Adolescence Obesity Risk Increases with Increased Screen Time: A Systematic Review and Dose-Response Meta-Analysis

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Research Article

Keywords: Screen time, obesity, dose-response, adiposity, and meta-analysis

Posted Date: March 3rd, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1267652/v1>

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Abstract

Background: Adolescence is a critical time period in human life. Adolescence is associated with reduced physical activity and increased sedentary behaviors. In the current systematic review and dose-response meta-analysis, we evaluated the association between screen time and obesity risk among adolescents.

Methods: A systematic search from PubMed, Embase and Scopus electronic databases through September 2021 was performed. Studies that evaluated the association between screen time and obesity among adolescents up to September 2021 were retrieved. A total of 64 qualified studies were included into meta-analysis.

Results: The results of the two-class meta-analysis showed that adolescents at the highest category of screen time were 1.4 times more likely to develop obesity (OR=1.393; CI=1.264, 1.536; $P < 0.001$). The results of subgrouping identified that continent was the possible heterogeneity source. No evidence of non-linear association between increased screen time and obesity risk among adolescents was observed ($P_{\text{nonlinearity}} = 0.278$).

Conclusion: For the first time, the current systematic review and meta-analysis revealed a positive association between screen time and obesity among adolescents without any dose-response evidence.

Registration: The protocol of the current work has been registered in the PROSPERO system (Registration number: CRD42021233899).

1. Background

Adolescence is a critical time period regarding physical activity-related behaviors since regular physical activity decreases and sedentary behavior increases in this time period [1, 2]. Screen-related physical activities like television watching are very common among adolescents particularly in modern societies; it is reported that, adolescents spend about 3 hours per day for screen activities [3]. Screen time constitutes an important part of an adolescent's life; adolescents are major TV users [4]. Fifty seven percent of adolescents reported watching TV every day with an average time of 1 hour and 49 minutes of TV watching [5]. Recent evidence has shown that increased screen-related sedentary behaviors had led not only to obesity growth [6], but also to mental problems among adolescents [7]. Sedentary behavior guidelines recommends less than two hours per day of recreational screen time for youth [8]. However, it has been estimated that more than 50% of adolescents exceed these recommendations for screen-related behaviors [9]. In a report from the Health Behavior in School-Age Children (HBSC), which was performed among adolescents aged 11, 13 and 15 years from 41 countries in Europe and in North America, 56–65% of the adolescents spent 2 h or more per day watching television [10]. Actually, sedentary behaviors are characterized by activities with low energy expenditure (< 1.5 metabolic equivalents) in a sitting position like television watching or other screen behaviors [11] and is an important risk factor for cardio-metabolic disease in adulthood [12–15]. In adolescents, obesity is associated with dyslipidemia, glucose intolerance, and hypertension [16]. In a population based study of 5625 adolescents in Iran [17], high screen time was positively associated with high blood pressure, high low density lipoprotein cholesterol and triglyceride amount ($P < 0.05$). Numerous studies have reported the association between screen time and adiposity among adolescents; however, the results are inconsistent. Some of the studies reported increased odds of obesity by increasing screen time [16, 18, 19]; for example, in the study by Cheng L [18], among 2201 Chinese adolescents, increased odds of obesity for those with more than 2 hours/ day screen time (1.53; CI = 0.95–2.09; $P < 0.001$). While in another population-based school setting study by Lopez-Gonzalez D [20] among 1319293 adolescents of 12–14 years old, no significant association between obesity and screen time was reported. Several other studies also reported no association between obesity and screen time [20–23]. Or, in some of the studies, only watching television or playing video games of more than three hours per day increased obesity risk among adolescents [24–26]. More surprisingly, a non-significant reduced risk of excess weight by increased screen time of more than 4 hours/day was observed in De-Lima et al study [27] (0.87 CI = 0.59–1.30). According to the review of literature, a great between-study heterogeneity was observed in studies that evaluated the association between screen time and obesity among adolescents. It seems that the type of the screen (TV, PC, DVD or video games and etc.) or the duration of screen use and several other factors possibly affect the association of obesity with screen time. Therefore, in the current systematic review and meta-analysis, we systematically searched and analyzed all of the available literature that evaluated the association between obesity and screen time and we also classified the results according to numerous factors including screen type, time, geographical distribution, setting, obesity status as well as studies' quality and sample size to identify possible determinants of these associations.

