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CLINICAL REVIEW

# The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review

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S U M M A R Y

Insufficient sleep, poor sleep quality and sleepiness are common problems in children and adolescents being related to learning, memory and school performance. The associations between sleep quality ($k = 16$ studies, $N = 13{,}631$), sleep duration ($k = 17$ studies, $N = 15{,}199$), sleepiness ($k = 17$, $N = 19{,}530$) and school performance were examined in three separate meta-analyses including influential factors (e.g., gender, age, parameter assessment) as moderators. All three sleep variables were significantly but modestly related to school performance. Sleepiness showed the strongest relation to school performance ($r = -0.133$), followed by sleep quality ($r = 0.096$) and sleep duration ($r = 0.069$). Effect sizes were larger for studies including younger participants which can be explained by dramatic prefrontal cortex changes during (early) adolescence. Concerning the relationship between sleep duration and school performance age effects were even larger in studies that included more boys than in studies that included more girls, demonstrating the importance of differential pubertal development of boys and girls. Longitudinal and experimental studies are recommended in order to gain more insight into the different relationships and to develop programs that can improve school performance by changing individuals' sleep patterns.



## Introduction

Sleep is crucial for children and adolescents' learning, memory processes and school performance.[1–3] Research shows that poor sleep, increased sleep fragmentation, late bedtimes and early awakenings seriously affect learning capacity, school performance, and neurobehavioral functioning.[1–3] Nevertheless, due to methodological differences between studies, it is difficult to draw generalizable conclusions about the relationship between sleep and school performance.

Previous research indicates an association between insufficient and poor sleep and school performance,[1–3] however, no systematic review, such as a meta-analysis, exists evaluating the empirical evidence. Meta-analysis is a statistical method combining different study results. It enables the discovery of consistencies in a set of seemingly inconsistent findings. By obtaining an effect size estimate of the true effect more accurate conclusions can be drawn than in a single study or a narrative review.[4] The meta-analysis presented here aims at gaining more insight into the relationship between children and adolescents' sleep and school performance.

Problems with initiating and maintaining sleep are common in children and adolescents and can be seen as indicative of poor sleep quality. Reported prevalence of such problems varies from 11% to 47%.[5,6] Furthermore, although empirical evidence demonstrates that children and adolescents require an average sleep time of approximately 9 hours/night[7] results revealed that 45% sleep less than 8 hours/night.[7,8] Insufficient sleep might be caused by an interaction of intrinsic (e.g., puberty, circadian or homeostatic changes) and extrinsic factors (e.g., early school start times, social pressure, academic workload) leading to later bedtimes while getting up times remain unchanged. Additionally, it is known that approximately 20–50% of children and adolescents report daytime sleepiness.[9,10]

Sleep can be defined as an active, repetitive and reversible state of perceptual disengagement from and unresponsiveness to the environment.[11] Empirical evidence demonstrates an association between sleep and the consolidation of cognitive performance, which is required for executive functioning including abstract reasoning, goal directed behavior, and creative processing.[1,12] The

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sleep related overnight brain processes are thought to influence cognitive, physical and emotional performance throughout the day.[2,13] A possible explanation for the association between sleep and cognitive- as well as school performance is based on the idea that shortness or disruptions of sleep reduces necessary overnight brain activity that is needed for neurocognitive functioning. Complex tasks requiring abstract thinking, creativity, integration, and planning are primarily influenced by sleep-related problems supporting this view.[14] These tasks, representing higher order neurocognitive functioning, are all characterized by an involvement of the prefrontal cortex, which is known to be sensitive to sleep.[1,15] Based on this evidence it can be suggested that insufficient or low quality sleep during (early) adolescence impairs the executive function of the prefrontal cortex[16] and consequently the decline of learning abilities and school performance.[17,18]

