# Exploring the myth of the chubby gamer:

# A meta-analysis on sedentary video gaming and body mass

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# Abstract

*Rationale.* High body mass and obesity are frequently linked to the use of sedentary media, like television (TV) or non-active video games. Empirical evidence regarding video gaming, however, has been mixed, and theoretical considerations explaining a relationship between general screen time and body mass may not generalize to non-active video gaming. *Objective.* The current meta-analysis had two main goals. First, we wanted to provide an estimate of the average effect size of the relationship between sedentary video gaming and body mass. In doing so we acknowledged several context variables to gauge the stability of the average effect. Second, to provide additional evidence on processes, we tested the displacement effect of physical activity by video gaming time with the help of a meta-analytic structural equation model. *Method.* Published and unpublished studies were identified through keyword searches in different databases and references in relevant reports were inspected for further studies. We present a random-effects, three-level meta-analysis based on 20 studies (total $N = 38{,}097$) with 32 effect sizes. *Results.* The analyses revealed a small positive relationship between non-active video game use and body mass, $\hat{\rho} = .09$, 95% CI [.03, .14], indicating that they shared less than 1% in variance. The studies showed significant heterogeneity, $Q$ (31) = 593.03, $p < .001$, $I^2 = 95.13$. Moderator analyses revealed that the relationship was more pronounced for adults, $\hat{\rho} = .22$, 95% CI [.04, .40], as compared to adolescents, $\hat{\rho} = .01$, 95% CI [-.21, .23], or children, $\hat{\rho} = .09$, 95% CI [-.07, .25]. Meta-analytic structural equation modeling found little evidence for a displacement of physical activity through time spent on video gaming. *Conclusion.* These results do not corroborate the assumption of a strong link between video gaming and body mass as respective associations are small and primarily observed among adults.

*Keywords*: video gaming, online gaming, body mass, body weight, meta-analysis

## Introduction

Next to TV, streaming media, and social networking sites, video gaming is one of the most popular pastime activities among adolescents and adults (Lenhart, Smith, Anderson, Duggan, & Perrin, 2015). A hobby reserved for computer geeks has turned into a multibillion-dollar industry, with a total of $36 billon spent by consumers in 2017 (Entertainment Software Association, 2018). At the same time, worldwide obesity has nearly tripled in recent decades (World Health Organization, 2017). Given the health consequences of obesity, the debate on causes and correlates of overweight has gained momentum (e.g., Flegal, Kit, Orpana, & Graubard, 2013; Hobbs, Griffiths, Green, Christensen, & McKenna, 2019; Joslyn & Haider-Markel, 2019). Video gaming has been widely discussed as one leisure activity that is positively associated with body mass and overweight (e.g., Borland, 2011; Inchley, Currie, Jewell, Breda, & Barnekow, 2017; Mazur et al., 2018). Empirical findings on the popular form of non-active video games (i.e., games that are played while sitting in front of a screen, sedentary video games), however, have been mixed. While some studies found positive associations between the intensity of playing sedentary games and indicators of overweight, such as body mass index (BMI) (Martinovic et al., 2015; Siervo, Cameron, Wells, & Lara, 2014), others found no relationship (e.g., Bickham, Blood, Walls, Shrier, & Rich, 2013; Scharrer & Zeller, 2014). Given these conflicting findings and the substantial interest in the topic by parents, teachers, health professionals, legislators, and the general public, our aim was to provide a meta-analytic summary on the relationship between playing non-active video games and body mass.

### General Screen Time and Body Mass

Media use is often blamed for causing overweight, especially the use of screen-based media, like TV and video gaming (cf. Hingle & Kunkel, 2014; Rogers, 2016). Most previous studies did not differentiate between video gaming and TV or other screen-based leisure activities. General screen time was found to be a predictor of higher body mass in a number of studies (Banks, Jorm, Rogers, Clements, & Bauman, 2011; Buchanan et al., 2016; Maher, Olds, Eisenmann, & Dollman, 2012; Mitchell, Rodriguez, Schmitz, & Audrain-McGovern, 2013), but the available evidence summarized in systematic reviews is still somewhat inconclusive. Whereas Marshall, Biddle, Gorely, Cameron, and Murdey (2004), as well as Foulds, Rodgers, Duncan, and Ferguson (2015) identified a significant relationship between TV viewing and indicators of fat mass among children and youth, others found no substantial associations (Chinapaw, Proper, Brug, van Mechelen & Singh, 2011; van Ekris et al., 2016). Importantly, there is a lack of recent meta-analytic evidence for links between body mass and specific screen-based activities other than TV use.

Several mechanisms are discussed that might explain the potential relationship between body mass and screen time. First, physical activities may be displaced by the time spent with sedentary media use, resulting in lower energy expenditure (e.g., Buchanan et al., 2016; Robinson et al., 2017). A second mechanism is increased energy intake due to consuming high caloric foods and drinks in front of the screen (e.g., Ford, Ward, & White, 2012; Pearson & Biddle, 2011). Third, researchers have argued that the influence of screen time on eating and drinking behavior is due to the effects of advertising for high-calorie products (Binder, Naderer, & Matthes, 2019; Harris, Bargh, & Brownell, 2009; McGinnis, Gootman, & Kraak, 2006; Robinson & Matheson, 2015). A fourth link between screen time and body mass could be sleep. Higher amounts of screen time were found to be associated with shorter sleep duration (Hale & Guan, 2015). Sleep deprivation, in turn, may cause weight gain due to hormone changes, stronger feelings of hunger, more frequent choices for high calorie foods, and snacks between mealtimes (Fatima, Doi, & Mamun, 2015; Miller, Lumeng, & LeBourgeois, 2015; Magee & Hale, 2012). Finally, reversing the causal perspective, the relative attractiveness of screen media may increase with an individual’s body mass, as alternative activities such as sports and other social activities appear more demanding and less attractive due to physiological and psychological challenges.

## A Special Case for Video Gaming?

The literature on screen time is heavily based on TV as the oldest screen medium. Usage patterns, however, have shifted towards computer-based activities (e.g., Inchley et al., 2017) and mechanisms discussed as underlying the screen time – body mass linkage might apply differently to video games. TV and video games are two different activities and there are some theoretical considerations that might explain diverging relationships between body mass and video gaming versus body mass and general screen time/TV.

First, evidence on the time displacement hypothesis is inconclusive for video gaming (Pearson, Braithwaite, Biddle, van Sluijs, & Atkin, 2014), thus, it remains unclear whether the time spent on playing video games comes at the expense of offline activities, such as sports. Second, despite the sedentary nature, playing video games can be more activating than watching TV. People playing sedentary video games showed higher energy expenditure than people resting (Barkley & Penko, 2009; Lanningham-Foster et al., 2006; Penko & Barkley, 2010; Wang & Perry, 2006). Third, console and computer games usually contain less advertising for unhealthy foods than TV fare (Leibowitz, Rosch, Ramirez, Brill, & Ohlhausen, 2012). Finally, eating and drinking high caloric food and beverages in front of the screen might be less prevalent with video games, as most popular sedentary video games require constant actions by both hands (Rey-Lopez, Vicente-Rodriguez, Biosca, & Moreno, 2008; Tomlin et al., 2014).

## The Current Meta-Analysis

At present, there is no meta-analytic summary available that explicitly focuses on sedentary video gaming and body mass. In their review, Marshall and colleagues (2004) examined media use and body mass in general terms. Six of the studies included in their meta-analysis reported on the relationship between video gaming and body mass, the meta-analyzed average effect of these six studies was not significant. Video gaming has become a lot more popular since 2002 (the most recent publication year for studies included by Marshall et al., 2004), resulting in a large number of new studies that have yet to be systematically summarized. The diverging results of primary studies and the potential differences regarding mechanisms call for a new and more detailed view on the relationship between non-active, sedentary video games – the most popular form of video games by far – and body mass. Note that we do not focus on active video games (e.g., *Wii sports* or *Dance Dance Revolution*), which are non-sedentary per definition, and might contribute to lower, rather than higher body mass (Gao, Chen, Pasco, & Pope, 2015; Mack et al., 2017; Staiano, Abraham, & Calvert, 2013). The current meta-analysis had two goals. First, we wanted to provide an estimate of the average effect size of the relationship between body mass and video gaming that includes recent research from the last one and a half decades. More importantly, we acknowledged several context variables to gauge the stability of the average effect (we had no a priori hypotheses on the direction of these effects). Second, to provide additional evidence on processes, we tested the displacement effect of physical activity by video gaming time with the help of a meta-analytic structural equation model (MASEM; Cheung & Hong, 2017). We hypothesized that video gaming was related to less physical activity and physical activity was, in turn, expected to be negatively related to body mass.