2. Methods

The results are reported according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist (Sup. Table 1) [28]. The protocol's registration code in PROSPERO is CRD42021233899.

a. Search Strategy, selection of studies, inclusion and exclusion criteria

A total of 6291 articles were retrieved after searching from PubMed, Embase and Scopus electronic databases through September 2021 (Figure 1). Search strategy for PubMed is provided in Sup. Table 2 and it has been adopted for each electronic database. Duplicate were removed and some of records were excluded according to title/ abstract, as a consequent, 2156 full-text articles were remained for final screening by two independent investigators. Then, 2092 manuscripts were removed because of not meeting the inclusion criteria. Finally, 64 manuscripts with the total number of 1425738 participants were included in the final meta-synthesis.

The following studies were included (1) observational designs (case control, cross-sectional or cohort studies with the baseline measurement of study parameters); (2) studies that evaluated the relationship (OR, RR or HR) between screen time and risk of obesity (3) the studies that were conducted only among adolescents (10 years $\leq$ age).

b. Data extraction and quality assessment

Data extraction was done in a standard EXCELL datasheet and was performed by two authors. The information that was included into data sheet were the name of first author and journal, publication year, country, setting, age range and number of participants, study design, adjusted covariate, gender, obesity and screen time definition, weight, height and screen time measurement tools, and main results of the studies. Any disagreements between reviewers were resolved by discussion. The methodological quality of studies were assessed using the Agency for Healthcare Research and Quality (AHRQ) checklist [29]. (Table 1).

c. Statistical analysis

The studies that reported the odds ratio of obesity (OR) in those with highest versus lowest screen time were included in two separate meta-analysis. Hozo et al [30] method was used when the median and rang were reported instead of mean and SD, and the median values were considered as best estimates of

mean when sample size of study was more than 25 and the SD was calculated as follows: $S^2 \approx (\frac{1}{12}(\frac{(a-2m+b)^2}{4} + (b-a)^2))$. Also, Walter and Yao method was used for missing SDs calculation, as $SD = (b-a)/4$ [31, 32]. If the number of participants in categories were not provided, equal number of participants in each category was assumed. When the odds ratio was not provided and the data of the exposure of variable in the groups were available, we calculated prevalence odds ratios (PORs) as suggested by Pearce N as the best approach for measuring effect size in prevalence studies [33] as follows:

$POR = \left[\frac{P1}{1-P1} \right] / \left[\frac{P0}{1-P0} \right]$. While P0 and P1 are the prevalence in exposed and non-exposed groups. Cochran's Q and I-squared tests were used to identify between-study heterogeneity. The possible sources of heterogeneity were identified using subgrouping and meta-regression analysis. STATA version 13 (STATA Corp, College Station, TX, USA), was used for data analysis and P-values less than 0.05 were considered as statistically significant.

Only the studies that reported at least three categories for screen time and the odds or prevalence of obesity were included in the dose-response meta-analysis. Accordingly, thirteen individual studies in five articles were included [34-46]. The median point in each screen time category was identified and when medians were not reported, then approximate medians using the midpoint of the lower and upper limits were estimated. When the lowest or highest screen time categories were open-ended, the screen time was calculated by assuming the similar interval for those categories and estimating the mid-point. The reference category was the lowest one assuming OR and CIs of 1 for it. The potential non- linear associations were assessed using random-effects dose-response meta-analysis by defining the restricted cubic splines with three knots at fixed percentiles (10%, 50% and 90%) of distribution and were used to calculate study-specific odds ratios.