Sleep quality and sleep duration may be seen as two separate sleep domains. Although these sleep domains overlap to some extent, qualitative differences exist between them. Sleep quality refers to the subjective indices of how sleep is experienced including the feeling of being rested when waking up and satisfaction with sleep.[19] Sleep duration, on the other hand, is a more objective sleep domain, namely the actual time during which the individual is asleep. Correlations between children and adolescents' sleep duration and sleep quality are low or not significant[5,20] supporting the idea that sleep quality and sleep duration represent two separate sleep domains. Theoretically it may be that sleep quality and sleep duration are not only different in their impact on measures of health and problem behavior but also on school performance.[1,5,19] Although both sleep domains are associated with sleepiness, emotional state, behavior and cognitive function,[13,16] these associations are stronger for sleep quality than for sleep duration.[19]

The most common direct consequence of insufficient or disrupted sleep is increased daytime sleepiness.[2,13] Increased daytime sleepiness may lead to reduced alertness and compromised daytime functioning of specific brain areas (e.g., the prefrontal cortex), causing impaired cognitive functioning.[14,21,22] Daytime sleepiness results from either low sleep quality, reduced sleep duration or a combination of the two sleep domains.[10] This might explain why studies demonstrated more consistently the negative consequences of daytime sleepiness on neurobehavioral functioning and school performance rather than of especially sleep duration.[2,23]

## Study aim

The study aim of the present meta-analysis is twofold. First, it aims at investigating the effects of sleep quality, sleep duration and sleepiness on school performance by analyzing the effects of each sleep domain separately. Second, the study examines possible moderating influences of parameter assessment, including the assessment of sleep variables as well as the assessment of school performance, gender and age.

## Method

### *Description of identified moderators*

A large variety of moderating or mediating factors (e.g., family, motivation, socio-economic status, race) can affect the proposed associations (e.g.,[3]). Although all of them might be relevant and influential, inclusion of moderators in a meta-analysis requires reports of their descriptive statistics in the majority of studies. As this was not the case for many variables, the moderator choice was reduced to parameter assessment, age and gender.

### *Parameter assessment*

Reliable assessment of sleep variables is a challenging task made increasingly difficult due to the usage of different methods, instruments, and definitions between studies.[2] Subjective measures of sleep characteristics include self-reports and parent reports. However, answers to questions about the child's 'sleep problem' or experienced sleepiness, are highly dependent on parental awareness of their child's sleep pattern and sleep problems.[1,2] More indirect objective methods mainly include polysomnography or actigraphy. Polysomnography is an overnight measurement yielding data from multiple sources, such as EEG, EKG, oxyhemoglobin saturation, electromyography and electrooculogram. In contrast to polysomnography, being usually done in a sleep laboratory, actigraphy measures bodily movements and can be used in the individual's natural environment providing information over an extended time period (e.g., 1–2 weeks).

Similarly, various approaches have been used to assess school performance. These methodological differences between studies range from subjective strategies (e.g., self-reported grade point average, parent or teacher reports on the student's grade, behavior ratings or reports on general school functioning) to objective methods (e.g., grade point average from the record, standardized tests). A comparison of school performance is even more complex, given the variety of rating systems between schools.[1]

### *Age*

Results revealed that age, reflecting the level of pubertal development is associated with daytime sleepiness. When individuals reach mid-puberty their experienced sleepiness increases relative to their daytime sleepiness level during earlier puberty. It can therefore be assumed that mid-pubertal adolescents may need more sleep than younger or older adolescents in order to reach the same level of daytime alertness and neurocognitive functioning.[2,16,24]