# Method

## Meta-Analytic Database

**Search process**. Relevant studies published until June 2018 were identified by searching the PsycINFO, MEDLINE, and ProQuest databases combining the search terms “obes*”, “overweight”, “fat*”, “corpulent”, “adipos*”, “body mass”, ”body composition”, and ”weight” with “online gam*”, “facebook gam*”, “video gam*”, and “computer gam*” (detailed information is available in the online supplement). Grey literature, such as unpublished reports, conference proceedings, or theses were identified in Google Scholar and ProQuest Dissertation Abstracts. Additional studies were retrieved from the references of all relevant reports (see Figure 1). This process resulted in 753 potentially relevant studies.

**Inclusion criteria**. Studies were included in the meta-analysis if they met the following criteria: the study contained (a) a measure of body mass (i.e., body mass index, body fat percentage, waist circumference, or subscapular skinfold thickness), (b) a measure of video game use (e.g., frequency or duration of video game sessions), (c) data on their zero-order relationship (or respective statistics that could be used to approximate this relationship), and (d) the sample size. Moreover, the language of the study report needed to be English, German, or French. The meta-analysis addressed sedentary video gaming; thus, we excluded studies on active video games such as *Wii Sports*, studies that reported on screen time (which represents a mix of TV, video gaming, and computer/Internet use), on general media use, on unspecified Internet use, or on unspecified computer use (e.g., Hesketh, Wake, Graham, & Waters, 2007). No restrictions were placed on country, date of publication, study design, participant age, gender, or other demographics. From a total of 753 reports, through their titles and abstracts, we identified 160 possibly relevant reports, and then inspected the full papers. We contacted all authors who had provided studies that could have been eligible but contained partial relationships only (e.g., as part of a multiple regression analysis or as adjusted odds ratios). After applying all eligibility criteria, 20 publications met our criteria and were included in the meta-analysis (see Table S1).

**Coding process**. A coding protocol (see supplemental material) summarized all relevant information including the definition of each variable, the range of potential values, and examples for each coding step. The first author and a student assistant independently extracted the relevant data (i.e., effect sizes, descriptive information, moderator variables) from each publication. The focal effects were the zero-order relationships between video gaming and body mass. For analyses on a possible mediating effect of physical activity, we also coded effects on the association between physical activity with body mass and video gaming. For studies that did not report respective correlation coefficients, we extracted any relevant statistics (e.g., odds ratio) that could be transformed into correlation coefficients. The inter-coder agreement for the coded effect sizes was 100% (Krippendorff's, 1970, $\alpha = 1.00$).

To evaluate the robustness of the meta-analytic results (including moderator analyses), we coded several variables: (a) publication year, (b) age group, (c) gender ratio in the sample, (d) the type of body mass measurement, (e) preexisting gender differences in body mass, and (f) indicators for a quality assessment. Due to frequently missing information on the mean age of the sample, we coded three age categories: children (up to 11 years old), adolescents (12 to 19 years old), and adults (mostly undergraduates). We further coded the operationalization of video gaming and body mass. Video gaming was coded in one of three categories: (1) time for video gaming absolute (i.e., hours/day), (2) subjective general intensity, and (3) frequency of gaming (i.e., number of sessions). Because nearly all studies measured time spent with video games, this variable was not included in our moderator analyses. The body mass measure was coded in one of six categories: (1) self-reported continuous BMI, (2) self-reported BMI that was dichotomized, (3) objective continuous BMI, (4) objective dichotomized BMI, (5) objective continuous non-BMI measures (percent fat mass through skinfold thickness, bioelectrical impedance analysis, or waist circumference), and (6) dichotomized non-BMI measures. Additionally, we coded information on the association between gender and body mass (converted into Cohen's *d*). If this indicator predicted the association between video gaming and body mass, this would have highlighted the possibility of gender explaining the link between video gaming and body mass, given that video gaming is typically more common in males. With a modified version of the *Quality Assessment Tool for Quantitative Studies* (Thomas, Ciliska, Dobbins, & Micucci, 2004) we rated each study's quality in three sections: selection bias, disclosure of study's participants, and data collection methods (1 = *high* *quality*; 2 = *medium quality*; 3 = *low quality*). The mean of the three section ratings was computed to form a global quality rating for each study. The respective interrater reliability between the two coders for the global rating was α = .56. This value was based on the ratings for 29 studies, including the studies that reported zero-order correlations (*k* = 20) and additional studies that reported adjusted odds ratios (*k* = 9). All differences could be resolved unanimously.

## Meta-Analytic Procedure

The meta-analysis was conducted following the guidelines of the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA, Moher et al., 2015) as well as standard procedures and recommendations for the social and medical sciences (Lipsey & Wilson, 2001).

**Effect size**. The Pearson product moment correlation was our primary effect size. A positive correlation coefficient indicates that more video game use (or being a video game player as compared to not being a video game player) is associated with higher body mass. Because some studies only reported odds ratios based on dichotomized measures (e.g., obesity groups based on BMI; see Table S1), a total of 15 odds ratios (46.88% of all effects) were transformed into correlations following Bonnett (2007). We decided to transform the odds ratios into correlations, rather than the other way around, to fit the nature of a linear relationship we expected between video gaming and body mass. This approach is prevalent in the meta-analytic literature (Gnambs & Appel, 2018; Grekin & O'Hara, 2014; Xu, Norton, & Rahman, 2018). We further distinguished between crude odds ratios (zero-order relationships) and adjusted odds ratios (second-order relationships) and excluded the latter from the analysis. Adjusted odds ratios as well as partial correlations are effect sizes that control for third variables (e.g., gender, general media use, education, age). Typically, the control variables differ between the studies and are not comparable. Therefore, effect sizes that adjust for different third variables reflect different partial effects and should not be pooled in common meta-analyses (e.g., Aloe, 2015; Roth, Le, Oh, Van Iddekinge, &

Bobko, 2018). Following a rather conservative approach (cf. Rothstein & Bushman, 2015), we decided to include only zero-order associations into our meta-analysis. We acknowledge that different opinions on the inclusion of adjusted odds ratios exist (cf. Aloe, Tanner-Smith, Becker, & Wilson, 2016). As a consequence, we provide an additional analysis that includes adjusted odds ratio data in the supplemental material. Moreover, residual analyses using the Cook's distance (cf. Viechtbauer & Cheung, 2010) identified one extreme effect size (i.e., an outlier) reported in Mwaikambo, Leyna, Killewo, Simba, and Puoane (2015). Because additional analyses excluding this effect did not result in different conclusions (see supplemental material), the effect size was included in the reported analyses.

**Univariate meta-analyses**. The effect sizes were pooled using a random effects model with a restricted maximum likelihood estimator (Viechtbauer, 2005). Because the precision of the population effects estimated in a given sample is a function of the sample size, meta-analyses aim at accounting for the differences in precision between samples. To account for this sampling error, the effect sizes were weighted by the inverse of their variances. In some studies, two or more associations between video game play and body mass were reported for one and the same sample (e.g., scores for two video gaming measures were each correlated with BMI). In these cases, all eligible associations were meta-analyzed. We accounted for the resulting dependencies by fitting a three-level meta-analysis to the data (Moeyaert et al., 2017; Van den Noortgate, López-López, Marín-Martínez, & Sánchez-Meca, 2013). The heterogeneity between studies ($\tau^{2.3}$) as well as between effect sizes ($\tau^{2.2}$) was statistically tested using the $\chi^2$-distributed $Q$-statistic (Cochran, 1954) and quantified by $I^2$ (Higgins, Thompson, Deeks, & Altman, 2003). Moderator analyses were performed using weighted, mixed-effects regression analyses. To evaluate the power of our meta-analysis and identify our a priori determined effects, we conducted power analyses for the pooled fixed effect (Jackson & Turner, 2017) and the moderating effects (Hedges & Pigott, 2004). The meta-analytic models were estimated in *R* version 3.5.0 using the *metafor* package version 2.0-0 (Viechtbauer, 2010).

**Moderator analyses**. The variables for the possible moderating effects were included as follows: publication year was centered around the mean (*M* = 2010.81, *SD* = 4.00) and included as a continuous variable. For the age groups, the first two categories, children (up to 11 years old) and adolescents, were each compared to adults (undergraduates or mixed samples of adults) as the reference group. The percentage of females in the sample was centered around .50 and included in the analysis. For possible systematic gender differences in body mass, a sample-wise estimate of gender differences in body mass (converted into Cohen's *d*) was included as a continuous variable. Concerning the type of body mass measure, self-reported BMI (reference group) was first compared to objective BMI, and then to objective measures like body fat percentage and waist circumference. Additionally, we distinguished between effect sizes that were based on continuous body mass indicators such as BMI and effect sizes that were based on a dichotomization, such as the categories of overweight/obese or not overweight/obese. The quality indicator was also included as a continuous variable.

