi:10.3389/fpsyt.2018.00166

Lallukka, T., Dregan, A., & Armstrong, D. (2011). Comparison of a sleep item from the general health questionnaire-12 with the jenkins sleep questionnaire as measures of sleep disturbance. *Journal of Epidemiology, 21*(6), 474-480. doi:10.2188/jea.JE20110023

Lam, L. T. (2014). Internet gaming addiction, problematic use of the internet, and sleep problems: A systematic review. *Current Psychiatry Reports, 16*(4). doi:10.1007/s11920-014-0444-1

Landry, G., Best, J., & Liu-Ambrose, T. (2015). Measuring sleep quality in older adults: A comparison using subjective and objective methods. *Frontiers in Aging Neuroscience, 7*(166). doi:10.3389/fnagi.2015.00166

Lehenbauer-Baum, M., Klaps, A., Kovacovsky, Z., Witzmann, K., Zahlbruckner, R., & Stetina, B. U. (2015). Addiction and engagement: An explorative study toward classification criteria for internet gaming disorder. *Cyberpsychology, Behavior, and Social Networking, 18*(6), 343-349. doi:10.1089/cyber.2015.0063

Lemmens, J. S., & Hendriks, S. J. F. (2016). Addictive online games: Examining the relationship between game genres and internet gaming disorder. *Cyberpsychology, Behavior, and Social Networking, 19*(4), 270-276. doi:10.1089/cyber.2015.0415

Lemmens, J. S., Valkenburg, P. M., & Gentile, D. A. (2015). The internet gaming disorder scale. *Psychological assessment, 27*(2), 567. doi:10.1037/pas0000062

Lemmens, J. S., Valkenburg, P. M., & Peter, J. (2009). Development and validation of a game addiction scale for adolescents. *Media Psychology, 12*(1), 77-95. doi:10.1080/15213260802669458

Lemmens, J. S., Valkenburg, P. M., & Peter, J. (2011). Psychosocial causes and consequences of pathological gaming. *Computers in Human Behavior, 27*(1), 144-152. doi:10.1016/j.chb.2010.07.015

Liau, A. K., Choo, H., Li, D., Gentile, D. A., Sim, T., & Khoo, A. (2015). Pathological video-gaming among youth: A prospective study examining dynamic protective factors. *Addiction Research & Theory, 23*(4), 301-308. doi:10.3109/16066359.2014.987759

Libman, E., Fichten, C. S., Bailes, S., & Amsel, R. (2000). Sleep questionnaire versus sleep diary: Which measure is better? *International Journal of Rehabilitation and Health, 5*(3), 205-209. doi:10.1023/A:1012955423123

Lichstein, K. L., Taylor, D. J., McCrae, C. S., & Petrov, M. E. (2017). Chapter 81 - insomnia: Epidemiology and risk factors. In M. Kryger, T. Roth & W. C. Dement (Eds.), *Principles and practice of sleep medicine (sixth edition)* (pp. 761-768.e764): Elsevier.

Lin, C.-Y., Imani, V., Brostrom, A., Arestedt, K., Pakpour, A. H., & Griffiths, M. D. (2019). Evaluating the psychometric properties of the 7-item persian game addiction scale for iranian adolescents. *Frontiers in Psychology, 10*. doi:10.3389/fpsyg.2019.00149

Lockley, S. W., & Foster, R. G. (2012). *Sleep: A very short introduction* (Vol. 295). New York: Oxford University Press.

Lockley, S. W., Skene, D. J., & Arendt, J. (1999). Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. *Journal of Sleep Research, 8*(3), 175-183. doi:10.1046/j.1365-2869.1999.00155.x

Loughran, S. P., Wood, A. W., Barton, J. M., Croft, R. J., Thompson, B., & Stough, C. (2005). The effect of electromagnetic fields emitted by mobile phones on human sleep. *NeuroReport, 16*(17). doi:10.1097/01.wnr.0000186593.79705.3c

Lowden, A., Åkerstedt, T., Ingre, M., Wiholm, C., Hillert, L., Kuster, N., . . . Arnetz, B. (2011). Sleep after mobile phone exposure in subjects with mobile phone-related symptoms. *Bioelectromagnetics, 32*(1), 4-14. doi:10.1002/bem.20609

Mannikko, N., Billieux, J., & Kaariainen, M. (2015). Problematic digital gaming behavior and its relation to the psychological, social and physical health of finnish adolescents and young adults. *Journal of Behavioral Addictions, 4*(4), 281-288. doi:10.1556/2006.4.2015.040

Maquet, P. (1995). Sleep function(s) and cerebral metabolism. *Behavioural Brain Eesearch, 69*(1-2), 75-83. doi:10.1016/0166-4328(95)00017-n

Marino, M., Li, Y., Rueschman, M. N., Winkelman, J. W., Ellenbogen, J., Solet, J. M., . . . Buxton, O. M. (2013). Measuring sleep: Accuracy, sensitivity, and specificity of wrist actigraphy compared to polysomnography. *Sleep, 36*(11), 1747-1755. doi:10.5665/sleep.3142

Markovitz, J. H., Raczynski, J. M., Wallace, D., Chettur, V., & Chesney, M. A. (1998). Cardiovascular reactivity to video game predicts subsequent blood pressure increases in young men: The cardia study. *Psychosomatic medicine, 60*(2), 186-191.