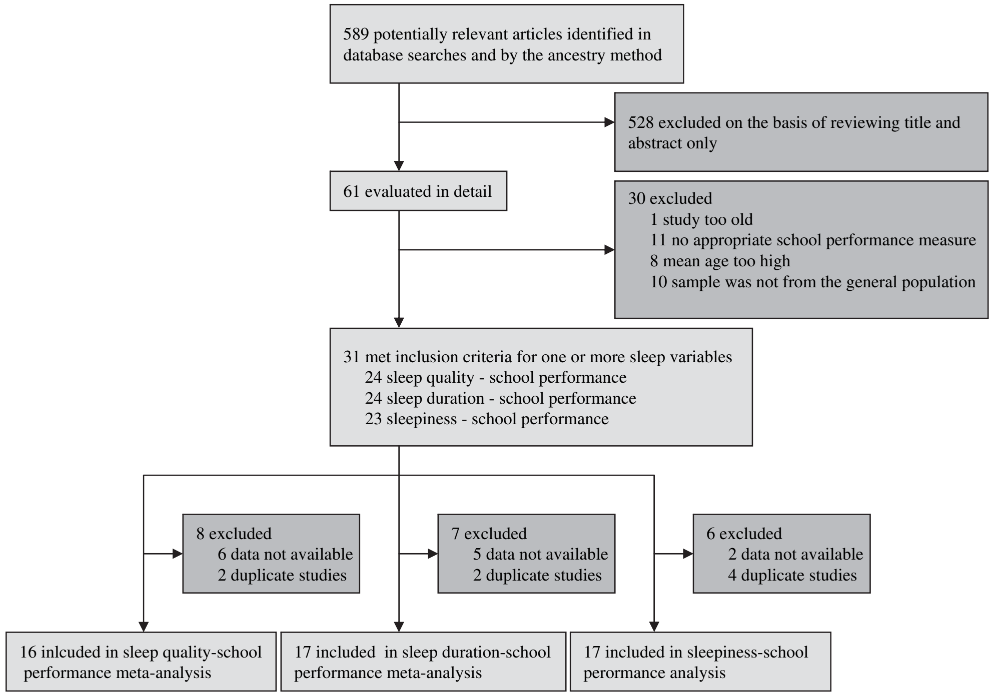
### *Gender*

Controversial evidence exists regarding the question of whether or not sleepiness, or effects of sleep reduction and poor sleep quality differ between males and females. Whereas some results showed a greater sleep need and higher levels of daytime sleepiness in females than in males,[24,25] no gender differences were apparent in other studies.[26] The inconsistent gender effects might be explained by the higher pubertal status of girls, meaning that results greatly depend on the sample's age range.

### *Selection of studies*

The primary search method involved systematic inspection of computerized scientific databases (e.g., PsychINFO, PubMed, Educational Resources Information Center (ERIC)). The search was reduced to studies being published after 1980. The databases were explored with a wide range of keywords entered in varying combinations: 'sleep', 'insomnia', 'sleepiness', 'sleep*', 'time in bed', 'academic performance', 'academic achievement', 'academic functioning', 'school performance', and 'school functioning'. The ancestry method was used as a secondary search method, referring to the exploration of reference lists of previous reviews and articles that had been identified during the first step. A detailed overview of the identification of eligible studies can be found in Fig. 1.

Studies were included if they met the following criteria: a) Participants' mean age ranged from 8 to 18 years. b) Participants represented a sample from the general population. Studies were excluded if they specifically included participants with psychiatric, mental or physical illness. Studies explicitly focusing on participants with sleep disorders were also not included. An exception




The literature search was conducted with scientific databases (e.g. PubMed, PsychInfo, Educarional Resources Information Center(ERIC)) to identify studies up to May 1st, 2009

**Fig. 1.** Flow chart for the selection of articles.

was made for studies that assessed insomnia characteristics in the general population, which was treated as an indication for sleep quality. c) School performance was directly assessed by questionnaires, standardized tests or grade point average. Questionnaires measuring 'school problems' but not 'school performance' were excluded from the analyses. d) In studies measuring sleep duration, the exact sleep duration had to be measured in minutes. e) In studies addressing sleep quality, sleep quality was either assessed by objective measurements (e.g., actigraphy), sleep efficiency, explicit questionnaires asking about sleep quality or an insomnia assessment. In order to meet the definition of insomnia assessment, questionnaires had to ask about at least two of the following sleep characteristics: Sleep latency, intermittent wakefulness, difficulties falling asleep, difficulties maintaining asleep and restorative sleep. f) In studies measuring sleepiness, sleepiness had to be measured by direct questions. Fatigue was not used as a measure of individuals' sleepiness. No studies were excluded from the analyses on the basis of flawed designs.