3. Results

a. Study characteristics

General characteristics of included studies are represented in Table 2. In the meta-analysis of the odds of obesity among high screen-user adolescents compared with less-users, totally, 64 individual studies were included; the study by Lopez Gonzalez the association of obesity with screen time was reported for boys and girls separately, so the results were also included as two independent results [20]. Similarly, was the study by Franceschin MJ [16] that reported the results of TV and PC, VG separately. The study by Zulficar T [25], provided results for TV use in weekdays, electronic game playing in weekdays, TV use in weekends and electronic game playing in weekends among immigrant boys and girls from high income and lower than middle income countries separately; therefore, the results were included as six studies in the analysis. In the studies by Pabon et al [47] and Haidar A et al [21], the results were reported separately for overweight and obesity. The study by Saha M et al [23] reported the results for PC, TV and video games separately. The study by Hu EY [48] reported the results for TV and video, computer game and computer use separately, so, it was included as two separate studies. Similarly the study by Godakanda I [49] reported the results separately for TV watching and Video/DVD watching. So, the results were included as two independent results. The study by Watharkar A [50] reported the results for TV, PC or cell phone separately. The study by Velásquez-Rodríguez CM [51] was reported separate results for healthy adolescents and adolescents with insulin resistance. The study by De Jong E et al [52] was reported as four studies of TV watchers of 1-1.5 and more than 1.5 hours and PC users of less than 30 minutes/day and more than 30 minutes per day. The studies by Ercan S [53] and El-Gilany AH [54] reported the results for TV and PC use of more than 2 hours for overweight and obese adolescents. The study by Drake KM [55], reported the screen time of 0-7, 7-14 and more than 14 hours for overweight + obese or obese adolescents separately. The study by Byun W [56] reported the results for overweight and obese adolescents separately. The study by Adesina AF [57] reported the results of TV watching for 0-2 hours, 3-4 hours and ≥ 5 hours for overweight and obese; so the results we included as four independent studies. Sun Y [24] reported separate results for girls and boys. Finally, Collins AE [26] reported the separate results for PC use and play station.

The results of the meta-analysis

The results of the two-class meta-analysis is presented in Figure 2. As it is shown, adolescents who were in the highest category of screen time were 1.2 times more likely to develop obesity compared with those in the lowest category [OR=1.393; CI=1.264, 1.536; P <0.001; I-squared (variation in ES attributable to heterogeneity) = 85.9%]. The results of subgrouping is shown in Table 3. Subgrouping according to continent reduced heterogeneity in some degree. For example, studies that were performed in America had the lowest heterogeneity. But other parameters were not potent sources of heterogeneity. The results of dose-response relationship between screen time and obesity among children is presented in Figure 3. There was no evidence of non-linear association between increased screen time and obesity risk among a (P-nonlinearity= 0.278). Funnel plots indicating publication bias are presented in Figure 4. The results of Begg and Eggers test showed some evidence of publication bias (Egger's P-value = 0.001; Begg's P-value = 0.001). Therefore, trim and fill analysis was done (Figure 5) and the obtained result was as follows: OR=1.575; CI= 1.083, 2.068; P <0.001).

4. Discussion

In the current meta-analysis, for the first time, we summarized the results of studies that evaluated the association between screen time and obesity risk among adolescents. In an appropriate number of participants (e.g. 1425738) we revealed that high screen time is associated with 1.2 time higher chance of obesity among teenagers. No evidence of non-linear association was observed in the dose-response analysis. Previous population based studies have revealed the obesity-promoting effects of high screen time; in the study by Lopez-Gonzalez D [20], in screening of more than 7511 registered schools, high screen time was considered as an obesogenic factor. Several other studies also revealed that screen time more than 2 or 3 hours per day increases the risk of obesity [18, 25]. Internet addicted adolescents had also elevated risk of obesity in one study [19]. However, several other studies reported no significant association between obesity and screen time was observed [22, 27, 47]. The possible strong reason for this inconsistency, is the type of screen (e.g. TV, video games or personal computer and so on) that is used in numerous studies. For finding the answer, we performed subgroup analysis; according to the results, those studies that defined video games as their screen failed to reveal a positive association between screen time and obesity [23, 47, 58]. In the study by Franceschin MJ et al [16] adolescents with watching TV more than two hours per day had almost doubled chance of being obese compared with those who had less than 2 hours per day TV watching (OR = 1.73; 95%CI = 1.24–2.42) while the association was not significant for video game playing or PC use. In the study by Sun Y et al [24], the positive association between video game playing and obesity risk was only observed among girls and not boys. Zulfiqar T et al [25], also reported the positive association between obesity and TV viewing and not for video games. Therefore, it seems that TV watching is a stronger motivator of obesity among adolescents. It is possibly because that some of video games can increase physical activity and physical health; in a meta-analysis by Primack BA et al [59], video games were associated with 69% improve in psychological therapy outcomes and 50% improve in physical activity outcomes. In another study by Williams WA [60], active video games were introduced as effective tools to improve physical activity among adolescents and were considered as a more acceptable and sustainable approach than many conventional methods.

