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Sleep problems in excessive technology use among adolescent: a systemic review and meta-analysis

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Abstract

Background: Inadequate sleep quantity and quality is a public health concern with an array of detrimental health outcomes. Portable technological devices have become a ubiquitous part of adolescents' lives and may affect their sleep duration and quality. The purpose of this study was to summarize published analyses of various technology uses and sleep outcomes and to examine whether there is an association between excessive technology use (ETU) and poor sleep outcomes in adolescents.

Method: We conduct a systematic review and meta-analysis. Pubmed, Embase, Science Direct, Google Scholar, Cochrane Library were used. Inclusion and exclusion criteria were performed. Only original research papers published from 1999 to 2018 and offcially reviewed by peers were included for analysis. We used the Review Manager 5.3 software for statistical analysis.

Results: Nineteen studies were included, and their quality was assessed. These studies involved 253,904 adolescents (mean [SD] age, 14.82 [0.83] years; 51.1% male). There was a strong and consistent association between ETU and sleep problems (odds ratio [OR], 1.33; 95% CI, 1.24–1.43) ($P < 0.00001$, $I^2 = 96\%$), reduced sleep duration (SMD, − 0.25; 95% CI, − 0.37-0.12) ($P < 0.00001$, $I^2 = 81\%$), and prolonged sleep onset latency (OR, 0.16; 95% CI, − 0.02-0.34) ($P = 0.05$, $I^2 = 66\%$).

Conclusions: ETU has a significant effect on sleep duration in adolescents over 14 years of age, prolong the SOL of adolescents, and may lead to several sleep problems. Interventions must be developed to raise awareness of the potential health hazard to improve sleep hygiene through an integrated approach involving teachers, health care professionals, and parents.

Keywords: Excessive technology use, Sleep problems, Adolescents, Meta-analysis

Background

Sleep plays an important role in the growth of young people. The problem of sleep affects human cognition and social function, and is also a warning signal for a variety of diseases. Sleep disorders negatively affects several domains including school performance, mood regulation, cognitive process, and general health in adolescents (Dahl & Lewin, 2002; Gruber et al., 2012; Fredriksen et al., 2004; Wolfson & Carskadon, 1998). The USA National Sleep Foundation (NSF, 2006) recommends that adolescents sleep for no less than 9 hours a day (National Sleep Foundation, 2006), but in the USA, 75% of those 17 to 18 years old report insufficient sleep, and young people in other developed countries have the same phenomenon (National Sleep Foundation, 2014).

Teenagers now have multiple electronic devices such as smart phones and ipad. The daily watch on the screen has increased significantly. Excessive technology use (ETU) may contribute to the adolescent insufficient sleep. Previous study have found that sleep reduction appears to be aggravated by excessive use of technology devices such as TV viewing (Tynjala et al., 1993), internet use (Yen et al., 2008), video gaming (Weaver et al., 2010; Rehbein et al., 2010) and mobile telephone use

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(Van den Bulck, 2007; Munezawa et al., 2011). ETU have been found to be associated with reduced sleep duration (Tynjala et al., 1993), delayed sleep onset latency (Tynjala et al., 1993; Weaver et al., 2010) and increased other sleep problems (Rehbein et al., 2010; Munezawa et al., 2011).

ETU in teenagers has been a hot spot of research for decades. A large number of academic literatures have reported related studies. However, the association between ETU and poor sleep outcomes has been underexplored, because the speed of technological devices developing has outpaced the research capabilities. In the current study, we present a systematic review to quantify the influence of ETU on sleep outcomes in a meta-analysis. Compared to previous study (Carter et al., 2016), we make a further exploration of sleep duration, sleep onset latency, as well as include several new related articles.

Method

Databases online

Pubmed, Embase, Science Direct, Google Scholar, Cochrane Library were used. We conducted extensive searches for studies published from 1999 using the terms "excessive Internet/technology use" or "problematic Internet/technology use" or "pathological Internet/technology use" or "Internet addiction" or "excessive computer/technology use" or "Internet gaming" or "computer gaming" or "Internet gaming addiction" combined with the terms "insomnia" or "sleep problems" or "sleep quality" or "sleep disorders" or "sleep disturbance" or "sleep deprivation". The year 1999 was chosen as the starting year for the search because that is when active empirical inquiry into the psychological factors affecting Internet addiction first began.

Study selection

This study was conducted following Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. After completing the search on the electronic databases, titles and abstracts of the identified articles were assessed for their suitability to be included in this research. Studies were included if they (1) were epidemiological studies of adolescents of school age between 11 and 20 years with appropriate study designs; (2) were cross-sectional, case-control and cohort studies that examined the relationship between ETU or problematic internet use and sleep problems including insomnia and poor sleep quality; (3) provided information of ETU and sleep outcomes in the shape of quantized data.