If studies met the inclusion criteria but could not be retrieved from the databases authors were contacted and asked for a copy of their publication. If different sleep domains were measured but no statistical information about the association with school performance was reported or if sleep variables were assessed independently but not analyzed separately, authors were asked for the missing information. If differentiation between sleep variables was impossible, then those studies were excluded. After effect sizes were calculated authors were contacted again, asking for their agreement with the effect size estimations.

## *Coding*

Two coders coded all studies independently. In the case of discrepancies in coding and/or effect size calculation results were carefully discussed until both coders agreed. Coded sample characteristics that were not available in the majority of studies (e.g., socio-economic status, Intelligence Quotient (IQ)) had to be excluded from further analyses. Sample characteristics that were included as moderators in the analyses were participants' mean age and gender. Gender was coded by using the percentages of boys included in the study. Design and measurement characteristics that were included as moderators in the analyses were as follows: a) objectivity of the assessment method of the independent variable (questionnaires and interviews were coded as subjective, actigraphy and polysomnography were coded as objective methods), b) objectivity of assessment method of the dependent variable (self-reports, parent reports or teacher reports were coded as subjective, grades from the school record and standardized tests were coded as objective methods), c) assessment method of the independent variable (e.g., self-report, parent report, actigraphy) and d) assessment method of the dependent variable (e.g., standardized tests, self-report).

## *Calculation and analysis of effect sizes*

Pearson's $r$, the correlation coefficient between the sleep variable and the school performance variable served as effect size estimation. If $r$ could not be obtained from the publication, other given statistics (e.g., $p$, $\chi^2$, or $F$) were used to estimate $r$.[4] When a study did not provide the statistical information necessary to calculate an effect size but reported a nonsignificant association, an effect size of 0 was assigned. This is a commonly used and conservative strategy that generally underestimates the true magnitude of effect sizes. Exclusion of these nonsignificant results from the meta-analysis would result in an overestimation of the magnitude of the combined effect size estimates.[27] Because $r$ has some undesirable statistical properties[4] correlations were transformed to Fisher's $z$ values. Weighted overall effect sizes and confidence intervals were calculated. For the ease of interpretation overall effect sizes were transformed back into $r$.

If two or more assessments of the same sleep variable were reported separately, average effect sizes were calculated. If studies assessed school performance by measuring participants' math, reading or language ability, the average of the reported outcome scores were used as school performance indicator. If grades were reported for different disciplines separately, their average was used as school performance measurement.

In order to enable the inclusion of an interaction term between age and gender in the analyses both variables were centered and multiplied. Dummy coding was used for sleep and school performance assessment, using 'self-report' as the reference category. If a category (e.g., teacher reports) consisted of only one study, the category was excluded from the analyses. One study used a combination of self-reports and parent reports to assess sleep quality and sleepiness.[28] As results could not be separated this study was not included in the analyses investigating sleep assessment effects. $Z$ values larger than 3.3 or smaller than $-3.3$ were used to identify outlying effect sizes.

*Data analysis*

Individual-study effect size estimates were analyzed using SPSS macros from Lipsey and Wilson[4] in order to estimate a population effect size. We chose to conduct a meta-analysis for each sleep variable separately because some studies yielded information about effect sizes for multiple sleep variables, introducing dependencies between studies that can not be accounted for in a combined analysis. Random and fixed effects models were computed. The differences between fixed and random effect models concern the way significance testing is executed. Significance testing in fixed effects models is based on the total number of participants, allowing greater statistical power, but limited generalizability. Significance testing in the random effects models is based on the total number of studies included in the meta-analysis, resulting in lower statistical power, but greater generalizability.[4,29] In view of generalizability we prefer the random effects model. However, considering our limited sample size we also report fixed effects models, in order to present a full picture of all effects. Homogeneity between studies was tested with $Q$ statistics, including Qbetween (Qb) and Qwithin (Qw) (tested at $\alpha = 0.05$). Heterogeneity between studies is an indication that differences among effect sizes come from some other source than subject-level sampling error, such as other study characteristics. Moderators were included in the analysis aiming at explaining differences between the effect sizes. As the number of studies in all analyses was rather small moderator effects were tested separately.