Due to a lack of reported information, three missing values were present in the gender ratio of the sample and 14 in the gender differences in body mass. Missing information on gender ratio was estimated with 50% females. For studies that did not report estimates of gender differences in body mass, the mean difference was chosen as the estimate.

**Meta-analytic structural equation modeling (MASEM)**. A possible mediating effect of physical activity was examined using MASEM following two steps (see Cheung & Hong, 2017). First, three univariate meta-analyses were conducted that pooled either the relationship between video gaming and body mass, between video gaming and physical activity, or between physical activity and body mass. Then the pooled correlation matrix was subjected to a path analysis in *metaSEM* version 1.1.0 (Cheung, 2015) using a weighted least squares estimator. As suggested by Cheung and Chan (2005), the asymptotic sampling covariance matrix of the pooled correlations was used as weight matrix for these analyses. Two regressions resulted from this procedure: body mass was regressed on video gaming and physical activity, and physical activity was regressed on video gaming. The significance of the indirect effects was evaluated using likelihood-based confidence intervals (Cheung, 2009).

**Publication bias**. Small-study bias was evaluated using funnel plots that visualized the observed effect sizes depending on their standard error (Stern, Egger, & Smith, 2001). Because smaller studies are more likely to yield negative or non-significant findings, these results have a greater propensity of remaining unpublished and, thus, yield an asymmetric funnel plot. Funnel plot asymmetry was investigated visually and by regressing the effect sizes on their standard errors (Stanley & Doucouliagos, 2014). A significant result can indicate systematically missing studies and, thus, the presence of publication bias. However, other explanations for funnel plot asymmetry are also possible (see Lau, Ioannidis, Terrin, Schmid, & Olkin, 2006).

**Benchmarks for Interpretation.** Empirical effect size distributions in psychology (Bosco, Aguinis, Signh, Field, & Pierce, 2015; Gignac & Szodorai, 2016) typically exhibit a median effect size around $r = .20$ (with the 25th and 75th percentiles around .10 and .30). Therefore, effects smaller than $r = .10$ can be considered small. Moreover, it is questionable whether context effects that explain less than 1 percent in variance of participants' health are clinically significant. We considered meta-analytic effects of at least $r = .10$ as small and practically relevant, whereas effects exceeding $r = .20$ were considered moderate. Similar thresholds are used to interpret moderating effects.

Following Higgins and colleagues (2003), we view values of $I^2 = .25, .50$, and .75 as low, medium, and high heterogeneity, respectively. These cutoffs refer to the total heterogeneity (across effect sizes and samples) and will be used to evaluate whether pronounced random variance is present. Because $I^2$ is a relative measure of heterogeneity, it does not inform about the predicted range of effects (Borenstein, Higgins, Hedges, & Rothstein, 2017). Therefore, we also compared the absolute heterogeneity in our meta-analysis to an empirical distribution of 188 heterogeneity estimates published between 1990 and 2013 in *Psychological Bulletin* (van Erp, Verhagen, Grasman, & Wagenmakers, 2017). This $\tau^2$ distribution had a median of .026, with the 25th and 75th percentiles falling at .010 and .048. Therefore, we considered these values as indicators of moderate, small, or large heterogeneity, respectively.

### Data and Code Availability

The coded data and the *R* scripts are provided in an online repository at osf.io/tb6un. The repository further includes a copy of the codebook, the modified quality assessment tool, the PRISMA checklist, and the supplemental material.

## Results

Out of 20 publications with 24 samples (total $N$ = 38,097) we included 32 effect sizes on the relationship between video gaming and body mass in the analyses. Six studies with ten samples reported more than one effect size, ranging from two to four effect sizes (see Table S1). The studies represented data of 18,669 (51.69%) females and 17,450 (48.31%) males (for a total $N$ = 36,119 with information on gender ratios). Most studies investigated children ($k$ = 10), only five studies investigated adolescents ($k$ = 5) or adults ($k$ = 5; mostly undergraduates). The mean age for studies with information on age was 15.27 ($SD$ = 11.35; for $N$ = 18,004 with information on mean age). Most studies were conducted in Europe ($k$ = 9) and North America ($k$ = 8); more specifically, the samples originated from the following countries (number of studies in parenthesis): Canada (2), France (2), Montenegro (1), Netherlands (1), New Zealand (1), Norway (1), Sweden (1), Spain (1), Switzerland (1), Tanzania (1), Thailand (1), United Kingdom (1), and United States (6). The majority of the studies reported BMI as the indicator for body mass ($k$ = 16). For video gaming, time spent on video gaming was assessed in most primary studies ($k$ = 16).

## Univariate Meta-Analysis

Across $k$ = 24 samples and 32 effect sizes, the unweighted mean correlation was $r$ = .11 ($SD$ = .15). The average power of the included studies to identify a small effect ($r$ = .10) or a moderate effect ($r$ = .20) was .56 and .75, respectively. Thus, most individual studies were underpowered to identify the small effect that was expected based on prior research. After accounting for sampling error, the pooled effect of the relationship between video gaming and body mass was $\hat{\rho} = .09$, 95% CI [.03, .14] (Table 1). Hence, higher video gaming was positively associated with higher body mass. The power of the meta-analysis to identify a small or moderate effect was .98 and 1.00, respectively. This relationship was significant ($\alpha$ = .05), but there remained significant total heterogeneity, $Q$ (31) = 593.03, $p$ < .001, $I^2$ = 95.13. This heterogeneity resulted mostly from differences between the studies, $I^{2.3}$ = 84.16, $\sigma^{2.3}$ = .014, rather than between the effect sizes, $I^{2.2}$ = 10.97, $\sigma^{2.2}$ = .002. Thus, about 84% of the observed variance in the effect sizes could be attributed to differences between the samples (e.g., participant characteristics, study procedures) rather than sampling error. However, the absolute heterogeneity estimate, $\sigma^2$ = .016, can be considered small to moderate as compared to typical meta-analyses in psychology (van Erp et al., 2017). Nevertheless, the observed heterogeneity underscored a need for further moderator analyses.

## Moderator Analyses

To address the high heterogeneity between the effect sizes, we conducted additional analyses to examine the robustness of our findings (see Table 2). We included the following variables: (a) publication year, (b) age group, (c) gender ratio in the sample, (d) the type of body mass measurement, (e) gender differences in body mass, and (f) an indicator for a quality assessment. The moderator variables were included simultaneously in the moderator model due to significant intercorrelations. We further conducted single moderator analyses that showed very similar results. These analyses along with correlations between the moderator variables are presented in the supplemental material.

The omnibus test for all moderators in the model was not significant, $F(9, 22) = 1.60$, $p = .176$, $R^2 = .27$. Yet, we found a significant moderation for the age groups; the omnibus test for age was $\chi^2$ ($df = 2$) = 6.56, $p = .038$. Compared to adults, adolescents showed a significantly lower relationship between video gaming and body mass, $B = -.21$, 95% CI [-.38, -.04] for the moderation effect. The corresponding moderation effect for children versus adults was not significant, $B = -.13$, 95% CI [-.30, .04]; however, the test had a limited power to identify a medium (Power = .74) or small moderating effect (Power = .26). For adolescents the pooled effect was $\hat{\rho} = .01$, 95% CI [-.21, .23] and, for children, the effect was $\hat{\rho} = .09$, 95% CI [-.07, .25], whereas adults showed an effect of $\hat{\rho} = .22$, 95% CI [.04, .40]. For adults, this effect size indicates an increase of 0.22 standard deviations in body mass when video gaming increases by one standard deviation. Thus, our meta-analysis of zero-order relationships points out markedly different associations between video gaming and body mass for different age groups. Consistent with a previous meta-analytic summary by Marshall and colleagues (2004), we identified no significant association between video gaming and body mass among youth up to 18 years of age. Extending the previous meta-analytic evidence, we did, however, identify a significant association among adult samples.

Apart from the age group effect, the year of publication, the gender ratio in the sample, as well as gender differences in body mass had no significant influence on the relationship between video gaming and body mass. Moreover, the type of body mass measure, self-reported BMI versus objective measures like body fat percentage, and continuous versus dichotomous variables, as well as the quality of the studies showed no significant impact on our findings.

Because studies with small sample sizes or non-significant effects are often not published, we examined the funnel plot for a potential publication bias. The funnel plot (see supplemental material) was widely symmetric and the test for funnel plot asymmetry was not significant, *B* = -0.58, *SE* = 1.43, *t*(30) = -0.41, *p* = .686. Thus, there was no indication for a substantial publication bias.