Exclusion criteria

Studies were excluded if they 1) did not provide sufficient information to calculate the aggregate prevalence and odds ratio (OR); 2) did not provide a specific definition or criteria for ETU or problematic internet use; 3) the authors did not respond to provide further information upon request including the psychiatric co-morbidity directly related to ETU (e.g. online gambling). Articles with abstracts that were written in the English language but had full texts written in non-English languages were excluded.

Quality assessment

The full texts of all relevant articles were retrieved, and their eligibility for inclusion was assessed. Two reviewers (Q.Z. and P. J.) independently assessed the methodological quality of all full-text articles, and discrepancies were resolved by a third reviewer (X.M.). We followed the guidelines in the Meta-analysis of Observational Studies in Epidemiology (MOOSE) statement for reporting (Stroup et al., 2000).

Definition of poor sleep quality

Since the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989) was developed, based upon the International Statistical Classification of Disease and Related Health Problems, 10th edition (ICD-10) (World Health Organization, 1992) and the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (American Psychiatric Association, 2013) criteria for classification of insomnia, it was employed in plenty of original studies to assess insomnia and sleep disturbances. Furthermore, early awakenings, night awakenings, and long sleep onset latency were used to assess the sleep quality.

Technology and internet use

In this study, type of technology included PC, mobile phone, television, video games, and music. Internet was used for game, video, music, social communication, and study. A number of adolescents' time of usage was before sleep. In our study, we define the ETU as the problematic internet use (PIU) and excessive use of PC, cell phone, MP3 player, tablet, game console and TV as well as the technology use before sleep in bed and heavy use in daytime.

Measurement of association between technology use and sleep outcomes

Included studies measured the association between technology use and the influence on sleep using either regression slopes (β), correlation coefficients (r), or ORs. To ensure consistency in interpretation, studies that reported dichotomous data or logistic regression analyses of sleep quality and continues data of sleep duration were pooled in a meta-analysis.

Statistical analysis and heterogeneity

All statistical analyses were performed with Review Manager 5.3 using the random-effects models for aggregate prevalence and pooled OR. Statistical heterogeneity was assessed using the I^2 statistic. Dichotomous and continues data were respectively presented as OR and SMD with the associated 95% CIs, *P* values, and I^2 summary data. Heterogeneity exceeding 85% was explored using subgroup analyses. Subgroups to explore heterogeneity were classified by country.

Results

Study selection

A total of 297 studies were identified, and 67 full texts were reviewed, leading to 40 being excluded (Fig. 1). 23 studies involving 253,904 adolescent (mean [SD] age, 14.82 [0.83] years; 51.1% male) were included after assessed for methodological quality, with 4 excluded because of poor methods conduct or reporting.

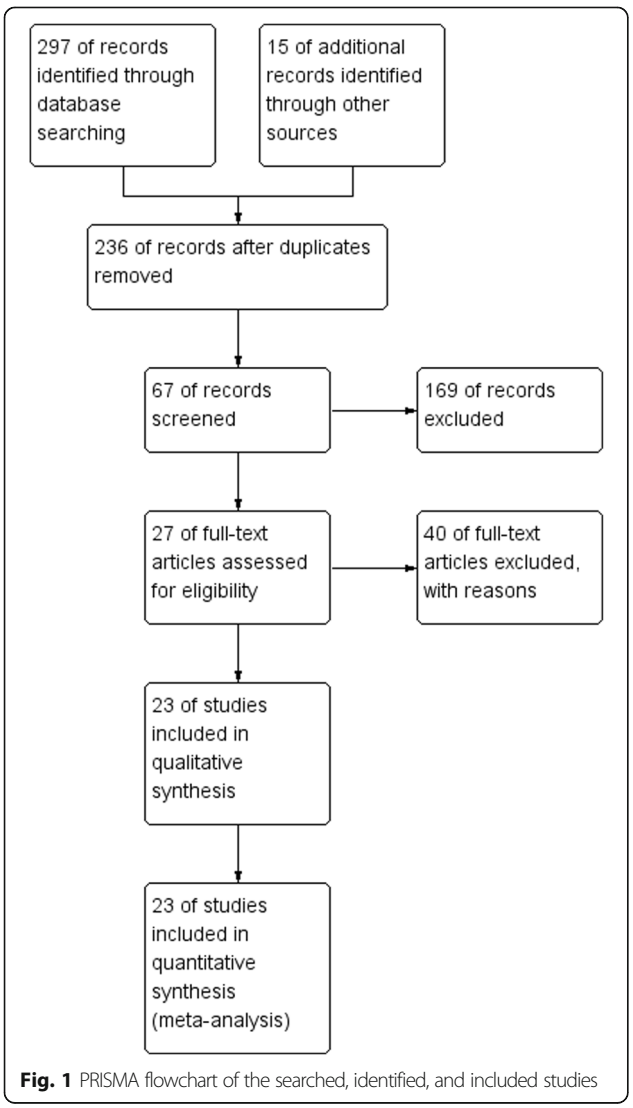

Fig. 1 PRISMA flowchart of the searched, identified, and included studies

Study characteristics

Table 1 showed characteristics of included studies. Author, publication year, country, study design and methods, participants (% male participants), case definition of technology exposure, exposure type of technology, age range (or average age) and sleep outcomes were listed.