High screen time, as a sedentary behavior, reduces lipoprotein lipase activity (LPL), and leads to reduced plasma triglycerides' absorption by skeletal muscles, reduced HDL level and postprandial increase in serum lipids, that consequently results in fat deposition in vessels or adipose tissue [61, 62]. Moreover, increased screen time increases food intake; previous studies revealed that television watching increases motivated response to food intake and snacking behavior among children and adolescents [4, 63–65]; this is also true for video games [66–68] and personal computer use [69, 70]. More importantly, several TV food advertisements promote junk food and fast food consumption and increasing obesity risk [71–74]. Therefore, the association between obesity and screen use is a multi-dimensional factor that all of its aspects needs to be clearly studied. Also, the results of included studies in the current meta-analysis were reported in a combination of both genders, therefore, it was not possible to give gender-specific results.

5. Conclusion

As mentioned before, the current meta-analysis is the first study that provided a quantitative result for the association between different screens with obesity among adolescents. Since the results were not separable for boys and girls, therefore, further studies with separate results for males and females and different screen devices are needed to better explain the obtained results.

Declarations

Ethical approval and consent to participate

The protocol of the current work has been registered in the PROSPERO system (Registration number: CRD42021243523). Also, the research has been approved by the ethics committee of Tabriz University of Medical Sciences (Identifier: 63190).

Consent to publish

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from Tabriz University of Medical Sciences but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of corresponding author.

Competing interest

The authors declare that there is no conflict of interest.

Funding

None.

Authors' contributions

All authors have read and approved the manuscript; MAF, supervised the project, performed the search, extraction and wrote the first draft of the manuscript and analyzed the data. LJ was also involved in search, extraction and revision of the paper. She also was involved in data analysis.

Acknowledgement

Not applicable.

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Tables

Table 1. Agency for Healthcare Research and Quality (AHRQ) checklist to assess quality of the cross-sectional studies

ARHQ Methodology Checklist items for Cross-Sectional study	Zhang Y [58]	De-Lima TR [27]	Zulfigar T [25]	Kerkadi A [22]	Hu J [75]	De-Jong E[52]	Franceschin MJ [16]	Dalamaria, T [19]	Cheng L [76]
1) Define the source of information (survey, record review)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
2) List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
3) Indicate time period used for identifying patients	⊕	⊕	⊕	–	⊕	⊕	⊕	⊕	⊕
4) Indicate whether or not subjects were consecutive if not population-based	⊕	–	–	⊕	–	–	–	–	–
5) Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants	–	–	–	U	–	–	–	–	–
6) Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)	–	–	U	U	U	U	U	U	⊕
7) Explain any patient exclusions from analysis	⊕	⊕	⊕	–	⊕	–	⊕	–	⊕
8) Describe how confounding was assessed and/or controlled.	⊕	⊕	⊕	⊕	⊕	⊕	–	⊕	⊕
9) If applicable, explain how missing data were handled in the analysis	⊕	–	⊕	⊕	⊕	–	⊕	⊕	⊕
10) Summarize patient response rates and completeness of data collection	⊕	⊕	⊕	⊕	⊕	–	⊕	⊕	⊕
11) Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained	–	–	–	⊕	–	–	–	–	–
Total score	8	6	7	7	7	4	6	6	8

Table 1. Cont'd

ARHQ Methodology Checklist items for Cross-Sectional study	Lopez-GonzalezD [20]	Pabón D [47]	Haidar A [21]	Saha M [23]	Mansoori M [77]	Godakanda I [49]	Talat MA[78]	Piryani MA [78]	Moradi G [79]
1) Define the source of information (survey, record review)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
2) List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
3) Indicate time period used for identifying patients	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕
4) Indicate whether or not subjects were consecutive if not population-based	⊕	-	-	-	-	-	⊕	-	-
5) Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants	U	U	U	-	-	U	U	U	-
6) Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)	U	U	U	-	⊕	U	U	U	-
7) Explain any patient exclusions from analysis	-	-	-	-	⊕	⊕	-	-	-
8) Describe how confounding was assessed and/or controlled.	⊕	⊕	-	⊕	⊕	⊕	⊕	⊕	⊕
9) If applicable, explain how missing data were handled in the analysis	⊕	⊕	⊕	-	-	⊕	-	-	-
10) Summarize patient response rates and completeness of data collection	⊕	-	-	-	⊕	-	-	-	-
11) Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained	⊕	-	-	-	-	⊕	-	-	-
Total score	8	5	4	4	7	7	5	4	4