## Results

*Description of studies*

The majority of the studies was cross-sectional in design. One study was a longitudinal study.[30] In this case it was decided to include only the first time of measurement in order to make results comparable to the other studies. In three cases more than one article was based on the same sample. Including all studies would violate the assumption of independence. Therefore, we decided to include the study that provided the most information about the effect sizes or which was the most recent publication.[31–33]

Twenty-six studies were included in the present meta-analysis assessing the relationship between one of the sleep domains and children and adolescents' school performance. Sixteen studies addressed sleep quality ($N = 13{,}631$), 17 studies sleep duration ($N = 15{,}199$) and 17 studies sleepiness ($N = 19{,}530$). No outlying effect sizes were identified. Effect sizes of $r \leq 0.10$, $r = 0.25$, and $r \geq 0.40$ were considered as indices of small, medium, and large effects, respectively.[4] Tables 1–3 provide an overview of all studies with effect sizes for each sleep domain separately. Figs. 2–4 demonstrate the effect sizes with sampling variances for each study.

*Sleep quality and school performance*

The meta-analysis yielded a small overall effect size ($z = 0.100$; $p < 0.001$ (CI [0.083;0.117]), $r = 0.100$, fixed model; $z = 0.096$; $p < 0.001$ (CI [0.061;0.153]), $r = 0.096$, random model), indicating that better sleep quality is associated with better school performance. As homogeneity analysis yielded a significant result ($Q(15) = 45.060$, $p < 0.001$), representing a significant variability in effect sizes between studies, moderator analyses were conducted. Table 4 gives the results for both fixed and random model analyses, for each moderator variable separately. In fixed effects models, the moderators age ($\beta = -0.501$; $p < 0.001$), and objectivity of sleep assessment ($\beta = -0.386$; $p = 0.009$) were significant indicating that larger effects were found for studies including younger participants and for studies using subjective sleep assessment methods. Results revealed that parent reports of their children's sleep resulted in significantly larger effects ($\beta = 0.374$; $p = 0.035$) and objective assessment methods in significantly smaller effects ($\beta = -0.349$; $p = 0.050$) when compared to self-reports. Furthermore, effects in studies using parent reports as the school performance assessment were significantly larger than effects in studies using self-reports ($\beta = 0.619$; $p < 0.001$). However, heterogeneity remained present, in most fixed effects models. When random effects models were computed, none of the moderators reached significance.

*Sleep duration and school performance*

The meta-analysis yielded a small overall effect size ($z = 0.071$; $p < 0.001$ (CI [0.055;0.087]), $r = 0.071$, fixed model; $z = 0.069$; $p < 0.001$ (CI [0.043;0.095]), $r = 0.069$, random model), indicating that more sleep is associated with better school performance. As the homogeneity analysis yielded a significant result ($Q(16) = 34.666$, $p = 0.004$) moderator analyses were conducted (see Table 5 for an overview). A significant age*gender interaction ($\beta = 0.587$; $p = 0.015$ fixed; $\beta = 0.652$; $p = 0.021$ random) and a main effect of age ($\beta = -0.591$; $p = 0.010$, fixed; $\beta = -0.526$; $p = 0.049$, random) were found. That means that the effects of age depend on participants' gender. Effect sizes were larger for studies including younger participants than for studies that included older participants. This age effect was stronger for studies that included more males than for studies that included more females. Again, in some models heterogeneity continued to be present.

*Sleepiness and school performance*

The meta-analysis yielded a small overall effect size ($z = -0.135$; $p < 0.001$ (CI [$-0.149$;$-0.121$]), $r = -0.134$, fixed model; $z = -0.134$; $p < 0.001$ (CI [$-0.182$;$-0.085$]), $r = -0.133$, random model), indicating that lower sleepiness scores are associated with better school performance. As the homogeneity analysis yielded a significant result ($Q(16) = 155.717$, $p < 0.001$) moderator analyses were conducted (see Table 6 for an overview). Age was a significant moderator in fixed as well as in random effects models ($\beta = 0.823$; $p < 0.001$, fixed; $\beta = 0.656$; $p < .001$, random) meaning that larger effects were found in studies including younger children than in studies including older children. In fixed effects models, the results revealed that studies that assessed school performance by using parent reports reported significantly larger effects than studies that used self-reported school performance ($\beta = -0.69$; $p < 0.001$). Heterogeneity remained present in some fixed effects models.