Included studies were conducted in **Europe** ($n = 9$) (Arora et al., 2012; Arora et al., 2013; Arora et al., 2014; Bruni et al., 2015; Hysing et al., 2015; Van den Bulck, 2004; Lemola et al., 2014; Nuutinen et al., 2014; Punama-ki et al., 2006), **East Asia** ($n = 10$) (An et al., 2014; Cheung & Wong, 2011; Choi et al., 2009; Liu et al., 2017; Mak et al., 2014; Park, 2014; Park & Lee, 2017; Tan et al., 2016; Tamura et al., 2017; Kim et al., 2018), and W**est Asia** ($n = 4$) (Fatih et al., 2013; Shochat et al., 2010; Sami et al., 2018; Hawi et al., 2018). Eight studies assessed the sleep duration of ETU and no excessive technology use (Arora et al., 2013; Arora et al., 2014; Fatih et al., 2013; Cheung & Wong, 2011; Choi et al., 2009; Lemola et al., 2014; Shochat et al., 2010; Hawi et al., 2018). Three studies assessed the sleep onset latency (Arora et al., 2014; Cheung & Wong, 2011; Shochat et al., 2010). Most of studies investigated association between the ETU and sleep problems.

Sleep outcomes

Sleep duration

Figure 2 shows the sleep duration of control and ETU groups. As can be seen, sleep duration of people in control condition is longer than that of ETU. The SMD is − 0.25, and 95%CI is (− 0.37, − 0.12) ($P < .00001$, $I^2 = 81\%$). The large heterogeneity was due to the study by Choi2009, which recruited people of average age of 16.7 ± 1.0. People's average age or age range in other studies were 13.9 ± 2.0 of Arora2013, 11–13 of Arora2014, 16.04 ± 1.02 of Canan2013, 14.70 ± 2.02 of Cheung2010, 14.82 ± 1.26 of Lemola2014, 14.0 ± 0.8 of Shochat2010, 16.2 ± 1.0 of Hawi2018, respectively. After that study was excluded, the SMD was − 0.30 (95% CI, − 0.37, − 0.23) ($P < .00001$, $I^2 = 21\%$). Considering the age range of subjects was large, we divided them into two groups: younger adolescents (average age ≤ 14 years) and older adolescents (average age > 14 years). The SMD of younger group is − 0.30, and 95%CI is (− 0.39, − 0.20) ($P = 0.87$, $I^2 = 0\%$). The SMD of older group is − 0.22, and 95% CI is (− 0.41, − 0.02) ($P < .00001$, $I^2 = 87\%$).

Sleep onset latency

Three studies reported sleep onset latency of frequent use group and control group (Fig. 3). Sleep onset latency

Table 1 Summary of studies included in the meta-analysis ($n = 19$)