Marshall, L., & Born, J. (2002). Brain-immune interactions in sleep. *International Review of Neurobiology, 52*, 93-131. doi:S0074-7742(02)52007-9

Mentzoni, R., Brunborg, G., Molde, H., Myrseth, H., Skouverøe, K., Hetland, J., & Pallesen, S. (2011). Problematic video game use: Estimated prevalence and associations with mental and physical health. *Cyberpsychology, Behavior and Social Networking, 14*, 591-596. doi:10.1089/cyber.2010.0260

Messias, E., Castro, J., Saini, A., Usman, M., & Peeples, D. (2011). Sadness, suicide, and their association with video game and internet overuse among teens: Results from the youth risk behavior survey 2007 and 2009. *Suicide and Life-Threatening Behavior, 41*(3), 307-315. doi:10.1111/j.1943-278X.2011.00030.x

Mihara, S., & Higuchi, S. (2017). Cross-sectional and longitudinal epidemiological studies of internet gaming disorder: A systematic review of the literature. *Psychiatry and Clinical Neurosciences, 71*(7), 425-444. doi:10.1111/pcn.12532

Modesti, P. A., Reboldi, G., Cappuccio, F. P., Agyemang, C., Remuzzi, G., Rapi, S., . . . Settings, E. S. H. W. G. o. C. R. i. L. R. (2016). Panethnic differences in blood pressure in europe: A systematic review and meta-analysis. *PLOS ONE, 11*(1), e0147601. doi:10.1371/journal.pone.0147601

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The, P. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The prisma statement. *PLOS Medicine, 6*(7), e1000097. doi:10.1371/journal.pmed.1000097

Monderer, R., Harris, S., & Thorpy, M. (2014). Chapter 51 - neurologic aspects of sleep medicine. In M. J. Aminoff & A. S. Josephson (Eds.), *Aminoff's neurology and general medicine* (5 ed., pp. 1033-1065): Academic Press.

Monk, T. H., REYNOLDS III, C. F., Kupfer, D. J., Buysse, D. J., Coble, P. A., Hayes, A. J., . . . Ritenour, A. M. (1994). The pittsburgh sleep diary. *Journal of Sleep Research, 3*(2), 111-120. doi:10.1111/j.1365-2869.1994.tb00114.x

Montag, C., Flierl, M., Markett, S., Walter, N., Jurkiewicz, M., & Reuter, M. (2011). Internet addiction and personality in first-person-shooter video gamers. *Journal of Media Psychology, 23*(4), 163-173. doi:10.1027/1864-1105/a000049

Morin, C. M., & Benca, R. (2012). Chronic insomnia. *The Lancet, 379*(9821), 1129-1141. doi:10.1016/S0140-6736(11)60750-2

Männikkö, N., Ruotsalainen, H., Miettunen, J., Pontes, H. M., & Kääriäinen, M. (2017). Problematic gaming behaviour and health-related outcomes: A systematic review and meta-analysis. *Journal of Health Psychology, 25*(1), 67-81. doi:10.1177/1359105317740414

Männikkö, N., Ruotsalainen, H., Tolvanen, A., & Kääriäinen, M. (2019). Problematic gaming is associated with some health-related behaviors among finnish vocational school students. *International Journal of Mental Health and Addiction*. doi:10.1007/s11469-019-00100-6

Nemes, S., Jonasson, J. M., Genell, A., & Steineck, G. (2009). Bias in odds ratios by logistic regression modelling and sample size. *BMC Medical Research Methodology, 9*(1), 56. doi:10.1186/1471-2288-9-56

Nogueira, M., Faria, H., Vitorino, A., Silva, F. G., & Neto, A. S. (2019). Addictive video game use: An emerging pediatric problem? *Acta Medica Portuguesa, 32*(3), 183-188. doi:10.20344/amp.10985

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A monte carlo simulation study. *Structural Equation Modeling: A Multidisciplinary Journal, 14*(4), 535-569. doi:10.1080/10705510701575396

Ohayon, M. M. (2002). Epidemiology of insomnia: What we know and what we still need to learn. *Sleep Medicine Reviews, 6*(2), 97-111. doi:10.1053/smrv.2002.0186

Ohayon, M. M. (2005). Relationship between chronic painful physical condition and insomnia. *Journal of Psychiatric Research, 39*(2), 151-159. doi:10.1016/j.jpsychires.2004.07.001

Orwin, R. G. (1983). A fail-safe n for effect size in meta-analysis. *Journal of Educational Statistics*, 157-159. doi:10.2307/1164923

Paine, S.-J., Gander, P. H., & Travier, N. (2006). The epidemiology of morningness/eveningness: Influence of age, gender, ethnicity, and socioeconomic factors in adults (30-49 years). *Journal of biological rhythms, 21*(1), 68-76. doi:10.1177/0748730405283154

Pallesen, S., Sivertsen, B., Nordhus, I. H., & Bjorvatn, B. (2014). A 10-year trend of insomnia prevalence in the adult norwegian population. *Sleep Medicine, 15*(2), 173-179. doi:10.1016/j.sleep.2013.10.009

Pandi-Perumal, S. R., Zisapel, N., Srinivasan, V., & Cardinali, D. P. (2005). Melatonin and sleep in aging population. *Experimental Gerontology, 40*(12), 911-925. doi:10.1016/j.exger.2005.08.009

Patel, S. R., & Hu, F. B. (2008). Short sleep duration and weight gain: A systematic review. *Obesity, 16*(3), 643-653. doi:10.1038/oby.2007.118

Peracchia, S., & Curcio, G. (2018). Exposure to video games: Effects on sleep and on post-sleep cognitive abilities. A sistematic review of experimental evidences. *Sleep Science (Sao Paulo, Brazil), 11*(4), 302-314. doi:10.5935/1984-0063.20180046

Peracchia, S., Triberti, S., & Curcio, G. (2017). Longer the game, better the sleep: Intense video game playing is associated to better sleep quality and better daytime functioning. *Annual Review of CyberTherapy and Telemedicine, 15*, 204-206.