**Table 1**
Studies assessing the relationship between sleep quality and school performance included in the analysis.

| Author | Year | *N* | % Boys | Mean age | Sleep assessment | School performance assessment | *r* | *z* |
|---|---|---|---|---|---|---|---|---|
| Al-Sharbati[44] | 2002 | 277 | 65.34 | 10.50 | Self-report | Self-report | 0.196 | 0.199 |
| BaHammam et al.[45] | 2006 | 1012 | 50.50 | 9.50 | Parent report | Parent report | 0.133 | 0.134 |
| Bruni et al.[46] | 2006 | 262 | 53.41 | 9.60 | Parent report | Teacher report | 0.168 | 0.170 |
| Chung & Cheung[47] | 2008 | 1339 | 50.76 | 14.82 | Self-report | Self-report | 0.041 | 0.041 |
| Giannotti et al.[48] | 1997 | 3040 | 40.52 | 17.00 | Self-report | Self-report | 0.060 | 0.060 |
| Horn & Dollinger[49] | 1989 | 239 | 49.79 | 12.00 | Self-report | Grades | 0.000 | 0.000 |
| Keller et al.[32] | 2008 | 124 | 46.00 | 8.73 | Actigraphy | Standardized tests | 0.153 | 0.154 |
| Lazaratou et al.[50] | 2005 | 713 | 44.46 | 16.50 | Self-report | Self-report | 0.120 | 0.121 |
| Mayes et al.[51] | 2008 | 412 | 52.00 | 8.60 | Polysomnography | Standardized tests | −0.060 | −0.060 |
| Meijer & van den Wittenboer[52] | 2004 | 127 | 52.94 | 11.70 | Self-report | Self-report | 0.048 | 0.048 |
| Meijer[18] | 2008 | 378 | 50.46 | 11.50 | Self-report | Self-report | 0.194 | 0.196 |
| Meijer[53] | 2008 | 158 | 61.40 | 14.55 | Self-report | Grades | 0.192 | 0.194 |
| Pagel et al.[9] | 2008 | 165 | 50.00 | 14.00 | Self-report | Self-report | 0.000 | 0.000 |
| Salcedo Aguilar et al.[54] | 2005 | 1155 | 46.49 | 14.00 | Self-report | Self-report | 0.088 | 0.088 |
| Warner et al.[55] | 2008 | 310 | 36.00 | 16.04 | Self-report | Self-report | 0.054 | 0.054 |
| Wiater et al.[28] | 2008 | 3920 | n.a. | 10.00 | Self-report/parent report | Parent report | 0.148 | 0.149 |

*N* = sample size; *r* = Pearson's correlation coefficient; *z* = Fisher's z transformation of Pearson's correlation coefficient; n.a. = not available.

### *Publication bias*

A common problem concerning meta-analytic research is the problem of publication bias, which refers to the phenomenon that many studies may remain unpublished because of small effect sizes or nonsignificant findings.[4,34] One way of examining what effect publication bias could have on the meta-analytic results can be achieved by inspecting the distribution of the individual study's effect sizes on the horizontal axis against its sample size, standard error or precision (the reciprocal of the standard error) on the vertical axis. If no publication bias is present the distribution of the effect size should be shaped as a funnel. A violation of funnel plot symmetry reflects publication bias: that is a selective inclusion of studies showing positive or negative outcomes.[4]

In the present meta-analysis funnel plot symmetry was tested by adding the standard error as a moderator to the random effects model. This regression weight did not become significant for sleep quality ($\beta = 0.013$; $p = 0.958$), sleep duration ($\beta = 0.168$; $p = 0.488$) and sleepiness ($\beta = -0.204$; $p = 0.510$). Additionally, rank order correlations (Spearman's rho) between effect size estimates and sample size were calculated. Correlations for sleep quality ($rs = 0.309$; $p = 0.228$), sleep duration ($rs = -0.380$; $p = 0.133$) and sleepiness ($rs = 0.309$; $p = 0.228$) did not reach significance. Based on these analyses it can be concluded that no publication biases were present.