Reference (author, year)	country	Study design & methods	Participants (% male participants)	Case definition of technology exposure and sleep outcomes	Exposure type of technology	**Age range (or Average age)**	**Sleep Outcomevariable**
An, 2014 (An et al., 2014)	China	cross-sectional school-based study	$n = 13,723$ (48%boys)	YIAT, PSQI, MSQA	Internet use	10.0–20.0 (15.26 ± 1.67)	Sleep quality
Arora, 2012 (Arora et al., 2012)	UK	cross-sectional school-based study	$n = 624$ (35.1%boys)	SSHS, TUQ	TV viewing; Video gaming; PC/laptop; Mobiles	11.0–18.0	Sleep quality
Arora, 2013 (Arora et al., 2013)	UK	cross-sectional school-based study	$n = 632$ (36.1%boys)	SSHS, TUQ	Computer use; Mobile telephone use; TV viewing; Video gaming	11.0–18.0 (13.9 ± 2.0)	Sleep duration
Arora, 2014 (Arora et al., 2014)	UK	cross-sectional study	$n = 738$ (54.5%boys)	SSHS, TUQ	Television; Video gaming; Mobile telephone; Music; Computer or l aptop (study); Internet (social)	11.0–13.0	Sleep duration, sleep-onset latency, sleep problems including early awakening, difficulty falling to sleep, night awakenings
Bruni,2015 (Bruni et al., 2015)	Italy	cross-sectional study	$n = 850$ (42.8%boys)	SSHS, MPIQ, SPQ, Questionnaire on the use of technology	mobile phone-related activities; Internet-related activities	11.0–16.0 (13.53 ± 1.72)	Sleep quality
Canan, 2013 (Fatih et al., 2013)	Turkey	cross-sectional school-based study	$n = 1956$ (47.5%boys)	YIAT, Questionnaire of sleep quality	Chat rooms and Internet; messaging; Web surfing; playing online games; academic activities; Other Internet activities such as e-mail checking; reading online news; watching online videos; shopping.	14.0–18.0 (16.04 ± 1.02)	Sleep duration, sleep problems including early awakening, difficulty falling to sleep, night awakenings
Cheung, 2010 (Cheung & Wong, 2011)	Hong Kong	school-based cross-sectional study	$n = 719$ (60.4%boys)	PSQI, CIAS, GHQ-12	Internet use	10.0–20.0 (14.70 ± 2.02)	Sleep onset latency, Sleep duration, sleep quality
Choi, 2009 (Choi et al., 2009)	Korea	cross-sectional study	$n = 2336$ (57.5%boys)	YIAT, ESS	Internet use	16.7 ± 1.0	Sleep duration, sleep problems including early awakening, difficulty falling to sleep, night awakenings
Hysing, 2015 (Hysing et al., 2015)	Norway	A large cross-sectional population-based survey study	$n = 9846$ (46.5%boys)	HBSC	PC, cell phone, MP3 player, tablet, game console and TV.	16.0–19.0	Sleep problems
Jan, 2014 (Van den Bulck, 2004)	Belgium	cross-sectional study	$n = 2546$	Questionnaires of media use, sleep variables, activity level.	television-viewing; Computer-game playing; Internet use	14.76 ± 1.71	Sleep time
Lemola, 2014 (Lemola et al., 2014)	Switzerland	cross-sectional study	$n = 362$ (55.2%boys)	ISI, Media Use assess items.	TV or movies, play video games, talk on the phone or text, and spend time online on FaceBook or in chat rooms or surf the Internet	12.0–17.0 (14.82 ± 1.26)	Sleep duration, sleep difficulties
Liu, 2017 (Liu et al., 2017)	China	cross-sectional study	$n = 1196$ (53%boys)	MPAI, PSQI	mobile phone	14.0–20.0 (16.75 ± 0.94)	Sleep quality
Mak, 2014 (Mak et al., 2014)	Hong Kong	cross-sectional survey	$n = 762$ (57.6%boys)	PSQI, SQI, ESS, Questionnaires of	Screen viewing	12.0–20.0 (15.27 ± 1.70)	Sleep quality, daytime sleepiness

Table 1 Summary of studies included in the meta-analysis ($n = 19$) *(Continued)*

Reference (author, year)	country	Study design & methods	Participants (% male participants)	Case definition of technology exposure and sleep outcomes	Exposure type of technology	**Age range (or Average age)**	**Sleep Outcomevariable**
				technology use			
Nuutinen, 2014 (Nuutinen et al., 2014)	Finland, France and Denmark.	a cross-sectional study	$n = 5402$ (47%boys)	HBSC	computer use	15.61 ± 0.37	Sleep habits
Park, 2014 (Park, 2014)	Korean	a cross-sectional study	n = 73,238 (52.4%boys)	YIAT, Questionnaires of sleep satisfaction	PIU	12.0–18.0 (15.06 ± 1.75)	Sleep satisfaction
Park, 2017 (Park & Lee, 2017)	Korean	a cross-sectional study	$n = 70,696$ (52.4%boys)	YIAT, Questionnaires of sleep satisfaction	PIU	12.0–18.0 (15.10 ± 1.75)	Sleep satisfaction
Punamaki, 2006 (Punamaki et al., 2006)	Finland	a cross-sectional study	$n = 7292$ (44.8%boys)	Questionnaires of ICT use and sleep habits	computer use; Mobile phone use	12.0–18.0	Sleeping habits
Shochat, 2010 (Shochat et al., 2010)	Israeli	a cross-sectional study	$n = 449$ (50.1%boys)	SSHS, EMFQ	electronic media	14.0 ± 0.8	Sleep duration, sleep onset latency, sleep habits
Tan, 2016 (Tan et al., 2016)	China	a cross-sectional study	$n = 1661$ (51.8%boys)	YIAT, PSQI	Internet use	12.0–18.0	Sleep disturbance
Sami, 2018 (Sami et al., 2018)	Israel	a cross-sectional study	$n = 631$ (45.5%boys)	YIAT, CASC	Internet use	12.0–18.0 (14.59 ± 1.53)	Sleep disturbance
Tamura, 2017 (Tamura et al., 2017)	Japan	a cross-sectional study	$n = 295$ (58.6%boys)	Questionnaires of mobile phone use, AIS	Mobile phone use	15.0–19.0 (16.2 ± 0.9)	Insomnia
Hawi, 2018 (Hawi et al., 2018)	Lebanon	a cross-sectional study	$n = 524$ (47.9%boys)	Questionnaires of sleep habit, IGD-20 Test	Internet game	15.0–19.0 (16.2 ± 1.0)	Sleep duration, sleep disturbance
Kim, 2018 (Kim et al., 2018)	Korea	a cross-sectional study	$n = 57,426$ (50.3%boys)	KYRBWS	Internet use	12.0–15.0 (13.5)	Sleep Satisfaction