Perlis, M. L., Giles, D. E., Mendelson, W. B., Bootzin, R. R., & Wyatt, J. K. (1997). Psychophysiological insomnia: The behavioural model and a neurocognitive perspective. *Journal of Sleep Research, 6*(3), 179-188. doi:10.1046/j.1365-2869.1997.00045.x

Petry, N. M., Rehbein, F., Gentile, D. A., Lemmens, J. S., Rumpf, H.-J., Mößle, T., . . . O'Brien, C. P. (2014). An international consensus for assessing internet gaming disorder using the new dsm-5 approach. *Addiction, 109*(9), 1399-1406. doi:10.1111/add.12457

Pontes, H. M., & Griffiths, M. D. (2014a). Assessment of internet gaming disorder in clinical research: Past and present perspectives. *Clinical Research and Regulatory Affairs, 31*(2-4), 35-48. doi:10.3109/10601333.2014.962748

Pontes, H. M., & Griffiths, M. D. (2014b). Internet addiction disorder and internet gaming disorder are not the same. *Journal of Addiction Research & Therapy, 5*(4). doi:10.4172/2155-6105.1000e124

Porter, G., Starcevic, V., Berle, D., & Fenech, P. (2010). Recognizing problem video game use. *Australian and New Zealand Journal of Psychiatry, 44*(2), 120-128. doi:10.3109/00048670903279812

Prentice, D. A., & Miller, D. T. (1992). When small effects are impressive. *Psychological Bulletin, 112*(1), 160-164. doi:10.1037/0033-2909.112.1.160

Randler, C., Bilger, S., & Díaz-Morales, J. F. (2009). Associations among sleep, chronotype, parental monitoring, and pubertal development among german adolescents. *The Journal of Psychology, 143*(5), 509-520. doi:10.3200/JRL.143.5.509-520

Rasch, B., & Born, J. (2013). About sleep's role in memory. *Physiological reviews, 93*(2), 681-766. doi:10.1152/physrev.00032.2012

Rehbein, F., & Baier, D. (2013). Family-, media-, and school-related risk factors of video game addiction. *Journal of Media Psychology, 25*(3), 118-128. doi:10.1027/1864-1105/a000093

Rehbein, F., Kleimann, M., & Mossle, T. (2010). Prevalence and risk factors of video game dependency in adolescence: Results of a german nationwide survey. [Validation Studies]. *Cyberpsychology, behavior and social networking, 13*(3), 269-277. doi:10.1089/cyber.2009.0227

Rehbein, F., Kliem, S., Baier, D., Mosle, T., & Petry, N. M. (2015). Prevalence of internet gaming disorder in german adolescents: Diagnostic contribution of the nine dsm-5 criteria in a state-wide representative sample. [Empirical Study; Interview; Quantitative Study]. *Addiction, 110*(5), 842-851. doi:10.1111/add.12849

Rikkers, W., Lawrence, D., Hafekost, J., & Zubrick, S. R. (2016). Internet use and electronic gaming by children and adolescents with emotional and behavioural problems in australia – results from the second child and adolescent survey of mental health and wellbeing. *BMC Public Health, 16*(1), 399. doi:10.1186/s12889-016-3058-1

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological bulletin, 86*(3), 638.

Şalvarlı, Ş. İ., & Griffiths, M. D. (2019). Internet gaming disorder and its associated personality traits: A systematic review using prisma guidelines. *International Journal of Mental Health and Addiction*. doi:10.1007/s11469-019-00081-6

Sateia, M. J. (2009). Update on sleep and psychiatric disorders. *Chest, 135*(5), 1370-1379. doi:10.1378/chest.08-1834

Satghare, P., Abdin, E., Vaingankar, J. A., Chua, B. Y., Pang, S., Picco, L., . . . Subramaniam, M. (2016). Prevalence of sleep problems among those with internet gaming disorder in singapore. *Asean Journal of Psychiatry, 17*(2), 188-198.

Saunders, J. B., Hao, W., Long, J., King, D. L., Mann, K., Fauth-Buhler, M., . . . Poznyak, V. (2017). Gaming disorder: Its delineation as an important condition for diagnosis, management, and prevention. *J Behav Addict, 6*(3), 271-279. doi:10.1556/2006.6.2017.039

Scharf, M. T., Naidoo, N., Zimmerman, J. E., & Pack, A. I. (2008). The energy hypothesis of sleep revisited. *Progress in Neurobiology, 86*(3), 264-280. doi:10.1016/j.pneurobio.2008.08.003

Scharkow, M., Festl, R., & Quandt, T. (2014). Longitudinal patterns of problematic computer game use among adolescents and adults—a 2-year panel study. *Addiction, 109*(11), 1910-1917. doi:10.1111/add.12662

Shaffer, H. J., LaPlante, D. A., LaBrie, R. A., Kidman, R. C., Donato, A. N., & Stanton, M. V. (2004). Toward a syndrome model of addiction: Multiple expressions, common etiology. *Harvard Review of Psychiatry, 12*(6), 367-374. doi:10.1080/10673220490905705

Short, M. A., Gradisar, M., Lack, L. C., Wright, H., & Carskadon, M. A. (2012). The discrepancy between actigraphic and sleep diary measures of sleep in adolescents. *Sleep Medicine, 13*(4), 378-384. doi:10.1016/j.sleep.2011.11.005

Signal, T. L., Gale, J., & Gander, P. H. (2005). Sleep measurement in flight crew: Comparing actigraphic and subjective estimates to polysomnography. *Aviation, Space, and Environmental Medicine, 76*(11), 1058-1063.