### Mediating Role of Physical Activity (MASEM Analysis)

We expected the amount of physical activity to mediate the effect of video gaming on body mass. Three univariate meta-analyses were conducted that quantified the associations between video gaming, body mass, and physical activity (Table 1). The pooled effect for the relationship between video gaming and body mass was previously estimated as $\hat{\rho} = .09$. The relationship between body mass and physical activity was estimated over $k_1$ = 11 independent samples with $k_2$ = 37 effect sizes. The pooled effect was significant with $\hat{\rho} = -.08$, 95% CI [-.15, -.01]. Higher physical activity was associated with lower body mass. However, for $k_1$ = 4 independent samples with $k_2$ = 14 effect sizes, the average relationship between video gaming and physical activity was only marginally significant (*p* = .074) with $\hat{\rho} = -.08$, 95% CI [-0.17, 0.01]. This result should be interpreted with caution because of the small sample of primary studies.

Based on these pooled correlations, we estimated the mediation model presented in Figure 2. In line with the univariate meta-analyses, video gaming (*B* = .08, 95% CI [.02, .14]) and physical activity (*B* = -.07, 95% CI [-.14, -.00]) had significant associations with body mass, whereas video gaming showed only a marginally significant main effect on physical activity (*B* = -.08, 95% CI [-.16, .00]). The respective indirect effect was *B* = .01, 95% CI [.00, .02] and, thus, explained only 7 percent of the total effect of video gaming on body mass. These results suggest only a very modest displacement of physical activity through time spent on video gaming. Because of the small number of samples, the results of this MASEM analysis need to be interpreted as preliminary, until they have been replicated with larger samples.

## Discussion

In many regions worldwide stereotypes connect video gaming to overweight and obesity (Kowert, Griffith, & Oldmeadow, 2012). At the same time intense video gaming has been discussed in the scientific literature as contributing to higher body mass. Much of the available evidence on the link between media use and body mass is based on measures of general screen time (including TV use, gaming, and other computer-based activities), or TV use alone (cf. Marshall et al., 2004). We identified potential differences between TV and video games regarding mechanisms underlying the link to body mass, and we conducted a meta-analysis of cross-sectional, non-experimental studies. We summarized the available evidence on the relationship between non-active video gaming and body mass, excluding studies in which video game use was mingled with other screen-based activities. Our aim was to identify the magnitude of this association, and to take a closer look at several context variables as part of moderator analyses. Moreover, (reduced) physical activity was investigated as a potential mediator that might account for this relationship.

We found a significant positive relationship between video gaming and body mass ($\hat{\rho} = .09$). Individuals who spend more time with sedentary video games exhibit a higher body mass. Although this relationship was significant, the correlation was rather small in size, that is, less than 1% of an individual's body mass can be explained by the time spent with video gaming. This association was quite stable across a range of context variables. Out of seven investigated moderators, only age group turned out to be a significant moderator. Among studies that focused on adolescents and children, video gaming and body mass were not significantly correlated, whereas a significant relationship was identified for adult samples.

This meta-analytic result provides a substantial addition to the literature and points out the importance of age (and potentially birth cohort). With respect to age and gaming, as of 2018, around 90% of teens in Western societies play video games (Anderson & Jiang, 2018, for US data), whereas the percentage of young adults playing video games is substantially lower (60% of 18-29 year olds in the US, Brown, 2017). Video gaming appears to be a transient activity for many (cf. Rothmund, Klimmt, & Gollwitzer, 2018). In addition, the mechanisms underlying an increase in body mass operate long-term, rather than short-term. Thus, associations likely manifest themselves after a longer time-span of video gaming, leading to a higher likelihood of substantial correlations at an adult age. The size of the relationship for adults ($\hat{\rho} = .22$) is noteworthy. It is similar to effect sizes often found in applied psychological research. The average empirical association between attitudes and behavior, for example, revolves around $r = .16$ (Bosco et al., 2015).

Based on the available information in the primary studies, we conducted a MASEM to test an indirect effect of physical activity. We found a significant indirect effect, indicating that people who spend more time with video games exercised less and therefore had higher body mass (Figure 2). Because of the small number of included studies this result can only be interpreted as a hint to a possible indirect effect.

## Limitations and Future Research

As meta-analyses are highly dependent on the quality of the available primary studies, there are some limitations to mention within this meta-analysis. First, many primary studies included different control variables: some studies acknowledged variables like age and gender, other studies included socioeconomic status or education level in addition to age and gender, while other studies controlled for specific variables like physical activity and energy intake. Because the choice of control variables results in different partial effects for the association between video gaming and body mass, we followed prevalent recommendations (Aloe, 2015; Roth et al., 2018; Rothstein &

Bushman, 2015) and focused on unadjusted effect sizes reflecting zero-order relationships. Although this allowed us to pool similar effects across studies, the analysis of zero-order associations could obfuscate the systematic influence of third variables. In primary studies, adjusting associations from the influence of control variables (such as gender) likely reduces the size of the focal association. Thus, we would expect smaller associations in a meta-analysis based on adjusted effect sizes. Supplementary analyses were conducted in which additional studies that reported adjusted effect sizes were included (see Table S3). However, the average association remained virtually unchanged. Second, the primary studies our analysis was based on are cross-sectional studies that do not allow causal interpretations. Is it the amount of time spent with non-active video games that causes weight gain or do people with higher body mass play video games more intensively because of lower physical fitness? This question cannot be answered by our findings. Nevertheless, a significant correlation is the minimum requirement for causality. Available longitudinal studies point to an effect of screen time on body mass rather than an effect of existing overweight on screen time later on (Berkey et al., 2002; Gordon-Larsen, Adair, & Popkin, 2002). Even though there is evidence for sedentary behavior to influence weight gain, the effect sizes in these longitudinal studies, as well as in our meta-analytic summary, are rather small. Thus, the association between non-active video gaming and body mass needs serious attention without scandalizing headlines by the popular press. Third, our meta-analysis identified some heterogeneity between the primary studies. Although we conducted moderator analyses, these explained only part of the between-study variance. Thus, additional factors our meta-analysis could not elucidate seem to have influenced the observed gaming-body mass association. This includes the actual games and genres that are preferred by gamers (too few studies provided such information). Games or even genres may differ in several potentially relevant characteristics, such as the stress evoked or in-game food advertising (cf. Terlutter & Capella, 2013). Very few studies reported separate effect sizes for men and women, therefore moderator analyses regarding the influence of participants' gender were based on the proportion of female participants in a given sample.

Fourth, several mechanisms have been discussed as underlying the video game-body mass association. Our results indicated that physical activity might be a mediating factor. However, because of the small effect, other mediators such as reduced sleep due to computer gaming prior to bedtime (e.g., Kuss & Griffiths, 2012; Sun, Sekine, & Kagamimori, 2009) need to be examined in the future. Last, it is likely that our set of primary studies does not include all of the empirical findings on video gaming and body mass. Although we followed the recommended literature search process and searched directly for unpublished data, our meta-analysis did not include grey literature. However, our analysis of a possible publication bias indicated no systematically missing studies.

Our literature search revealed that empirical research on the link between playing non-active video games and obesity is quite rare. Much of the research in the field is focused on TV use or no distinction between different screen media is made. In contrast to the rather little attention that non-active video games received, research on active video games has prospered in recent years (cf. Gao et al., 2015). Given the high popularity of sedentary video games for boys and girls, men and women (the unprecedented popularity of the battle royale game *Fortnite* is a point in case), non-active video gaming deserves more scholarly attention.

## Conclusion

This meta-analysis investigated the relationship between non-active (sedentary) video gaming and body mass, contributing to the research literature on the behavioral correlates of overweight and obesity. We identified a small significant correlation between video gaming and body mass overall. This relationship was qualified by participants' age. The focal association was identified for adult samples, but there was no significant association for samples of children or adolescents. Based on a smaller subset of primary studies, we found a small indirect effect on body mass, indicating a displacement of physical activity by video gaming. In summary, sedentary video gaming is only weakly associated with body mass, physical activity might play a mediating role, and the relationship varies with participants’ age.

# References

References marked with asterisk (*) were included in the meta-analysis.