YIAT Young Internet Addiction Test, *PSQI* Pittsburgh Sleep Quality Index, *MSQA* Multidimensional Sub-health Questionnaire of Adolescents, *SSHS* School Sleep Habits Survey, *TUQ* Technology Use Questionnaire, *MPIQ* Mobile Phone Involvement Questionnaire, *SPQ* Shorter Promis Questionnaire, *CIAS* Chinese Internet Addiction Scale, *GHQ-12* The 12-item version of General Health Questionnaire, *ESS* Epworth Sleepiness Scale, *HBSC* Health Behavior in School-aged Children, *ISI* Insomnia Severity Index, *MPAI* Mobile Phone Addiction Index, *SQI* Sleep Quality Index, *ICT* Information and Communication Technology, *EMFQ* Electronic Media and Fatigue questionnaire, *CASC* Child and Adolescent Sleep Checklist, *AIS* Athens Insomnia Scale, *IGD* Internet Gaming Disorder, *KYRBWS* Korea Youth Risk Behavior Web-based Survey

of people in control group is shorter than that of technology group ($P = 0.05$). The pooled SMD for sleep onset latency was 0.16 (95% CI, − 0.02-0.34) (P = 0.05, I^2 = 66%).

Sleep problems

There were data from 22 studies (An et al., 2014; Arora et al., 2012; Arora et al., 2014; Bruni et al., 2015; Fatih et al., 2013; Cheung & Wong, 2011; Choi et al., 2009; Hysing et al., 2015; Van den Bulck, 2004; Lemola et al., 2014; Liu et al., 2017; Mak et al., 2014; Nuutinen et al., 2014; Park, 2014; Park & Lee, 2017; Punama-ki et al., 2006; Shochat et al., 2010; Tan et al., 2016; Sami et al., 2018; Tamura et al., 2017; Hawi et al., 2018; Kim et al., 2018) that investigated association between the technology use and sleep problems (Fig. 4), including poor sleep quality (An et al., 2014; Arora et al., 2012; Bruni et al., 2015; Hysing et al., 2015; Lemola et al., 2014; Liu et al., 2017; Mak et al., 2014; Sami et al., 2018; Hawi et al., 2018), early awakenings (Arora et al., 2014; Fatih et al., 2013; Choi et al., 2009; Shochat et al., 2010), difficulty falling asleep (Arora et al., 2014; Fatih et al., 2013; Choi et al., 2009; Shochat et al., 2010), night awakenings (Arora et al., 2014; Fatih et al., 2013; Choi et al., 2009), less sleep quantity (Van den Bulck, 2004; Nuutinen et al., 2014; Park, 2014; Park & Lee, 2017; Punama-ki et al., 2006; Shochat et al., 2010; Kim et al., 2018) and insomnia (Cheung & Wong, 2011; Tan et al., 2016; Tamura et al., 2017). Three subgroups were classified by country. The OR of Asia subgroup was 1.55 (95% CI, 1.48–1.62) ($P = 0.24$, $I^2 = 23\%$). The large heterogeneity of Asia-China subgroup was due to the study of An2014. After that study was excluded, the pooled OR was 1.10 (95% CI, 1.05, 1.15) ($P = 0.002$, $I^2 = 79\%$). The large heterogeneity of Europe subgroup was due to the study of Jan2004, which recruited people of two average ages: first year: first year of secondary school (average age, 13 years); fourth year: fourth year of secondary school (average age, 16 years). After the study of Jan2004 was excluded, the OR was 1.24 (95% CI, 1.16, 1.33) ($P < .00001$, $I^2 = 80\%$).

In Asia subgroup, dichotomous data were available from study of Canan2013 that investigated sleep problem including difficulty falling asleep, night awakenings, and early morning awakenings, the prevalences of which in no frequent use population were 37.9, 36.0, 16.1% respectively, and the prevalences of frequent use population were 44.9, 44.1, 19.0% respectively. In the study of Choi2009, Tamura2017 and Park2017, dichotomous data were also available, and there was an increased odds of sleep problems in people who had frequently used a technology device. In the study of Park2014, the associations between sleep satisfaction and problematic internet use was investigated [β coefficients (SE) were 0.47 (0.03)], and odd ratio adjusted for age, sex, residing region, perceived academic performance, family economic status, parents' level of education, and body mass index. In the recent study of Sami2018, Hawi2018, and Kim2018, the ORs were 1.70, 1.41, and 1.72 respectively.