Singleton, N., Bumpstead, R., O'Brien, M., Lee, A., & Meltzer, H. (2003). Psychiatric morbidity among adults living in private households, 2000. *Int Rev Psychiatry, 15*(1-2), 65-73. doi:10.1080/0954026021000045967

Sivertsen, B., Harvey, A. G., Pallesen, S., & Hysing, M. (2015). Mental health problems in adolescents with delayed sleep phase: Results from a large population-based study in n orway. *Journal of Sleep Research, 24*(1), 11-18.

Sivertsen, B., Krokstad, S., Øverland, S., & Mykletun, A. (2009). The epidemiology of insomnia: Associations with physical and mental health.: The hunt-2 study. *Journal of Psychosomatic Research, 67*(2), 109-116. doi:10.1016/j.jpsychores.2009.05.001

Sivertsen, B., Salo, P., Mykletun, A., Hysing, M., Pallesen, S., Krokstad, S., . . . Øverland, S. (2012). The bidirectional association between depression and insomnia: The hunt study. *Psychosomatic Medicine, 74*(7). doi:10.1097/PSY.0b013e3182648619

Song, F., Hooper, L., & Loke, Y. (2013). Publication bias: What is it? How do we measure it? How do we avoid it? *Open Access Journal of Clinical Trials, 5*, 71-81. doi:10.2147/OAJCT.S34419

Starcevic, V., Berle, D., Porter, G., & Fenech, P. (2011). Problem video game use and dimensions of psychopathology. *International Journal of Mental Health and Addiction, 9*(3), 248-256. doi:10.1007/s11469-010-9282-5

Stavropoulos, V., Anderson, E. E., Beard, C., Latifi, M. Q., Kuss, D., & Griffiths, M. (2019). A preliminary cross-cultural study of hikikomori and internet gaming disorder: The moderating effects of game-playing time and living with parents. *Addictive Behaviors Reports, 9*, 100137. doi:10.1016/j.abrep.2018.10.001

Sterne, J. A. C., Egger, M., & Smith, G. D. (2001). Investigating and dealing with publication and other biases in meta-analysis. *BMJ, 323*(7304), 101. doi:10.1136/bmj.323.7304.101

Stockdale, L., & Coyne, S. M. (2018). Video game addiction in emerging adulthood: Cross-sectional evidence of pathology in video game addicts as compared to matched healthy controls. *Journal of Affective Disorders, 225*, 265-272. doi:10.1016/j.jad.2017.08.045

Stone, A. L., Becker, L. G., Huber, A. M., & Catalano, R. F. (2012). Review of risk and protective factors of substance use and problem use in emerging adulthood. *Addictive Behaviors, 37*(7), 747-775. doi:10.1016/j.addbeh.2012.02.014

Stone, K. L., & Ancoli-Israel, S. (2017). Chapter 171 - actigraphy. In M. Kryger, T. Roth & W. C. Dement (Eds.), *Principles and practice of sleep medicine (sixth edition)* (pp. 1671-1678.e1674): Elsevier.

Strittmatter, E., Kaess, M., Parzer, P., Fischer, G., Carli, V., Hoven, C. W., . . . Wasserman, D. (2015). Pathological internet use among adolescents: Comparing gamers and non-gamers. *Psychiatry Research, 228*(1), 128-135. doi:10.1016/j.psychres.2015.04.029

Taylor, D. J., Mallory, L. J., Lichstein, K. L., Durrence, H. H., Riedel, B. W., & Bush, A. J. (2007). Comorbidity of chronic insomnia with medical problems. *Sleep, 30*(2), 213-218. doi:10.1093/sleep/30.2.213

The Norwegian Media Authority [Medietilsynet]. (2018). Barn og medierundersøkelsen 2018: 9 – 18-åringer om medievaner og opplevelser. Retrieved from https://medietilsynet.no/globalassets/publikasjoner/barn-og-medier-undersokelser/2018-barn-og-medier

Toker, S., & Baturay, M. H. (2016). Antecedents and consequences of game addiction. *Computers in Human Behavior, 55*, 668-679. doi:10.1016/j.chb.2015.10.002

Turel, O., Romashkin, A., & Morrison, K. M. (2016). Health outcomes of information system use lifestyles among adolescents: Videogame addiction, sleep curtailment and cardio-metabolic deficiencies. *PLoS ONE [Electronic Resource], 11*(5), e0154764. doi:10.1371/journal.pone.0154764

Uehli, K., Mehta, A. J., Miedinger, D., Hug, K., Schindler, C., Holsboer-Trachsler, E., . . . Künzli, N. (2014). Sleep problems and work injuries: A systematic review and meta-analysis. *Sleep Medicine Reviews, 18*(1), 61-73. doi:10.1016/j.smrv.2013.01.004

Ursin, R., Bjorvatn, B., & Holsten, F. (2005). Sleep duration, subjective sleep need, and sleep habits of 40-to 45-year-olds in the hordaland health study. *Sleep, 28*(10), 1260-1269. doi:10.1093/sleep/28.10.1260

Van de Laar, M., Verbeek, I., Pevernagie, D., Aldenkamp, A., & Overeem, S. (2010). The role of personality traits in insomnia. *Sleep Medicine Reviews, 14*(1), 61-68. doi:10.1016/j.smrv.2009.07.007

Van den Bulck, J. (2000). Is television bad for your health? Behavior and body image of the adolescent “couch potato”. *Journal of Youth and Adolescence, 29*(3), 273-288. doi:10.1023/A:1005102523848

Van Rooij, A. J., Ferguson, C. J., Carras, M. C., Kardefelt-Winther, D., Shi, J., Aarseth, E., . . . Przybylski, A. K. (2018). A weak scientific basis for gaming disorder: Let us err on the side of caution. *Journal of Behavioral Addictions, 7*(1), 1. doi:10.1556/2006.7.2018.19