Aloe, A. M. (2015). Inaccuracy of regression results in replacing bivariate correlations. *Research Synthesis Methods*, *6*, 21-27. doi:10.1002/jrsm.1126

Aloe, A. M., Tanner-Smith, E. E., Becker, B. J., & Wilson, D. B. (2016). *Campbell methods policy note on synthesizing bivariate and partial effect sizes* (Version 1.1). Oslo: The Campbell Collaboration. doi:10.4073/cmpn.2016.2

Anderson, M. & Jiang, J. (2018). *Teens, social media & technology 2018.* Pew Research Center. Retrieved from http://www.pewinternet.org/2018/05/31/teens-social-media-technology-2018/

*Ballard, M., Gray, M., Reilly, J., & Noggle, M. (2009). Correlates of video game screen time among males: Body mass, physical activity, and other media use. *Eating Behaviors*, *10*, 161-167. doi:10.1016/j.eatbeh.2009.05.001

Banks, E., Jorm, L., Rogers, K., Clements, M., & Bauman, A. (2011). Screen-time, obesity, ageing and disability: findings from 91 266 participants in the 45 and Up Study. *Public Health Nutrition*, *14*, 34-43. doi:10.1017/S1368980010000674

Barkley, J. E., & Penko, A. (2009). Physiologic responses, perceived exertion, and hedonics of playing a physical interactive video game relative to a sedentary alternative and treadmill walking in adults. *Journal of Exercise Physiology Online*, *12*, 12-22

Berkey, C. S., Rockett, H. R., Field, A. E., Gillman, M. W., Frazier, A. L., Camargo, C. A., & Colditz, G. A. (2000). Activity, dietary intake, and weight changes in a longitudinal study of preadolescent and adolescent boys and girls. *Pediatrics, 105,* e56-e56. doi: 10.1542/peds.105.4.e56

Bickham, D. S., Blood, E. A., Walls, C. E., Shrier, L. A., & Rich, M. (2013). Characteristics of screen media use associated with higher BMI in young adolescents. *Pediatrics, 131,* 935-941. doi: 10.1542/peds.2012-1197

Binder, A., Naderer, B., & Matthes, J. (2019). Do children's food choices go with the crowd? Effects of majority and minority peer cues shown within an audiovisual cartoon on children's healthy food choice. *Social Science & Medicine, 225,* 42-50. doi: 10.1016/j.socscimed.2019.01.032

Bonett, D. G. (2007). Transforming odds ratios into correlations for meta-analytic research. *American Psychologist, 62*, 254-255. doi: 10.1037/0003-066X.62.3.254

Borenstein, M., Higgins, J. P., Hedges, L. V., & Rothstein, H. R. (2017). Basics of meta-analysis: $I^2$ is not an absolute measure of heterogeneity. *Research Synthesis Methods, 8,* 5-18. doi:10.1002/jrsm.1230

Borland, S. (2011). Playing computer games increases obesity risk in teens by making them hungry. *Daily Mail.* Retrieved from: http://www.dailymail.co.uk/health/article-1389096/Playing-games-encourages-obesity-teens-making-hungry.html

Bosco, F. A., Aguinis, H., Singh, K., Field, J. G., & Pierce, C.A. (2015). Correlational effect size benchmarks. *Journal of Applied Psychology, 100,* 431-449. doi:10.1037/a0038047

Brown, A. (2017). *Younger men play video games, but so do a diverse group of other Americans.* Pew Research Center. Retrieved from http://www.pewresearch.org/fact-tank/2017/09/11/younger-men-play-video-games-but-so-do-a-diverse-group-of-other-americans/

Buchanan, L. R., Rooks-Peck, C. R., Finnie, R. K., Wethington, H. R., Jacob, V., Fulton, J. E., … the Cummunity Preventive Services Task Force (2016). Reducing recreational sedentary screen time. *American Journal of Preventive Medicine*, *50*, 402-415. doi:10.1016/j.amepre.2015.09.030

Cheung, M.W. L. (2009). Comparison of methods for constructing confidence intervals of standardized indirect effects. *Behavior Research Methods, 41*, 425-438. doi:10.3758/BRM.41.2.425

Cheung, M. W. L. (2015). metaSEM: An R package for meta-analysis using structural equation modeling. *Frontiers in Psychology 5*, 1521. doi:10.3389/fpsyg.2014.01521

Cheung, M. W.-L., & Chan, W. (2005). Meta-analytic structural equation modeling: A two-stage approach. *Psychological Methods, 10,* 40-64. doi:10.1037/1082-989X.10.1.40

Cheung, M. W. L., & Hong, R. Y. (2017). Applications of meta-analytic structural equation modeling in health psychology: Examples, issues, and recommendations. *Health Psychology Review, 11*, 265-279. doi:10.1080/17437199.2017.134

Chinapaw, M. J. M., Proper, K. I., Brug, J., Van Mechelen, W., & Singh, A. S. (2011). Relationship between young peoples' sedentary behaviour and biomedical health indicators: a systematic review of prospective studies. *Obesity reviews, 12,* e621-e632. doi:10.1111/j.1467-789X.2011.00865.x

Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics, 10,* 101-129. doi:10.2307/3001666

*Dupuy, M., Godeau, E., Vignes, C., & Ahluwalia, N. (2011). Socio-demographic and lifestyle factors associated with overweight in a representative sample of 11-15 year olds in France: Results from the WHO-collaborative health behaviour in school-aged children (HBSC) cross-sectional study. *BMC Public Health, 11,* 442. doi:10.1186/1471-2458-11-442

Entertainment Software Association (2018). *2018 Essential Facts*. Retrieved from http://www.theesa.com/wp-content/uploads/2018/05/EF2018_FINAL.pdf

van Erp, S., Verhagen, J., Grasman, R. P. P. P., & Wagenmakers, E.-J. (2017). Estimates of between-study heterogeneity for 705 meta-analyses reported in Psychological Bulletin from 1990–2013. *Journal of Open Psychology Data, 5*, 4. doi:10.5334/jopd.33

Fatima, Y., Doi, S. A. R., & Mamun, A. A. (2015). Longitudinal impact of sleep on overweight and obesity in children and adolescents: A systematic review and bias-adjusted meta-analysis. *Obesity Reviews*, *16*, 137-149. doi:10.1111/obr.12245

Flegal, K. M., Kit, B. K., Orpana, H., & Graubard, B. I. (2013). Association of all-cause mortality with overweight and obesity using standard body mass index categories: A systematic review and meta-analysis. *JAMA*, *309*, 71-82. doi:10.1001/jama.2012.113905

*Foley, L. S., Maddison, R., Jiang, Y., Olds, T., & Ridley, K. (2011). It's not just the television: Survey analysis of sedentary behaviour in New Zealand young people. *International Journal of Behavioral Nutrition and Physical Activity*, *8*, 132-143. doi:10.1186/1479-5868-8-132

Ford, C., Ward, D., & White, M. (2012). Television viewing associated with adverse dietary outcomes in children ages 2–6. *Obesity Reviews*, *13*, 1139-1147. doi:10.1111/j.1467-789X.2012.01028.x

Foulds, H. J. A., Rodgers, C. D., Duncan, V., & Ferguson, L. J. (2016). A systematic review and meta-analysis of screen time behaviour among North American indigenous populations. *Obesity Reviews*, *17*, 455-466. doi:10.1111/obr.12389

Gao, Z., Chen, S., Pasco, D., & Pope, Z. (2015). A meta-analysis of active video games on health outcomes among children and adolescents. *Obesity Reviews*, *16*, 783-794. doi: 10.1111/obr.12287

Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences, 102*, 74-78. doi:10.1016/j.paid.2016.06.069

Gnambs, T., & Appel, M. (2018). Narcissism and social networking behavior: A meta-analysis. *Journal of Personality, 86*, 200-212. doi:10.1111/jopy.12305

Gordon-Larsen, P., Adair, L. S., & Popkin, B. M. (2002). Ethnic differences in physical activity and inactivity patterns and overweight status. *Obesity Research*, *10*, 141-149. doi: 10.1038/oby.2002.23

Grekin, R., & O'Hara, M. W. (2014). Prevalence and risk factors of postpartum posttraumatic stress disorder: a meta-analysis. *Clinical Psychology Review*, *34*, 389-401. doi: 10.1016/j.cpr.2014.05.003

*Grydeland, M., Bergh, I. H., Bjelland, M., Lien, … & Anderssen, S. A. (2012). Correlates of weight status among Norwegian 11-year-olds: The HEIA study. *BMC Public Health*, *12*, 1053. doi:10.1186/1471-2458-12-1053

Hale, L., & Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: a systematic literature review. *Sleep Medicine Reviews*, *21*, 50-58. doi:10.1016/j.smrv.2014.07.007

Harris, J. L., Bargh, J. A., & Brownell, K. D. (2009). Priming effects of television food advertising on eating behavior. *Health Psychology*, *28*, 404-413. doi:10.1037/a0014399