In Asia-China subgroup, the associations between technology use and sleep quality was reported by An2014 [β coefficients (SE) were 0.894 (0.055)], Cheung2010 [β coefficients (SE) were 0.08 (0.01)], Liu2017 [β coefficients (SE) were 0.34 (0. 1033)]. In the study of Mak2014, the associations between technology use and sleep quality, and associations between technology use and excessive daytime sleepiness were accessed, and pooled OR was 1.14 (95% CI, 1.08, 1.20) ($P < 0.001$). In the study of Tan2016, the prevalence of problematic internet use was 17.2% among adolescents, with 40.0% of adolescents suffering from sleep disturbance, problematic internet use was found to be a significant predictor of sleep disturbance (β = 0.048, $P < 0.001$).

In Europe subgroup, study of Arora2012 developed a model adjusted for age, sex, ethnicity, activity, school, snacking, depression, bedroom sharing and morningness-eveningness. After conducting pathway analysis, the impact of frequent technology use to sleep quality was evaluated [β coefficients (SE) were 0.75 (0.27)]. In the study of Arora2014, the OR and 95% confidence intervals for the multinomial regression between technologies and sleep parameters were 1.41 [1.18, 1.68]. Correlation between internet/mobile phone use and sleep problems was reported in the study of Bruni2015 (β = 0.31, $P < 0.01$). In the study of Hysing2015, the long sleep onset latency and sleep deficit were contribute to sleep problems, the pooled OR was 1.26 (95% CI, 1.22, 1.30) ($P < 0.001$). The effect of weekday and weekend technology use on sleep problems was investigated by Jan2004, the pooled OR was 1.07 (95% CI, 1.05, 1.09) ($P = 0.16$, I^2 = 36%). In the study of Lemola2014, regression models revealed that electronic media use in bed before sleep was related to sleep difficulties (β = 0.21, P < 0.001). In the study of Nuutinen2014, three countries' data were collected, the pooled OR was 1.22 (95% CI, 1.12, 1.33) ($P = 0.46$, $I^2 = 0\%$). Technology use including computer use and mobile phone use leaded to sleep problems in the study of Punamaki2006, the associations between technology use and sleep problems were reported in 12 and 14 years adolescents group and in 16 and 18 years adolescents group, the pooled OR was 1.24 (95% CI, 1.14, 1.35) ($P = 0.07$, $I^2 = 53\%$). In the study of Shochat2010, technology use included internet use and television use, the pooled OR for sleep problems was 1.11 (95% CI, 1.07, 1.15) ($P = 0.01$ $I^2 = 54\%$).

Discussion

The present study sought to quantify the relationships between technology uses and sleep outcomes in adolescent

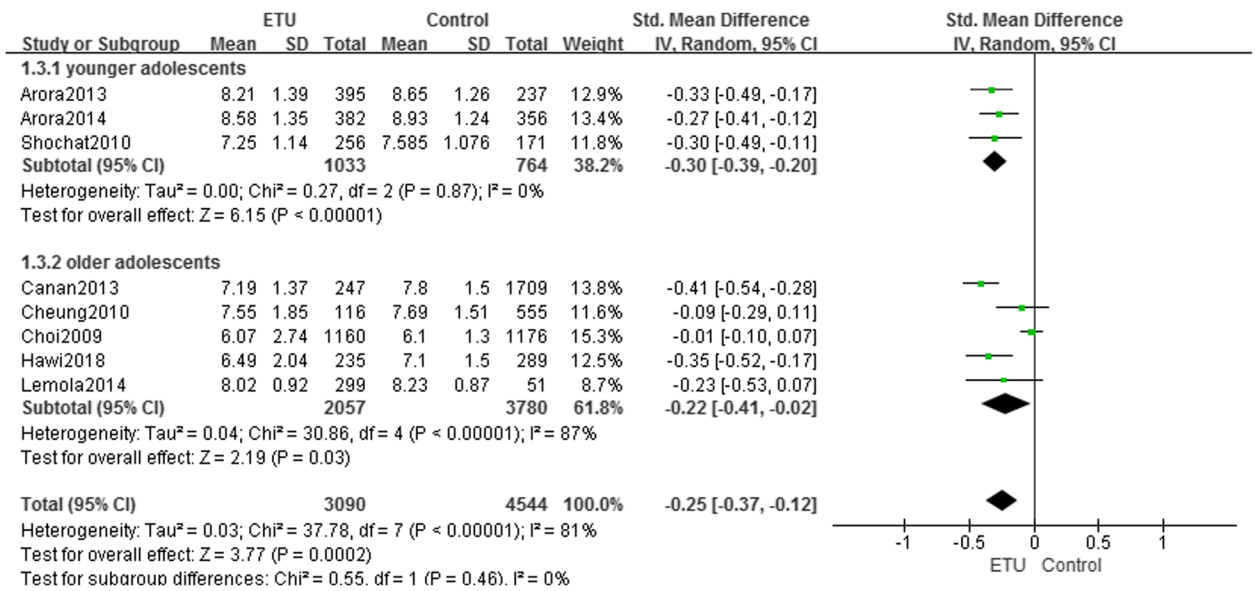

Fig. 2 Sleep duration of adolescents in ETU and control condition. Control condition: no frequently technology use

participants. The current meta-analysis ultimately contained results from 23 articles and involved combined sample sizes that ranged from 295 to 73,238 subjects, with 253,904 in total. This large sample could supply a considerable empirical basis for determining the contribution of technology overuses on poor sleep outcomes. In the first, ETU may disrupt the sleep by directly shortening or interrupting sleep time. In the second, the information on the Internet could be psychologically stimulating and affect the mood before sleep. Thirdly, the light emitted from the electronic screen may affect the circadian rhythm and physiological sleep (Cain & Gradisar, 2010; Hale & Guan, 2015; Chang et al., 2015). There may be other aspects of ETU that have not been found to damage sleep.