Van Rooij, A. J., Schoenmakers, T. M., van den Eijnden, R. J. J. M., Vermulst, A. A., & van de Mheen, D. (2012). Video game addiction test: Validity and psychometric characteristics. *Cyberpsychology, Behavior, and Social Networking, 15*(9), 507-511. doi:10.1089/cyber.2012.0007

Van Rooij, A. J., Schoenmakers, T. M., Vermulst, A. A., Van Den Eijnden, R. J. J. M., & Van De Mheen, D. (2011). Online video game addiction: Identification of addicted adolescent gamers. *Addiction, 106*(1), 205-212. doi:10.1111/j.1360-0443.2010.03104.x

Vollmer, C., Randler, C., Horzum, M. B., & Ayas, T. (2014). Computer game addiction in adolescents and its relationship to chronotype and personality. *SAGE Open, 4*(1). doi:10.1177/2158244013518054

Vyazovskiy, V. V., & Harris, K. D. (2013). Sleep and the single neuron: The role of global slow oscillations in individual cell rest. *Nature Reviews Neuroscience, 14*(6), 443-451. doi:10.1038/nrn3494

Wang, X., & Perry, A. C. (2006). Metabolic and physiologic responses to video game play in 7- to 10-year-old boys. *Archives of Pediatrics & Adolescent Medicine, 160*(4), 411-415. doi:10.1001/archpedi.160.4.411

Weinstein, A., & Weizman, A. (2012). Emerging association between addictive gaming and attention-deficit/hyperactivity disorder. *Current Psychiatry Reports, 14*(5), 590-597. doi:10.1007/s11920-012-0311-x

Wells, G., Shea, B., O’Connell, D., Peterson, J., Welch, V., Losos, M., & Tugwell, P. (2014). Newcastle-ottawa quality assessment scale cohort studies. *Ontario, Canada: University of Ottawa*.

Wenzel, H., Bakken, I., Johansson, A., Gotestam, K., & Oren, A. (2009). Excessive computer game playing among norwegian adults: Self-reported consequences of playing and association with mental health problems. *Psychological Reports, 105*(3, Pt2), 1237-1247. doi:10.2466/pr0.105.F.1237-1247

Widyanto, L., Griffiths, M. D., & Brunsden, V. (2011). A psychometric comparison of the internet addiction test, the internet-related problem scale, and self-diagnosis. *Cyberpsychology, Behavior, and Social Networking, 14*(3), 141-149. doi:10.1089/cyber.2010.0151

Wilson, S., & Nutt, D. (2013). *Sleep disorders*. Oxford: Oxford University Press USA - OSO.

Wittek, C. T., Finserås, T. R., Pallesen, S., Mentzoni, R. A., Hanss, D., Griffiths, M. D., & Molde, H. (2016). Prevalence and predictors of video game addiction: A study based on a national representative sample of gamers. *International Journal of Mental Health and Addiction, 14*(5), 672-686. doi:10.1007/s11469-015-9592-8

Wood, R. T. A. (2008). Problems with the concept of video game “addiction”: Some case study examples. *International Journal of Mental Health and Addiction, 6*(2), 169-178. doi:10.1007/s11469-007-9118-0

World Health Organization. (2018). *International classification of diseases for mortality and morbidity statistics*. Geneva: WHO.

Xie, L., Kang, H., Xu, Q., Chen, M. J., Liao, Y., Thiyagarajan, M., . . . Iliff, J. J. (2013). Sleep drives metabolite clearance from the adult brain. *Science, 342*(6156), 373-377. doi:10.1126/science.1241224

Young, K. S. (1998). Internet addiction: The emergence of a new clinical disorder. *CyberPsychology & Behavior, 1*(3), 237-244. doi:10.1089/cpb.1998.1.237

Aarseth, E., Bean, A. M., Boonen, H., Colder Carras, M., Coulson, M., Das, D., . . . Van Rooij, A. J. (2017). Scholars' open debate paper on the world health organization icd-11 gaming disorder proposal. *Journal of Behavioral Addictions, 6*(3), 267-270. doi:10.1556/2006.5.2016.088

Appendix

Appendix A. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Front page
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	III & IV
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	1 - 22
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	22
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	22 & 23
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	23
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	23
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	23
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	23, 25, 28 & 31
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	24 & 25
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	24 & Appendix B
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	24 & 25
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	25 & 26
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	24, 25 & 26

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	26
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	26
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	27 & 28
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	27 - 30
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	31
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	31-34 & Appendix D
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	31-34
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	31-34
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	31-34
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	34-43
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	39-41
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	43
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Acknowledges

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

Appendix B. Coding Schema

		Report identification	
		Study ID – Effect size ID	
		Coder ID	
		Author(s)	
		Type of manuscript	1: Research paper 2: Dissertation / Thesis 3: Public report 4: Unpublished data 5: Other: specify
		Year published	=
		Study setting	
		Study design	1: Cross-sectional 2: Cross-sectional longitudinal 3: Experimental 4: Qualitative 5: Quasi-experimental 7: Case study 8: Intervention study 9: Prospective study 10: Other; specify
		Country	=
		Continent	1: Europe 2: Middle east 3: Asia 4: Australia 5: Africa 6: South America 7: North America
		Year of data collection	=
		Ethical approval	1: yes 2: no
		Conflict of interest stated	1: no 2: yes
		Participants	
		Total *N*	=