Hedges, L. V., & Pigott, T. D. (2004). The power of statistical tests for moderators in meta-analysis. *Psychological Methods, 9*, 426-445. doi:10.1037/1082-989X.9.4.426

Hesketh, K., Wake, M., Graham, M., & Waters, E. (2007). Stability of television viewing and electronic game/computer use in a prospective cohort study of Australian children:

Relationship with body mass index. *International Journal of Behavioral Nutrition and Physical Activity, 4,* 60-67. doi:10.1186/1479-5868-4-60

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

Hobbs, M., Griffiths, C., Green, M. A., Christensen, A., & McKenna, J. (2019). Examining longitudinal associations between the recreational physical activity environment, change in body mass index, and obesity by age in 8864 Yorkshire Health Study participants. *Social Science & Medicine, 227,* 76-83. doi: 10.1016/j.socscimed.2018.06.027

*Horn, O. K., Paradis, G., Potvin, L., Macaulay, A. C., & Desrosiers, S. (2001). Correlates and predictors of adiposity among Mohawk children. *Preventive Medicine, 33*, 274-281. doi:10.1006/pmed.2001.0881

Inchley, J., Currie, D., Jewell, J., Breda, J., & Barnekow, V. (2017). Adolescent obesity and related behaviours: trends and inequalities in the WHO European Region, 2002–2014. *Observations from the Health Behaviour in School-aged Children (HBSC) WHO collaborative cross-national study. Copenhagen, Denmark: World Health Organization.*

*Jackson, L. A., Von Eye, A., Fitzgerald, H. E., Witt, E. A., & Zhao, Y. (2011). Internet use, videogame playing and cell phone use as predictors of children’s body mass index (BMI), body weight, academic performance, and social and overall self-esteem. *Computers in Human Behavior, 27*, 599-604. doi:10.1016/j.chb.2010.10.019

Jackson, D., & Turner, R. (2017). Power analysis for random-effects meta-analysis. *Research Synthesis Methods, 8*, 290-302. doi:10.1002/jrsm.1240

Joslyn, M. R., & Haider-Markel, D. P. (2019). Perceived causes of obesity, emotions, and attitudes about Discrimination Policy. *Social Science & Medicine, 223*, 97-103. doi: 10.1016/j.socscimed.2019.01.019

Krippendorff, K. (1970). Estimating the reliability, systematic error and random error of interval data. *Educational and Psychological Measurement*, *30*, 61-70. doi:10.1177/001316447003000105

Kowert, R., Griffiths, M. D., & Oldmeadow, J. A. (2012). Geek or chic? Emerging stereotypes of online gamers. *Bulletin of Science, Technology & Society*, *32*, 471-479. doi: 10.1177/0270467612469078

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

Lanningham-Foster, L., Jensen, T. B., Foster, R. C., Redmond, A. B., Walker, B. A., Heinz, D., & Levine, J. A. (2006). Energy expenditure of sedentary screen time compared with active screen time for children. *Pediatrics*, *118*, e1831-e1835. doi:10.1542/peds.2006-1087

Lau, J., Ioannidis, J. P. A., Terrin, N., Schmid, C. H., & Olkin, I. (2006). Evidence based medicine: The case of the misleading funnel plot. *BMJ: British Medical Journal*, *333*, 597-600. doi:10.1136/bmj.333.7568.597

Leibowitz, J., Rosch, J. T., Ramirez, E., Brill, J., & Ohlhausen, M. (2012). *A review of food marketing to children and adolescents*. Washington, DC: Federal Trade Commission.

Lenhart, A., Smith, A., Anderson, M., Duggan, M., & Perrin, A. (2015). *Teens, technology, and friendships. Pew Research Center*. Retrieved from http://www.pewinternet.org/2015/08/06/teens-technology-and-friendships/

Lipsey, M. W., & Wilson, D. B. (2001). *Applied social research methods series; Vol. 49. Practical meta-analysis.* Thousand Oaks, CA, US: Sage Publications.

Mack, I., Bayer, C., Schäffeler, N., Reiband, N., Brölz, E., Zurstiege, G., ... Zipfel, S. (2017). Chances and limitations of video games in the fight against childhood obesity—A systematic review. *European Eating Disorders Review*, *25*, 237-267. doi:10.1002/erv.2514

Magee, L., & Hale, L. (2012). Longitudinal associations between sleep duration and subsequent weight gain: A systematic review. *Sleep Medicine Reviews*, *16*, 231-241. doi:10.1016/j.smrv.2011.05.005

Maher, C., Olds, T. S., Eisenmann, J. C., & Dollman, J. (2012). Screen time is more strongly associated than physical activity with overweight and obesity in 9-to 16-year-old Australians. *Acta Paediatrica*, *101*, 1170-1174. doi:10.1111/j.1651-2227.2012.02804.x

Marshall, S. J., Biddle, S. J., Gorely, T., Cameron, N., & Murdey, I. (2004). Relationships between media use, body fatness and physical activity in children and youth: A meta-analysis. *International Journal of Obesity*, *28*, 1238-1246. doi:10.1038/sj.ijo.0802706

*Martinovic, M., Belojevic, G., Evans, G. W., Lausevic, D., ... & Boljevic, J. (2015). Prevalence of and contributing factors for overweight and obesity among Montenegrin schoolchildren. *The European Journal of Public Health*, *25*, 833-839. doi:10.1093/eurpub/ckv071

Mazur, A., Caroli, M., Radziewicz-Winnicki, I., .... & Hadjipanayis, A. (2018). Reviewing and addressing the link between mass media and the increase in obesity among European children. *Acta Paediatrica*, *107*, 568-576. doi: 10.1111/apa.14136

McGinnis, J. M., Gootman, J. A., Kraak, V. I. (Eds.). (2006). *Food marketing to children and youth: Threat or opportunity?* Washington, D.C.: National Academies Press.

Miller, A. L., Lumeng, J. C., & LeBourgeois, M. K. (2015). Sleep patterns and obesity in childhood. *Current Opinion in Endocrinology, Diabetes, and Obesity*, *22*, 41-47. doi:10.1097/MED.0000000000000125

Mitchell, J. A., Rodriguez, D., Schmitz, K. H., & Audrain-McGovern, J. (2013). Greater screen time is associated with adolescent obesity: A longitudinal study of the BMI distribution from ages 14 to 18. *Obesity*, *21*, 572-575. doi:10.1002/oby.20157

*Mo-Suwan, L., Nontarak, J., Aekplakorn, W., & Satheannoppakao, W. (2014). Computer game use and television viewing increased risk for overweight among low activity girls: Fourth Thai national health examination survey 2008-2009. *International Journal of Pediatrics*, *2014*. doi:10.1155/2014/364702

Moeyaert, M., Ugille, M., Beretvas, S. N., Ferron, J., Bunuan, R., & Van den Noortgate, W. (2017). Methods for dealing with multiple outcomes in meta-analysis: a comparison between averaging effect sizes, robust variance estimation and multilevel meta-analysis. *International Journal of Social Research Methodology, 20*, 559-572. doi:10.1080/13645579.2016.1252189

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., ... Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*, 1. doi:10.1186/2046-4053-4-1

*Mwaikambo, S. A., Leyna, G. H., Killewo, J., Simba, A., & Puoane, T. (2015). Why are primary school children overweight and obese? A cross sectional study undertaken in Kinondoni district, Dar-es-salaam. *BMC Public Health*, *15*, 1269. doi:10.1186/s12889-015-2598-0

Nintendo EAD Group No. 2 (2008). *Wii Sports* [Wii Game]. Kyoto: Nintendo.