## Discussion

With the present meta-analysis we get individual estimates of the different effects of sleep quality, sleep duration, and sleepiness on children and adolescents' school performance. Inspection of the three confidence intervals indicated the presence of statistically significant differences. As the confidence intervals of sleep quality, sleep duration and sleepiness hardly overlap it can be concluded that the association between sleep duration and school performance is significantly smaller than the association between sleep quality and school performance, which again is significantly smaller than the association between sleepiness and school performance. This finding is supported by previous research demonstrating that the negative consequences of daytime sleepiness on neurobehavioral functioning and school performance are more consistent compared to the sometimes inconsistent effects of sleep duration.[2,23] Moreover, the low correlation generally found between sleep duration and sleep quality raises the idea of two separate sleep domains which is in line with the finding that sleep quality and sleep duration have different contributions to school performance.[19] Smaller effects of sleep duration might be caused by the fact that this sleep domain does not control for individuals' sleep need and individual vulnerability to sleep loss, being defined as the magnitude of performance impairment given a fixed amount of sleep reduction.[35] As these concepts are difficult to measure it

**Table 2**
Studies assessing the relationship between sleep duration and school performance included in the analysis.

| Author | Year | *N* | % Boys | Mean age | Sleep assessment | School performance assessment | *r* | *z* |
|---|---|---|---|---|---|---|---|---|
| BaHammam et al.[45] | 2006 | 1012 | 50.50 | 9.50 | Parent report | Parent report | 0.073 | 0.073 |
| Bruni et al.[46] | 2006 | 262 | 53.41 | 9.60 | Parent report | Teacher report | −0.071 | −0.071 |
| Chung & Cheung[47] | 2008 | 1339 | 50.76 | 14.82 | Self-report | Self-report | 0.072 | 0.072 |
| Drake et al.[56] | 2003 | 410 | 51.90 | 12.80 | Self-report | Self-report | 0.160 | 0.161 |
| Eliasson et al.[57] | 2002 | 1200 | n.a. | 14.50 | Self-report | Self-report | 0.000 | 0.000 |
| Fredriksen et al.[30] | 2004 | 2259 | 50.40 | 12.50 | Self-report | Self-report | 0.130 | 0.131 |
| Giannotti et al.[58] | 1997 | 888 | 47.07 | 9.90 | Parent report | Parent report | 0.110 | 0.110 |
| Keller et al.[32] | 2008 | 124 | 46.00 | 8.73 | Actigraphy | Standardized tests | 0.193 | 0.195 |
| Lazaratou et al.[50] | 2005 | 658 | 44.46 | 16.50 | Self-report | Self-report | 0.001 | 0.001 |
| Loessl et al.[59] | 2008 | 601 | 44.90 | 15.40 | Self-report | Self-report | 0.088 | 0.088 |
| Meijer & van den Wittenboer[52] | 2004 | 129 | 52.94 | 11.70 | Self-report | Self-report | 0.182 | 0.184 |
| Meijer[18] | 2008 | 386 | 50.46 | 11.50 | Self-report | Self-report | 0.075 | 0.075 |
| Meijer[53] | 2008 | 146 | 35.60 | 14.55 | Self-report | Grades | 0.152 | 0.153 |
| O'Brien & Mindell[60] | 2005 | 205 | n.a. | 16.62 | Self-report | Self-report | 0.082 | 0.082 |
| Perez-Chada et al.[61] | 2007 | 2210 | 50.00 | 13.30 | Parent report | Grades | 0.065 | 0.065 |
| Warner et al.[55] | 2008 | 310 | 36.00 | 16.04 | Self-report | Self-report | 0.007 | 0.007 |
| Wolfson & Carskadon[62] | 1998 | 3060 | 48.00 | 16.08 | Self-report | Self-report | 0.060 | 0.060 |

*N* = sample size; *r* = Pearson's correlation coefficient; *z* = Fisher's z transformation of Pearson's correlation coefficient; n.a. = not available.