		Total Mean age (S.D)	State the mean age and standard deviation of the whole sample.
		Total Age range	State the age range of the whole sample. (e.g. 18-35)
		Total Sex (% females)	State the percentage of females in whole sample.
		Total Age category	1: Children <10 2: Adolescents 10-18 3: Young adults 18-34 4: Adults >35 5: Mix Child/adolescents <18 6 Mix adults > 18 7: Mix
		N Problematic gamers (%)	=
		N non-Problematic gamers (%)	=
		Problematic gamer sex (% female)	=
		Response rate %	=
		Type of selection	1: Random population sampling 2: Primary / High school students 3: College / University students 4: Gaming community 5: Public/Medical records 6: Treatment 7: Other; specify
		Gaming device	1: PC 2: TV-console 3: Handheld gaming console 4: Smartphone/Tablet 5: Mix
		Internet connected gaming	1: yes 2: no
		Methodology	
		Gaming data collection method	1: Self report (Survey) 2: Parental report (Survey) 3: Interview 4: Objective measurements
		Problematic gaming (PG) instrument	=
		PG Operationalization	1: Excessive Gaming 2: Self-identifying as PG 3: Dependence/Addiction Criteria 4: Other; specify

		PG Instrument Reliability / Cronbach's alpha	=
		PG parameter is categorical or continuous (scale)	1: Categorical 2: Continuous (Scale)
		If PG parameter is categorical, cut of value =	=
		Sleep parameter	1: Sleep length 2: Sleep quality 3: Sleep loss/deprivation 4: Insomnia 5: Sleep problems / difficulties 6: Involuntary awakenings 7: Snoring 8: Hypersomnia 9: Circadian rhythm (M-E) 10: Social jetlag 11: Daytime sleepiness 12: Sleep onset latency 13: Delayed sleep phase 14: Other; specify
		Sleep data collection method	1: Self report (Survey) 2: Parental report (Survey) 3: Interview 4: Objective measurements
		Sleep parameter instrument	=
		Sleep parameter instrument reliability / Cronbach's alpha	=
		Sleep parameter is categorical or continuous (scale)	1: Categorical 2: Continuous (scale)
		If sleep parameter is categorical, cut of value =	=
		Results	
		Reports association between PG and sleep problems	1: yes 2: no
		Reports differences in sleep parameters in PG individuals and non- PG individuals	1: yes 2: no
		Type of coefficient / estimate	=
		Result/Effect size	=
		Confidence interval	=
		p-value	=
		If group comparisons, result adjusted for confounding variables	1: age 2: sex

			3: Education 4: Psychopathology (Anxiety / Depression) 5: Alcohol / Illegal substance use 6: Previously reported sleep problems (if longitudinal) 7: Other; specify

Appendix C: Newcastle - Ottawa Quality Assessment Scale

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE **(adapted for cross sectional studies)**	
Selection: Maximum 5 stars (tick one box in each section)	
1. Representativeness of the sample: a) Truly representative of the average in the target population. (all subjects or random sampling) ★ b) Somewhat representative of the average in the target population. (non- random sampling) ★ c) selected group of users d) no description of the sampling strategy	☐ ☐ ☐ ☐
2. Sample size: a) Justified and satisfactory ★ b) Not justified	☐ ☐
3. Non-respondents: a) Comparability between respondents and non-respondents characteristics is established, and the response rate is satisfactory ★ b) The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory c) No description of the response rate or the characteristics of the responders and the non-responders	☐ ☐ ☐
4. Ascertainment of the exposure (risk factor): a) Validated measurement tool ★★ b) Non-validated measurement tool, but the tool is available or described. c) No description of the measuring tool	☐ ☐ ☐
Comparability: Maximum 2 stars (tick one or both boxes, as appropriate)	
1. The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled: a) Study controls for <u>age and/or sex</u> ★ b) Study controls for any additional factors (<u>e.g. psychopathy, educational level, prior sleep problems</u>) ★	☐ ☐
Outcome: Maximum 3 stars (tick one box in each section)	
1. Assessment of outcome: a) Independent blind assessment ★★ b) Record linkage ★★ c) Objective measurements ★★ d) Self report ★ e) Other / no description	☐ ☐ ☐ ☐ ☐

	☐
2. Statistical test: a) The statistical test used to analyze the data is clearly described and appropriate, ★ and the measurement of the association is presented, including confidence intervals and the probability level (p value) b) The statistical test is not appropriate, not described or incomplete	☐ ☐
Stars in total =	

Appendix D. Table of study characteristics and results.

First author	Year	Country	Sample size (n)	Mean age (SD) / range	Sex (Females %)	PG prevalence % (subgroups)[a]	PG instrument	PG cutoff	Sleep Instrument	Sleep cutoff	Sleep parameter(s) and result(s)	NOS
Achab, S.	2011	France	448	26.6 (7.1) /18-54	17.3	27.5	DSM-IV-TR Substance dependence Adapted Scale (DAS)	≥ 3 of 7 criteria	Single items	Continuous	Sleep duration ↓	6
										Yes/No	Sleep quality ↓	
											Daytime sleepiness ↑	
											Sleep deprivation ↑	
Al Gammal, M. A.	2019	Egypt	60	21.9 (2.7) / 18-26	53.3	23.3 (18.3 / 5.0)	IGDS	≥ 5 of 9 criteria	PSQI	–	Sleep quality ↑	4
Arnesen, A. A.	2010	Norway	816	27.9 (7.36) / 16-40	56.1	4.0	GASA	≥ 4 of 7 items	BIS	Continuous	Insomnia ↑	6
Bonnaire, C.	2017	France	434	13.15 (0.5) / -	46.8	8.5	GASA	≥ 4 of 7 items	Single item	Yes/No	Sleep problems ↓^{NS}	5
Brunborg, G. S.	2013	Norway	1320	13.6 (0.32) / 14-15	52.1	17.1 (4.2 / 12.9)	GASA	2-3 / ≥ 4 core symptoms	Single items	≥ once a week	Sleep problems ↑	9
											Daytime sleepiness ↑	
Hawi, N. S.	2018	Lebanon	524	16.1 (1.0) / 15-19	52.1	44.9 (9.2 / 35.7)	IGD-20	≥ 50 / ≥ 71 test score	Single items	Sometimes or more	Sleep duration ↓	7
											Woke up to continue playing ↑	