Penko, A. L., & Barkley, J. E. (2010). Motivation and physiologic responses of playing a physically interactive video game relative to a sedentary alternative in children. *Annals of Behavioral Medicine*, *39*, 162-169. doi:10.1007/s12160-010-9164-x

Pearson, N., & Biddle, S. J. (2011). Sedentary behavior and dietary intake in children, adolescents, and adults. *American Journal of Preventive Medicine*, *41*, 178-188. doi:10.1016/j.amepre.2011.05.002

Pearson, N., Braithwaite, R. E., Biddle, S. J., van Sluijs, E. M. F., & Atkin, A. J. (2014). Associations between sedentary behaviour and physical activity in children and adolescents: A meta‐analysis. *Obesity Reviews, 15*, 666-675. doi:10.1111/obr.12188

*Pitrou, I., Shojaei, T., Wazana, A., Gilbert, F., & Kovess-Masféty, V. (2010). Child overweight, associated psychopathology, and social functioning: A French school-based survey in 6-to 11-year-old children. *Obesity*, *18*, 809-817. doi:10.1038/oby.2009.278

Rey-Lopez, J. P., Vicente-Rodríguez, G., Biosca, M., & Moreno, L. A. (2008). Sedentary behaviour and obesity development in children and adolescents. *Nutrition, Metabolism and Cardiovascular Diseases*, *18*, 242-251. doi:10.1016/j.numecd.2007.07.008

Robinson, T. N., & Matheson, D. M. (2015). Environmental strategies for portion control in children. *Appetite*, *88*, 33-38. doi:10.1016/j.appet.2014.12.001

Robinson, T. N., Banda, J. A., Hale, L., Lu, A. S., Fleming-Milici, F., Calvert, S. L., & Wartella, E. (2017). Screen media exposure and obesity in children and adolescents. *Pediatrics, 140*, 97-101. doi:10.1542/peds.2016-1758K

Roth, P. L., Le, H., Oh, I. S., Van Iddekinge, C. H., & Bobko, P. (2018). Using beta coefficients to impute missing correlations in meta-analysis research: Reasons for caution. *Journal of Applied Psychology, 103*, 644-658. doi:10.1037/apl0000293

Rothmund, T., Klimmt, C. & Gollwitzer, M. (2018). Low temporal stability of excessive video game play in German adolescents. *Journal of Media Psychology, 30*, 53-65. doi: 10.1027/1864-1105/a000177

Rothstein, H. R., & Bushman, B. J. (2015). Methodological and reporting errors in meta-analytic reviews make other meta-analysts angry: A commentary on Ferguson (2015). *Perspectives on Psychological Science, 10*, 677-679. doi:10.1177/1745691615592235

*Scharrer, E., & Zeller, A. (2014). Active and sedentary video game time: Testing associations with adolescents' BMI. *Journal of Media Psychology*, *26,* 39-49. doi:0.1027/1864-1105/a000109

*Siervo, M., Cameron, H., Wells, J. C., & Lara, J. (2014). Frequent video-game playing in young males is associated with central adiposity and high-sugar, low-fibre dietary consumption. *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity*, *19,* 515-520. doi:10.1007/s40519-014-0128-1

*Stettler, N., Signer, T. M., & Suter, P. M. (2004). Electronic games and environmental factors associated with childhood obesity in Switzerland. *Obesity*, *12,* 896-903. doi:10.1038/oby.2004.109

Staiano, A. E., Abraham, A. A., & Calvert, S. L. (2013). Adolescent exergame play for weight loss and psychosocial improvement: A controlled physical activity intervention. *Obesity*, *21,* 598-601. doi:10.1002/oby.20282

Stanley, T. D., & Doucouliagos, H. (2014). Meta-regression approximations to reduce publication and selection bias. *Research Synthesis Methods, 5*, 60-78. doi:10.1002/jrsm.1095

Sterne, J. A., Egger, M., & Smith, G. D. (2001). Investigating and dealing with publication and other biases in meta-analysis. *BMJ*, *323*, 101-105.

Sun, Y., Sekine, M., & Kagamimori, S. (2009). Lifestyle and overweight among Japanese adolescents: The Toyama birth cohort study. *Journal of Epidemiology*, *19,* 303-310. doi:10.2188/jea.JE20080095

Terlutter, R., & Capella, M. L. (2013). The gamification of advertising: analysis and research directions of in-game advertising, advergames, and advertising in social network games. *Journal of Advertising*, *42*, 95-112. doi:10.1080/00913367.2013.774610

Thomas, B.H., Ciliska, D., Dobbins, M., & Micucci, S. (2004). A process for systematically reviewing the literature: Providing the research evidence for public health nursing interventions. *Worldviews on Evidence-Based Nursing, 1*, 176–184. doi:10.1111/j.1524-475X.2004.04006.x

*Thomée, S., Lissner, L., Hagberg, M., & Grimby-Ekman, A. (2015). Leisure time computer use and overweight development in young adults–a prospective study. *BMC Public Health*, *15*, 839. doi:10.1186/s12889-015-2131-5

Tomlin, D., McKay, H. A., Forster, M., Rhodes, R. E., Rose, H., Higgins, J. W., & Naylor, P. J. (2014). Exploring the relationship between diet and TV, computer and video game use in a group of Canadian children. *International Journal of Child Health and Nutrition*, *3*, 195-203. doi:10.6000/1929-4247.2014.03.04.6

*Touchette, É., Petit, D., Tremblay, R. E., Boivin, M., Falissard, B., Genolini, C., & Montplaisir, J. Y. (2008). Associations between sleep duration patterns and overweight/obesity at age 6. *Sleep*, *31*, 1507-1514. doi:10.1093/sleep/31.11.1507

Van den Noortgate, W., López-López, J. A., Marín-Martínez, F., & Sánchez-Meca, J. (2013). Three-level meta-analysis of dependent effect sizes. *Behavior Research Methods*, *45*, 576-594. doi:10.3758/s13428-012-0261-6

*Vandewater, E. A., Shim, M. S., & Caplovitz, A. G. (2004). Linking obesity and activity level with children's television and video game use. *Journal of Adolescence*, *27*, 71-85. doi:10.1016/j.adolescence.2003.10.003

Van Ekris, E., Altenburg, T. M., Singh, A. S., Proper, K. I., Heymans, M. W., & Chinapaw, M. J. M. (2016). An evidence update on the prospective relationship between childhood sedentary behaviour and biomedical health indicators: A systematic review and meta-analysis. *Obesity Reviews, 17,* 833-849. doi:10.1111/obr.12426

*Vicente-Rodríguez, G., Rey-López, J. P., Martín-Matillas, M., … & Bueno, M. (2008). Television watching, videogames, and excess of body fat in Spanish adolescents: The AVENA study. *Nutrition*, *24,* 654-662. doi:10.1016/j.nut.2008.03.011

Viechtbauer, W. (2005). Bias and efficiency of meta-analytic variance estimators in the random-effects model. *Journal of Educational and Behavioral Statistics, 30,* 261-293. doi:10.3102/10769986030003261

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36,* 1-48. doi:10.18637/jss.v036.i03/

Viechtbauer, W., & Cheung, M. W. L. (2010). Outlier and influence diagnostics for meta-analysis. *Research Synthesis Methods*, *1,* 112-125. doi:10.1002/jrsm.11

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,* 411-415. doi:10.1001/archpedi.160.4.411

*Wack, E., & Tantleff-Dunn, S. (2009). Relationships between electronic game play, obesity, and psychosocial functioning in young men. *CyberPsychology & Behavior*, *12,* 241-244. doi:10.1089/cpb.2008.0151

*Weaver, J. B., Mays, D., Weaver, S. S., Kannenberg, W., Hopkins, G. L., Eroĝlu, D., & Bernhardt, J. M. (2009). Health-risk correlates of video-game playing among adults. *American Journal of Preventive Medicine*, *37,* 299-305. doi:10.1016/j.amepre.2009.06.014

*Wijtzes, A. I., Bouthoorn, S. H., Jansen, W., Franco, O. H., Hofman, A., Jaddoe, V. W., & Raat, H. (2014). Sedentary behaviors, physical activity behaviors, and body fat in 6-year-old children: The generation R study. *International Journal of Behavioral Nutrition and Physical Activity*, *11*, 96. doi:10.1186/s12966-014-0096-x

World Health Organization (2017). *Obesity and Overweight: Fact Sheet*. Retrieved from http://www.who.int/mediacentre/factsheets/fs311/en/

Xu, Y., Norton, S., & Rahman, Q. (2018). Early life conditions, reproductive and sexuality-related life history outcomes among human males: A systematic review and meta-analysis. *Evolution and Human Behavior*, *39*, 40-51. doi:10.1016/j.evolhumbehav.2017.08.005