On the addictive aspect of technological devices or Internet use, young people may be more vulnerable than adults (Griffths & Hunt, 1998). They may be more likely to be affected by internal conditions because their brain and mental state are in development. An interesting result of our meta-analysis was that studies in Asia, especially in Korea, reported larger effect sizes than Europe and Asia-China studies for outcome variables. This result was consistent with other findings (Winkler et al., 2013) indicating that culture-related differences in the study procedures as well as methodological differences may have caused this outcome. Meanwhile, sleep duration has significant differences among different age groups, while sleep onset latency does not (Ohayon et al., 2004). Our results indicated that ETU has a significant effect on sleep duration in adolescents over 14 years of age.

Although we have carried out a large number of sample analyses, our research still has some limitations. The limitations of research in this area include (1) the measurement error of self-reported data makes it difficult for us to determine the accuracy of the results, (2) in different articles the classification of the use of technology is different, and the definition of ETU is not the same (3) the speed of technology development is far beyond the

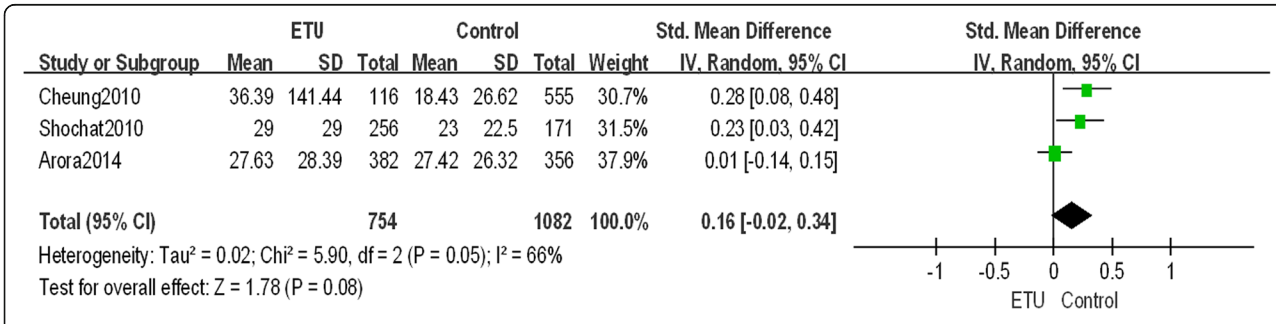

Fig. 3 Sleep onset latency of adolescents in ETU and control condition

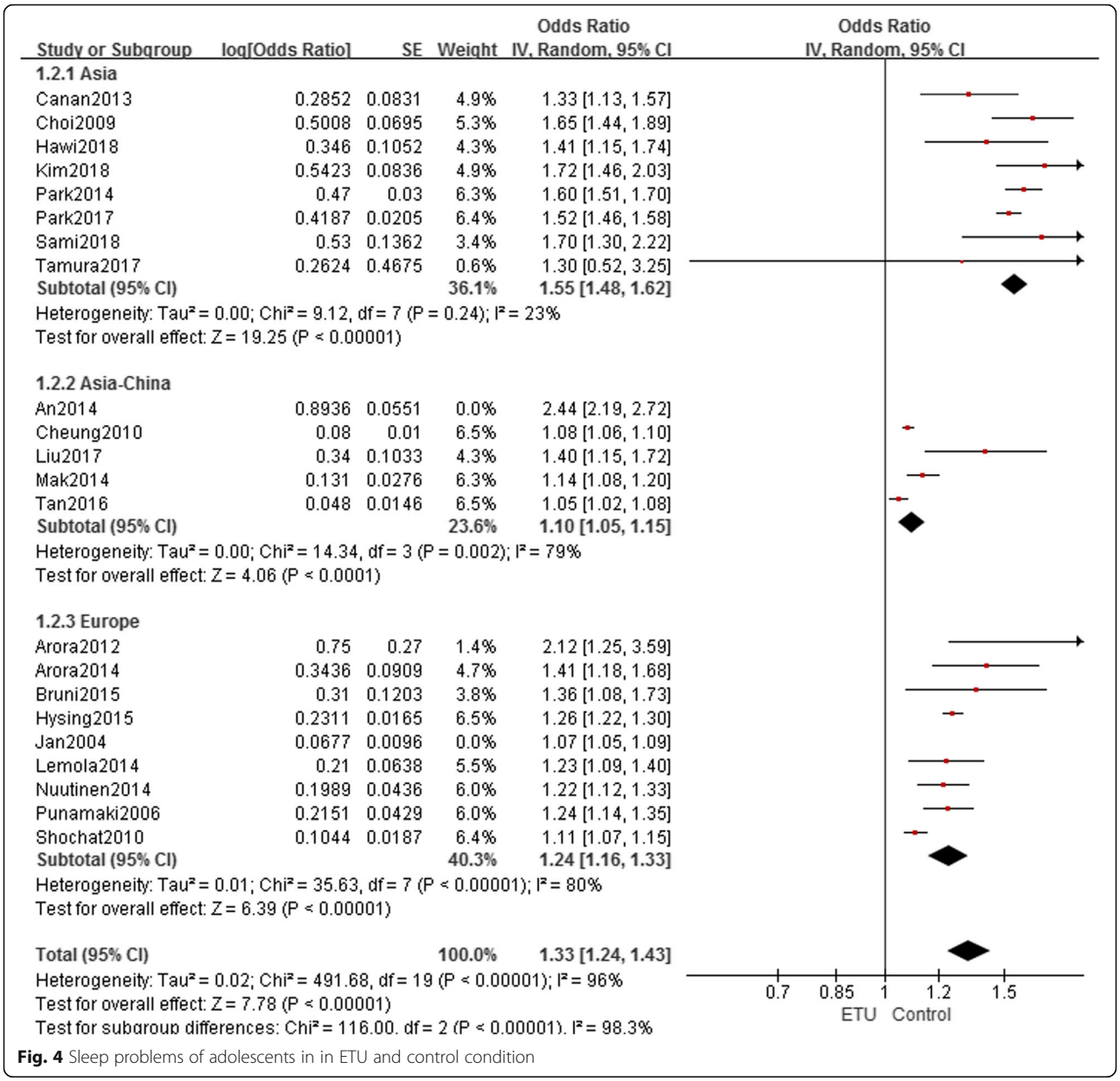

Fig. 4 Sleep problems of adolescents in in ETU and control condition

speed of research (4) the design of observational studies has its inherent weaknesses.

Despite these limitations, the results of our study have several suggestions and implications. A detailed investigation of sleep duration and sleep onset latency in the ETU subjects was carried out. The results suggesting that the deleterious association between screen-based technology overuse and sleep is a major public health problem in adolescents. We suggest that if a young people who own technological devices has a sleep problem it is possible to consider whether or not it is related to ETU. During the clinical visits by health visitors or school nurses, we also encourage screening of adolescents to identify whether their sleep is associated with ETU, meanwhile, formulating a treatment plan for a specific situation.

Conclusion