Table 1. Cont'd

Table 2. The characteristics of studies that were included in the two-class meta-analysis of odds of obesity and increased screen time among adolescents

ARHQ Methodology Checklist items for Cross-Sectional study	Watharkar A [50]	De- Lucena JMS [80]	Velásquez- RodríguezCM [51]	De Jong E [52]	Ercan S [53]	Collins AE [26]	Drake KM [55]	Sun Y [24]	Adesina AF [57]	El- Gilany AH [54]	Byun W [56]
1) Define the source of information (survey, record review)	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	
2) List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	
3) Indicate time period used for identifying patients	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	
4) Indicate whether or not subjects were consecutive if not population-based	-	⊕	-	⊕	-	-	⊕	-	-	⊕	
5) Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants	-	-	-	-	-	-	-	-	-	-	
6) Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)	-	U	-	U	-	-	-	U	-	⊕	
7) Explain any patient exclusions from analysis	-	⊕	⊕	⊕	-	-	⊕	⊕	⊕	⊕	
8) Describe how confounding was assessed and/or controlled.	U	⊕	-	⊕	U	U	⊕	⊕	U	⊕	
9) If applicable, explain how missing data were handled in the analysis	-	-	⊕	-	-	-	⊕	-	-	⊕	
10) Summarize patient response rates and completeness of data collection	-	⊕	•	⊕	-	-	⊕	⊕	-	⊕	
11) Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained	-	-	-	-	-	-	⊕	-	-	-	
Total score	3	7	5	7	3	3	8	6	4	8	

Journal/ Year/ First author	Country	Setting/ num	Design	Age (y)/ gender	Overweight/ obesity status and definition	Disease status	ST definition	ST measurement	Main findings
Revista Paulista de Pediatria/ 2021/ Dalmacia T [19]	Brazil	School/ 1387	Cross-sectional	14-18/ both	Obesity/ $\geq 85^{\text{th}}$ percentile of age	Healthy	Internet addiction	Questionnaire	Increased odds of obesity in internet addicted adolescents [OR= 1.1; CI = 0.9-3.18].
BMC Public Health/ 2020/ Zhang Y[58]	China	School/ 2264	Cross-sectional	12-15/ both	Obesity/ $\geq 85^{\text{th}}$ percentile of age	Healthy	TV, VG, PC	Questionnaire	Non-significant association between screen time and odds of obesity.
Nutrients/ 2020/ Lopez-Gonzalez D [20]	Mexico	School/ 1319293	Cross-sectional	12-17/ both	Overweight/ obesity defined as $\leq 95^{\text{th}}$ and $\geq 85^{\text{th}}$ and $\geq 95^{\text{th}}$ percentile of age respectively	Healthy	TV, electronic games	Questionnaire	Non-significant association between obesity and screen time.
Rev Bras Cineantropometri Desempenho Hum/ 2020/ Franceschin MJ [16]	Brazil	School/ 1015	Cross-sectional	15.3/ both	Overweight/ obesity defined as $1 \leq \text{BMI}$ Z-score < 2	Healthy	TV, Video game or PC	Questionnaire	A significant increased odds of overweight/ obesity in those with more than 2 hours per day TV watching (1.73 (1.24-2.42)). The OR for PC and video games was 1.01 (0.71-1.45).
Revista Paulista de Pediatria/ 2020/ De Lima TR [27]	Brazil	School/ 583	Cross-sectional	11-17/ both	Overweight defined as BMI Z-score ≥ 1	Healthy	TV, Video game or PC	Questionnaire	Non-significant reduced risk of excess weight by increased screen time of more than 4 hours/day (0.87 CI = 0.59-1.30)
Public Health Nutrition/ 2020/ Cheng L [18]	China	School/ 2201	Cross-sectional	10/ both	Obesity/ $\geq 95^{\text{th}}$ percentile of age	Healthy	TV/video games/ PC/iPad/ phone	Questionnaire	Increased odds of obesity for those with more than 2 hours/ d screen time (1.53; CI= 0.95-2.09)
J Immigrant Minor health/ 2019/ Zulfiqar T [25]	Australia	Community/ 2215 +2000	Cross-sectional	10-11/ both	Overweight/ obesity + $\text{BMI} \geq 25 \text{ kg/m}^2$	Healthy	TV, electronic games	Questionnaire	TV watching of more than 3 hours/ day in weekends was associated with odds of obesity in boys (1.4 (1.0,1.9) and girls (1.5 (1.1,1.9) P < 0.05
In J Environ Res Pub Health/ 2019/ Kerkadi A [22]	Qatar	Community/ 1161	Cross-sectional	14-18/ both	Overweight $25 \leq \text{BMI} \leq 30 \text{ kg/m}^2$ and	Healthy	TV, Video game or PC	Questionnaire	No significant association between