Table 1. Univariate Meta-Analyses

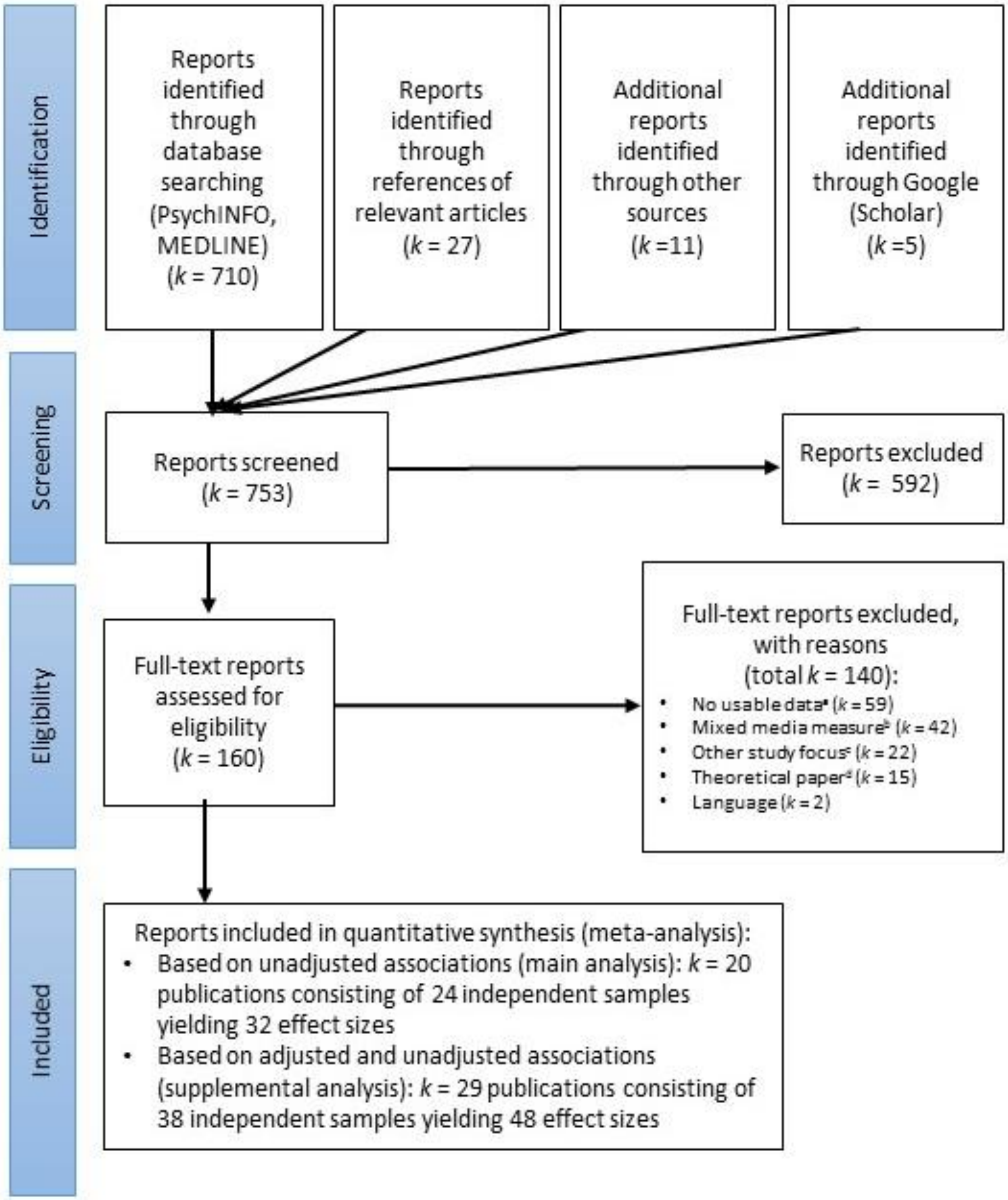
| | Average Effect | | | | | | Heterogeneity | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $k_1/k_2$ | $N$ | Effect Size ($\rho$) | 95% *CI* | *(df)* *t* | *p* | *Q* | *df* *(Q)* | *p* | $I^{2.3}$ | $I^{2.2}$ | $\sigma^{2.3}$ | $\sigma^{2.2}$ |
| Video Gaming and | | | | | | | | | | | | | |
| Body Mass | 20/32 | 38,097 | 0.086 | [.026; .145] | (31)<br>2.94 | .006 | 593.03 | 31 | <.001 | 84.16 | 10.97 | .014 | .002 |
| Video Gaming and | | | | | | | | | | | | | |
| Physical Activity | 4/14 | 3,864 | -0.080 | [-.168; .009] | (13)<br>-1.95 | .074 | 47.44 | 13 | <.001 | 36.26 | 38.63 | .003 | .004 |
| Physical Activity and | | | | | | | | | | | | | |
| Body Mass | 11/37 | 20,582 | -0.077 | [-.143; -.010] | (36)<br>-2.27 | .029 | 765.51 | 36 | < .001 | 12.66 | 83.35 | .003 | .021 |

*Notes*. $k_1$ = Number of studies; $k_2$ = Number of effect sizes; $I^{2.3}$ = level 3 heterogeneity between studies, $I^{2.2}$ = level 2 heterogeneity between effect sizes $\sigma^{2.3}$ = level 3 variance between studies, $\sigma^{2.2}$ = level 2 variance between effect sizes.

Table 2. Moderator Analyses

| Variable | *B* | *95% CI* | *SE* | *t* | *p* | Power$_s$ | Power$_m$ |
|---|---|---|---|---|---|---|---|
| Intercept | .30 | [-.07, .66] | .18 | 1.66 | .111 | | |
| Publication Year[a] | .01 | [-.00, .03] | .01 | 1.66 | .112 | .93 | >.99 |
| Age Group | | | | | | | |
| Adults vs. Children[c,d] | -.13 | [-.30, .04] | .08 | -1.61 | .122 | .26 | .74 |
| Adults vs. Adolescents[c,d] | -.21 | [-.38, -.04] | .08 | -2.54 | .019 | .24 | .71 |
| Gender ratio in sample[a,b] | .01 | [-.08, .10] | .04 | 0.21 | .834 | .92 | >.99 |
| Gender differences in body mass | .04 | [-.60, .68] | .31 | 0.11 | .910 | .77 | >.99 |
| Body Mass Measure | | | | | | | |
| Self-reported BMI vs objective BMI[c,e] | .05 | [-.08, .18] | .06 | 0.84 | .410 | .38 | .91 |
| Self-reported BMI vs. other measures[c,e] | .06 | [-.11, .23] | .08 | 0.77 | .449 | .20 | .60 |
| Continuous vs. dichotomous body mass measures[c,f] | .02 | [-.13, .16] | .07 | 0.26 | .797 | .31 | .83 |
| Study Quality Index | -.07 | [-.25, .11] | .09 | -0.80 | .434 | .79 | >.99 |
| $\sigma^{2.3}$ / $\sigma^{2.2}$ | 0.009 / 0.003 | | | | | | |
| $k_1$ / $k_2$ | 20/ 32 | | | | | | |
| $R^2$ | .27 | | | | | | |

*Note*. All moderators were included simultaneously; $\sigma^{2.3}$ = level 3 variance between studies, $\sigma^{2.2}$ = level 2 variance between effect sizes; $R^2$ = Proportion of explained random variance; $k_1$ = Number of studies; $k_2$ = Number of effect sizes; Power = Power to identify a small ($r$ = .10) or medium effect ($r$ = .20); [a] centered; [b] percentage females; [c] dummy coding; [d] reference group = adults; [e] reference group = self-reported BMI; [f] reference group = continuous measures.



*Notes.* [a] no results on relevant associations, missing information or associations controlled for third variables. [b] only indicators for screen time, computer use, or video gaming mixed with other media uses (e.g., internet use). [c] focus on active video games, eating behavior, weight loss intervention, health communication. [d] theoretical papers and reviews

Figure 1. Flowchart of the literature search process.

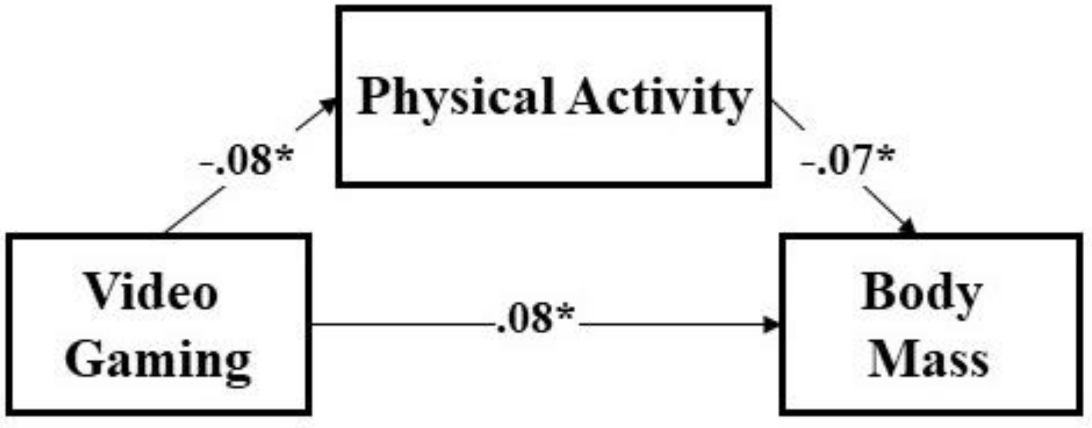


Figure 2. Meta-analytic structural equation model (MASEM). Standardized regression parameters are presented. $*p < .05$