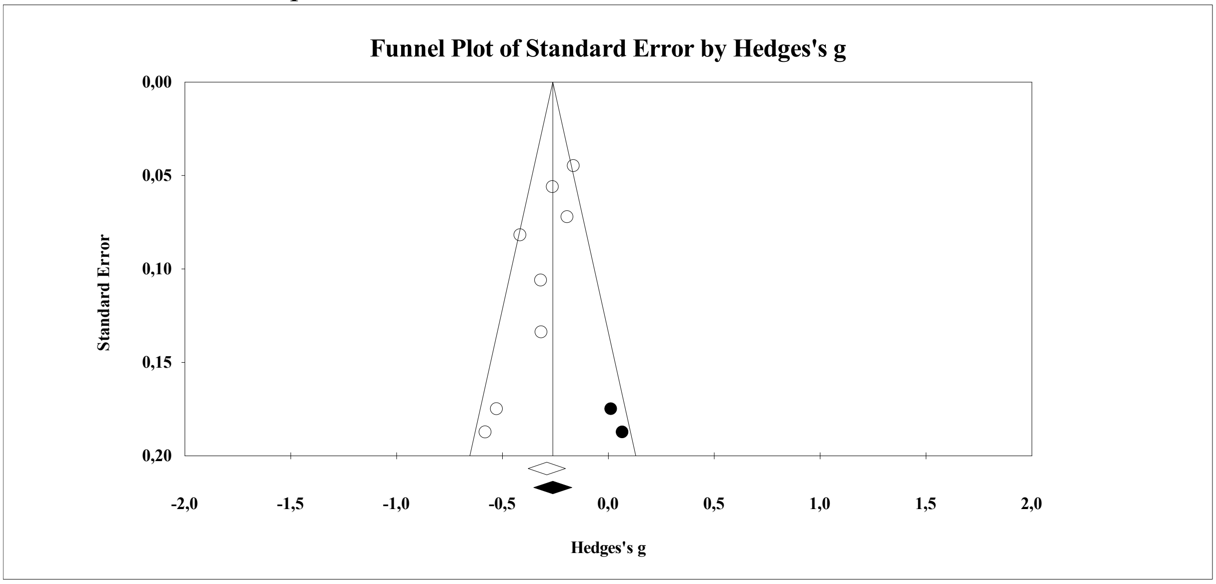
Kim, N.	2016	South Korea	230	16.63 (1.02) / 15-18	Males only	51.3	OGASA	≥ 38 test score	Single item	>< 6 hours of sleep	Sleep duration	↓	5
King, D. L.	2014	Australia	1287	14.9 (1.5) / 12-18	50.4	–	PTU	–	SAMQ	–	Sleep duration	↓	5
											Sleep onset latency	↑	
											Electronic media related sleep disruption	↑	
Ko, C.-H.	2019	Taiwan	207 / 138[c]	25.59 (3.8) / 20-38	21.7	50*	Diagnostic interview based on DSM-IGD and ICD-GD criteria	IGD: ≥ 5 of 9 criteria GD: endorsement of 4, 5, 6, and 9th criteria of IGD	Diagnostic interview	Yes/No	Insomnia	↑	4
										Yes/No	Delayed sleep phase disorder	↑	
										<1, 1-2, >3 am	Falling asleep at a later time	↑	
										<9 am, 9 am-12 pm, > 12 pm	Waking up at a later time	↑	
										Yes/No	Turning night into day	↑	
										Less than 4 hours sleep 2 or more days a week	Inadequate sleep time	↑	
Lin, C.-Y.	2019	Iran	4442	15.3 (1.6) / 13-18	49.7	73.9 (47.9 / 26.0)	GAS	Latent class analysis (LCA)	PSQI	Continuous	Sleep quality	↓	9
Männikkö, N.	2015	Finland	293	18.7 (3.4) / 13-24	49	8.2	GAS	≥ 4 of 7 items	Single item	Every week or more often	Sleep problems	↑	4

Männikkö, N.	2019	Finland	773	17.5 (4.4) / 16-19	41.1	–	IGDT-10	Continuous	Single item	Continuous	Sleep duration	↓	5
Nogueira, M.	2019	Portugal	152	11.5 (–) / 10-14	47	37.5 (33.6 / 3.9)	DSM-5 pathological gambling	≥ 4 / ≥ 5 of 9 items	Single item	Continuous	Sleep duration	↑	2
									PDSS	Continuous	Daytime sleepiness	↑	
Peracchia, S.	2017	Italia	300	14.76 (1.08) / –	62	50[*]	AICA-S	4-6 hours playing a day = “Hard gamers”	PSQI	Continuous	Sleep quality	↑[NS]	4
											Daytime sleepiness	↓	
								< 1 hour playing a day = “Casual gamers”			Sleep efficiency	↑	
Rehbein, F.	2010	Germany	15.168 / 7761[b]	15.3 (0.69) / 15-16	48.7/0[b]	6.7 (4.17 / 2.5)	KFN-CSAS-II	≥ 35 / ≥ 42 test score	Single items	Continuous	Sleep duration	↓	6
										Always having problems falling asleep the week before	Sleep problems	↑	
Rehbein, F.	2015	Germany	11.003	14.9 (0.74) / 13-18	48.9	1.2	CSAS	≥ 5 of 9 criteria	Single item	Continuous	Sleep problems	↑	6
Satghare, P.	2016	Singapore	1085	23.7 (5.3) / 13-40	44.5	–	IGDQ	≥ 5 of 9 criteria	ISI	≥ 10 test score	Insomnia	↑	6
Stockdale, L.	2018	USA	174	20.8 (2.18) / –[*]	15	50[*]	IGDS	≥ 5 of 9 items	Neuro-QOL-SD-SF	Continuous	Sleep problems	↑	7