obesity BMI≥ 30
kg/m²

screen time
of more
than 2
hours/ day
and risk of
overweight/
obesity
(OR=1; CI=
0.7–1.4)

Table 2. Cont'd.

Journal/ Year/ First author	Country	Setting/ num	Design	Age (y)/ gender	Overweight/ obesity status and definition	Disease status	ST definition	ST measurement	Main findings
Plos One/ 2019/ Pabon et al [47]	USA	Community/ 2358+546	Cross- sectional	13-17/ both	Overweight/ obesity defined as 1 $\leq$ BMI Z- score <2	Healthy	TV, Video game	Questionnaire	No significant association between increased screen time and risk of overweight or obesity.
BMC Public Health/ 2019/ Haidar A [21]	USA	School/ 6716	Cross- sectional	14.88/ both	Overweight/ obesity defined as $\leq$ 95 th and $\geq$ 85 th and $\geq$ 95 th percentile of age respectively	Healthy	TV, DVD, movies	Questionnaire	No significant association between increased screen time and risk of overweight or obesity.
J Nepal Health Res Counc/ 2018/ Saha M [23]	Bangladesh	School/ 288	Cross- sectional	10-14/ both	Obesity defined as $\geq$ 95 th percentile of age	Healthy	TV, Video game, PC	Questionnaire	No significant association between increased screen time and risk of overweight or obesity.
Tropical Doctor/ 2018/ Mansouri N [77]	Pakistan	School/ 887	Cross- sectional	11-15/ both	Overweight defined as $\leq$ 95 th and $\geq$ 85 th percentile of age	Healthy	TV	Questionnaire	Watching TV more than 2 hours/ day was associated with increased risk of overweight (6.42 (4.32– 9.54) P <0.0001)
Prev Chronic Dis/ 2018/ Hu EY[48]	USA	School/ 15624	Cross- sectional	14- 18/ both	Obesity defined as $\geq$ 95 th percentile of age	Healthy	TV, Video or computer game, PC use	Questionnaire	Increased risk of obesity for those with more than 3 hours/ day TV watching (1.38 (1.09– 1.76) and more than 3 hours video game or PC use (1.19 (0.98– 1.43)
BMC Res Notes/ 2018/ Godakanda I [49]	USA	School/ 880	Cross- sectional	14-15/ both	Overweight defined as BMI Z- score $\geq$ 1	Healthy	TV, Video/ DVD	Questionnaire	Television watching time $\geq$ 2 h/day (2.6 (1.7–3.8) and Video/DVD watching $\geq$ 2 h/day (3.1 (1.8-5.3) were associated with increased risk of overweight.
Egypt Ped Assoc Gazette/ 2016/ Talat MA [78]	Egypt	School/ 32400	Cross- sectional	12- 15/both	Overweight/ obesity defined as $\leq$ 95 th and $\geq$ 85 th and $\geq$ 95 th	Healthy	TV	Questionnaire	More than 2 hours TV watching was associated with increased