In this study, we summarized published articles of various technology uses and sleep outcomes. We suggested that there is a significant association between ETU and poor sleep outcomes in adolescents. ETU has a significant effect on sleep duration in adolescents over 14 years of age, prolong the SOL of adolescents, and may lead to several sleep problems. We recommend that interventions to minimize technology use need to be developed and evaluated. Parents should understand the effects of

the ETU factor on adolescents' sleep and pay more attention to their sleep and make children go to bed earlier, so as to ensure sleep time and improve sleep quality. In addition, teachers and doctors must help parents to raise awareness of the potential health hazard and to improve sleep hygiene.

Abbreviations

CIAS: Chinese Internet Addiction Scale; EMFQ: Electronic Media and Fatigue questionnaire; ESS: Epworth Sleepiness Scale; ETU: Excessive Technology Use; GHQ-12: The 12-item version of General Health Questionnaire; HBSC: Health Behavior in School-aged Children; ICT: Information and Communication Technology; ISI: Insomnia Severity Index; MPAI: Mobile Phone Addiction Index; MPIQ: Mobile Phone Involvement Questionnaire; MSQA: Multidimensional Sub-health Questionnaire of Adolescents; PIU: Problematic Internet Use; PSQI: Pittsburgh Sleep Quality Index; SPQ: Shorter Promis Questionnaire; SQI: Sleep Quality Index; SSHS: School Sleep Habits Survey; TUQ: Technology Use Questionnaire; YIAT: Young Internet Addiction Test

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Availability of data and materials

Data and material is available in Ningbo Key Laboratory of Sleep Medicine (Address: Zhuangyu South Road No.1, Zhenhai District, Ningbo City, Zhejiang Province, China, 315,201).

Authors' contributions

Study concept and design: XM. Acquisition, analysis, or interpretation of data: All authors. Drafting of the manuscript: XM. Statistical analysis: QZ, XL. Obtained funding: XW. Administrative, technical, or material support: ZH. Study supervision: XW and ZH. All authors read and approved the final manuscript.

Ethics approval and consent to participate

All analyses were based on previous published studies, thus no ethical approval and participate consent are required.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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