Turel, O.	2016	USA	125	13.02 (2.24) / 10-17	33	–	OVGA	Continuous	*Fitbit*-actiography	Continuous	Sleep duration	↓	5
Vollmer, C.	2014	Turkey	471	12.89 (1.05) / 11-16	39.7	–	CGA	Continuous	CSM	Continuous	Morningness	↓	7
Wenzel, H.	2009	Norway	3405	–* / 16-74	–*	1.4	Single engagement item	≥ 4h playing a day	–	–	Sleep problems	↑	5

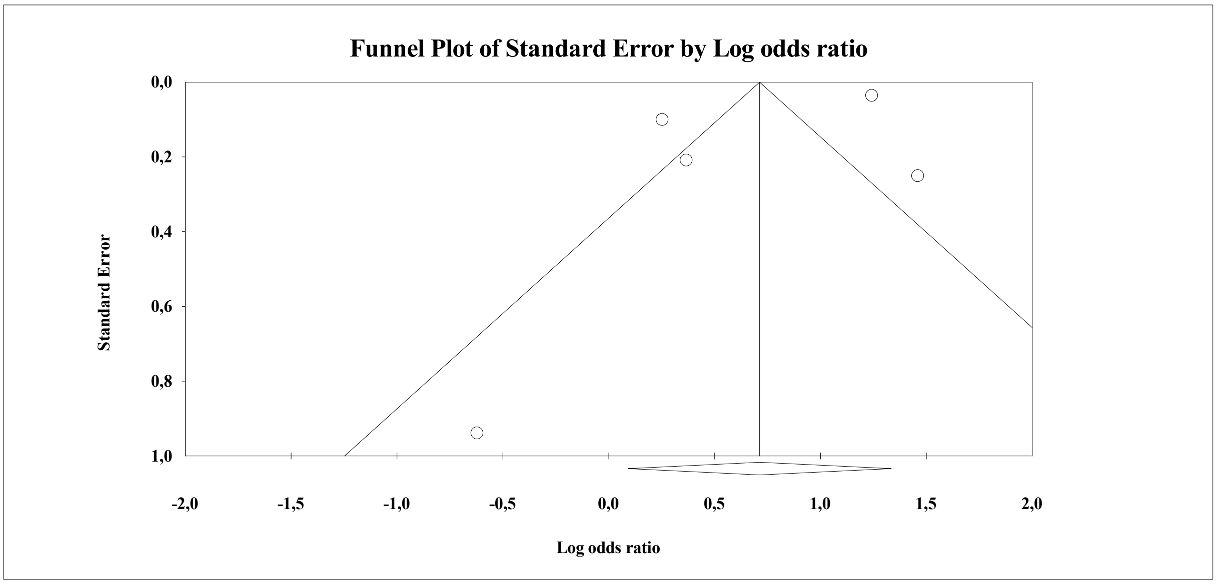
Note. ↓ = inverse association with problematic gaming, ↑ = positive association with problematic gaming, [a] = collapsed subgroups of problem gamers, subgroups in brackets (e.g. problem/addicted) [b] = only boys were included in the analysis, [c] = included in analysis, – = not reported in manuscript, * = balanced comparison groups, [NS] = not significant, NOS = Newcastle-Ottawa quality assessment scale score, IGDS = Internet Gaming Disorder Scale (Lemmens et al., 2015), GAS(A) = Gaming Addiction Scale for Adolescents (Lemmens et al., 2011), IGD-20 = Internet Gaming Disorder test (Pontes et al., 2014), OGASA = Online Game Addiction Scale for Adolescents (KADO, 2006), PTU = The Pathological Technology Use checklist, DSM-IGD = Internet Gaming Disorder (APA, 2013), ICD-GD = Gaming Disorder (World Health Organization, 2018), IGDT-10 = The Internet Gaming Disorder Test (Király et al. 2017), AICA-S = Assessment of Internet and Computer Game Addiction Scale (Wölfing et al., 2011), KFN-CSAS-II = The Video Game Dependency Scale (Rehbein et al. 2010), CSAS =Computerspielabhängigkeits-skala (Rehbein et al.), IGDQ = Internet Gaming Disorder Questionnaire (Satghare, 2016), OVGA = Online Video Game Addiction scale (Van Rooij et al., 2011), CGA = Computer Game Addiction scale (Ayas, Çakir, & Horzum, 2011), PSQI = Pittsburgh Sleep Quality Index (Buysse et al., 1989), BIS = Bergen Insomnia Scale (Pallesen et al., 2008), PDSS = Pediatric Daytime Sleepiness Scale (Drake et al., 2003), SAMQ = The Sleep Activity and Media Questionnaire, ISI= Insomnia Severity Index (Bastien et al., 2001), Neuro-QOL-SD-SF = Quality of Life in Neurological Disorders Sleep Disturbances Short Form, CSM = Composite Scale of Morningness (Önder, Beşoluk, Horzum, 2013), ESS = Epworth Sleepiness Scale (Johns M.W, 1991), SHI = Sleep Hygiene Index (Martin et al., 2006).

Appendix E. Funnel plot on problematic gaming and sleep duration, with Duval and Tweedie's trim and fill procedure.



Note. Closed circles represent imputed theoretical missing studies by the trim and fill procedure. Closed diamond displays the adjusted point estimate after assessing for possible bias.

Appendix F. Funnel plot on problematic gaming and sleep quality.



Note. Increased odds indicate poorer sleep quality

Appendix G. Funnel plot on problematic gaming and sleep problems.