					percentile of age respectively					risk of obesity (1.36 CI= 0.45–6.8; P = 0.048)
BMJ Open/ 2016/ Piryani S [81]	Nepal	School/ 360	Cross-sectional	16-19/ both	Overweight defined as BMI Z-score ≥ 1	Healthy	TV	Questionnaire	Watching TV more than 2 hours/ day was associated with increased risk of obesity (OR= 8.86 (3.90 to 20.11) <0.001	
Med J Islamic Rep Iran/ 2016/ Moradi G [79]	Iran	School/ 2506	Cross-sectional	10-12/ both	Overweight/ obesity defined as $\leq 95^{\text{th}}$ and $\geq 85^{\text{th}}$ and $\geq 95^{\text{th}}$ percentile of age respectively	Healthy	TV, VG	Questionnaire	Screen time was associated with increased risk of overweight and obesity (1.41(1.17-1.69)	
Indian J Comm Health/ 2015/ Watharkar A [50]	India	School/ 806	Cross-sectional	12-15/ both	Overweight/ obesity defined as $\leq 95^{\text{th}}$ and $\geq 85^{\text{th}}$ and $\geq 95^{\text{th}}$ percentile of age respectively	Healthy	TV, PC, cell phone	Questionnaire	Increased risk of overweight obesity for those with more than 2 hours TV watching (OR=3.72; CI= 2.38-5.83) or more than 2 hours computer or mobile phone use (OR=1.68; CI= 1.09-2.57)	
Revista Paulista de Pediatria/ 2015/ De Lucena JMS [80]	Brazil	School/ 2874	Cross-sectional	14-19/ both	Overweight $25 \leq \text{BMI} \leq 30$ kg/m ² and obesity $\text{BMI} \geq 30$ kg/m ²	Healthy	TV, PC, VG	Questionnaire	Excessive screen time was associated with increased risk of overweight/ obesity (1.25 (0.93-1.67)	
BMC Pediatr/ 2014/ Velásquez-Rodríguez CM [51]	Finland	Community/ 120	Cross-sectional	10-18/ both	Overweight defined as $\leq 95^{\text{th}}$ and $\geq 85^{\text{th}}$ percentile of age	Healthy and with insulin resistance	TV	Questionnaire	Increased risk of overweight in excessive TV watchers among adolescents with insulin resistance (OR= 2.39; CI= 0.94-6.05) but not among healthy adolescents.	
Int J Obes/ 2013/ De Jong E [52]	Netherland	School/ 2429+2004+2068	Cross-sectional	10-13/ both	Overweight $25 \leq \text{BMI} \leq 30$ kg/m ² and obesity $\text{BMI} \geq 30$ kg/m ²	Healthy	TV, PC	Questionnaire	No significant association between TV watching more than 1.5 hours or PC use of more than 30 minutes and	

									overweight/ obesity.
JCRPE/ 2012/ Ercan S [53]	Turkey	School/ 8848	Cross- sectional	11-18/ both	Overweight $25 \leq \text{BMI} \leq 30$ kg/m ² and obesity $\text{BMI} \geq 30$ kg/m ²	Healthy	TV, PC	Questionnaire	Increased risk of overweight and obesity for those with more than 2 hours TV watching or PC use.
Pediatrics/ 2012/ Drake KM [55]	England	School/ 1718	Cross- sectional	12-18/ both	Overweight/ obesity defined as $\leq 95^{\text{th}}$ and $\geq 85^{\text{th}}$ and $\geq 95^{\text{th}}$ percentile of age respectively	Healthy	TV, DVD, video game	Questionnaire	Screen time of 7.1 -14 and >14 hours/week was associated with increased obesity risk of OR= 1.28 CI= 1.06, 1.55; P<0.05 and OR= 1.37 CI= 1.09, 1.71; P < 0.01 respectively.
J Korean Med Sci/ 2012/ Byun W [56]	Korea	Community/ 1033	Cross- sectional	12-18/ both	Overweight/ obesity defined as $\geq 95^{\text{th}}$ percentile of age	Healthy	TV, PC, video game	Questionnaire	Increased risk of overweight and obesity was observed by increased screen time
Ital J Pediatr / 2012/ Adesina AF[57]	Nigeria	School/ 690	Cross- sectional	10-19/ both	Overweight $25 \leq \text{BMI} \leq 30$ kg/m ² and obesity $\text{BMI} \geq 30$ kg/m ²	Healthy	TV	Questionnaire	Increased risk of overweight and obesity was observed by increased screen time
Childhood Obesity/ 2011/ El- Gilany AH [54]	Egypt	School/ 953	Cross- sectional	14-19/ both	Overweight defined as $\leq 95^{\text{th}}$ and $\geq 85^{\text{th}}$ percentile of age	Healthy	TV, PC	Questionnaire	Increased risk of overweight/ obesity for those with more than 2 hours TV watching (2.6 (1.7– 3.9) or more than 2 hours computer use (1.8 (1.3–2.5)
J Epidemiol/ 2009/ Sun Y [24]	Japan	School/ 5753	Cross- sectional	12-13/ both	Overweight $25 \leq \text{BMI} \leq 30$ kg/m ²	Healthy	TV, VG	Questionnaire	Watching TV more than 3 hours/ d was associated with increased risk of overweight in boys (OR=1.79; CI=1.21– 2.67 and girls OR= 2.37; CI= 1.55–3.62; P <0.001
Int J Pediatr Obes/ 2008/ Collins AE[26]	Indonesia	School/ 1758	Cross- sectional	12-15/ both	Obesity defined as $\text{BMI} \geq 25$ kg/m ²	Healthy	PC, PS	Questionnaire	Increased risk of obesity in those with more than 3 hours/ d PC use (OR= 1.85; CI=

Table 3. Subgroup analysis for the odds of obesity in highest versus lowest screen-user adolescents								
Group	No. of studies*	OR (95% CI)			P _{within group}	P _{between group *}	P _{heterogeneity}	I ² , %
Total	64	1.393	1.264	1.536	<0.001		0.105	85.9
Continent						<0.001		
America	13	1.127	1.025	1.238	0.013		0.144	30
Europe	17	1.420	1.150	1.753	0.001		<0.001	92.6
Asia	19	1.834	1.477	2.276	<0.001		<0.001	87.2
Oceania	8	1.099	0.927	1.304	0.278		0.056	49.1
Africa	7	1.649	1.148	2.368	0.007		0.060	50.5
Screen type						<0.001		
TV	28	1.767	1.423	2.195	<0.001		<0.001	82.9
PC	10	1.628	1.141	2.325	0.007		<0.001	86.7
VG	4	1.266	0.924	1.734	0.142		0.162	41.7
TV+VG	13	1.090	1.008	1.180	0.031		<0.001	71.1
VG + PC	2	1.148	0.971	1.357	0.105		0.462	0.0
TV + VG + PC	7	1.093	0.938	1.274	0.256		0.363	8.6
Age group						<0.001		
<15	28	1.498	1.253	1.790	<0.001		<0.001	79.1
≥15	8	1.587	1.203	2.094	0.001		<0.001	81.5
Both	28	1.254	1.102	1.427	0.001		<0.001	88.5
Setting						<0.001		
School	51	1.518	1.332	1.730	<0.001		<0.001	88.1
Community	13	1.121	1.039	1.210	0.003		0.134	31.2
Obesity status						<0.001		
Obesity	24	1.390	1.187	1.627	<0.001		<0.001	74.7
Overweight	13	1.551	1.203	2.001	0.001		<0.001	92.6
Overweight/ obesity	27	1.331	1.157	1.530	<0.001		<0.001	85.3
Sample size						<0.001		
1000 >	19	1.875	1.368	2.570	<0.001		<0.001	85.3
1000-5000	31	1.151	1.073	1.235	0.002		<0.001	61.7
≥ 5000	14	1.596	1.188	2.146	<0.001		<0.001	89.9
Study quality *						<0.001		
Low	9	2.296	1.580	3.338	<0.001		<0.001	88.4
Moderate	42	1.278	1.151	1.418	<0.001		<0.001	73.7
High	13	1.259	1.085	1.461	0.002		<0.001	84.4
*low quality = 0–3; moderate quality = 4–7; high quality ≥ 8; all of the included studies were in moderate quality group therefore, subgrouping was not performed.								

Figures

Figure 1

Study flowchart

Figure 2

Odds ratio (OR) with 95% confidence interval (CI) of obesity in highest versus lowest screen user adolescents. I^2 represents the degree of heterogeneity.

Figure 3

Dose-response association between screen time and odds of obesity. Linear relation (solid line) and 95% CI (dashed lines) of pooled OR of obesity by 1 *min/day* increment of screen time (p -nonlinearity = 0.310) among adolescents.

Figure 4

Begg's funnel plot (with pseudo 95% CIs) of the odds of obesity in highest versus lowest screen time categories among adolescents.

Figure 5

Filled funnel plot with pseudo 95% confidence limits for studies evaluating the association between screen time and obesity among adolescents [OR=1.575; CI=1.083, 2.068; $P < 0.000$).

Supplementary Files

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