**Table 3**
Studies assessing the relationship between sleepiness and school performance included in the analysis.

| Author | Year | N | % Boys | Mean age | Sleep assessment | School performance assessment | *r* | *z* |
|---|---|---|---|---|---|---|---|---|
| Chung & Cheung[47] | 2008 | 1339 | 50.76 | 14.82 | Self-report | Self-report | −0.078 | −0.078 |
| Bruni[46] | 2006 | 262 | 53.41 | 9.60 | Parent report | Teacher report | −0.160 | −0.161 |
| Drake et al.[56] | 2003 | 410 | 51.9 | 12.80 | Self-report | Self-report | −0.150 | −0.151 |
| Giannotti et al.[48] | 1997 | 3040 | 40.52 | 17.00 | Self-report | Self-report | −0.060 | −0.060 |
| Giannotti et al.[58] | 1997 | 888 | 47.07 | 9.90 | Parent report | Parent report | −0.090 | −0.090 |
| Joo et al.[33] | 2005 | 3871 | 69.83 | 16.8 | Self-report | Grades | −0.066 | −0.066 |
| Keller et al.[32] | 2008 | 124 | 46.00 | 8.73 | Self-report | Standardized tests | −0.280 | −0.288 |
| Loessl et al.[59] | 2008 | 566 | 44.9 | 15.40 | Self-report | Self-report | −0.013 | −0.013 |
| Meijer[18] | 2008 | 394 | 50.46 | 11.50 | Self-report | Self-report | −0.286 | −0.294 |
| Meijer[53] | 2008 | 160 | 38.10 | 14.55 | Self-report | Grades | −0.177 | −0.179 |
| Meijer & van den Wittenboer[52] | 2004 | 128 | 52.94 | 11.70 | Self-report | Self-report | −0.075 | −0.075 |
| O'Brien & Mindell[60] | 2005 | 380 | 57.10 | 16.62 | Self-report | Self-report | −0.110 | −0.110 |
| Pagel et al.[9] | 2008 | 165 | 50.00 | 14.00 | Self-report | Self-report | −0.149 | −0.150 |
| Perez-Chada et al.[61] | 2007 | 2210 | 50.00 | 13.30 | Self-report | Grades | −0.193 | −0.195 |
| Saarenpää-Heikkilä et al.[31] | 2000 | 518 | 48.26 | 13.25 | Self-report | Self-report | −0.074 | −0.074 |
| Salcedo Aguilar et al.[54] | 2005 | 1155 | 46.49 | 14.00 | Self-report | Self-report | −0.080 | −0.085 |
| Wiater et al.[28] | 2008 | 3920 | n.a. | 10.00 | Self-report/parent report | Parent report | −0.270 | −0.277 |

$N$ = sample size; $r$ = Pearson's correlation coefficient; $z$ = Fisher's z transformation of Pearson's correlation coefficient; n.a. = not available.

could be argued that sleepiness or chronic sleep reduction[18] might be better constructs for estimating the consequences of sleep reduction or poor sleep. Furthermore, these overall results highlight the need to treat sleep duration, sleep quality and sleepiness as separate sleep variables in future research.

All three overall effect sizes were rather small. An explanation for the modest effect sizes could be found in a time gap between the time point at which sleep was measured and the time point to which school performance assessment refers, which can result in less reliability and lower correlations. Another possible explanation is that most studies measured sleep and performance as rather stable constructs and did not investigate the relationship between changes in sleep and changes in school performance which may result in stronger associations. That is, when measuring the correlation between changes rather than the correlation between stable characteristics other important variables that influence school performance (e.g., community Socio Economic Status (SES), general life style[3]) or sleep, (e.g., sleep environment[2]) remain stable resulting in a much purer estimation of the true relationship between sleep and school performance. Future research should concentrate on such effects by conducting longitudinal research or controlling for influential variables, aiming at developing programs that improve sleep and consequently school performance.

Furthermore, the study investigated the role of possible moderating influences within these associations. Subjective sleep quality measures showed a stronger relationship with school performance than objective measurements. Differences between subjective and objective sleep quality measures are a common

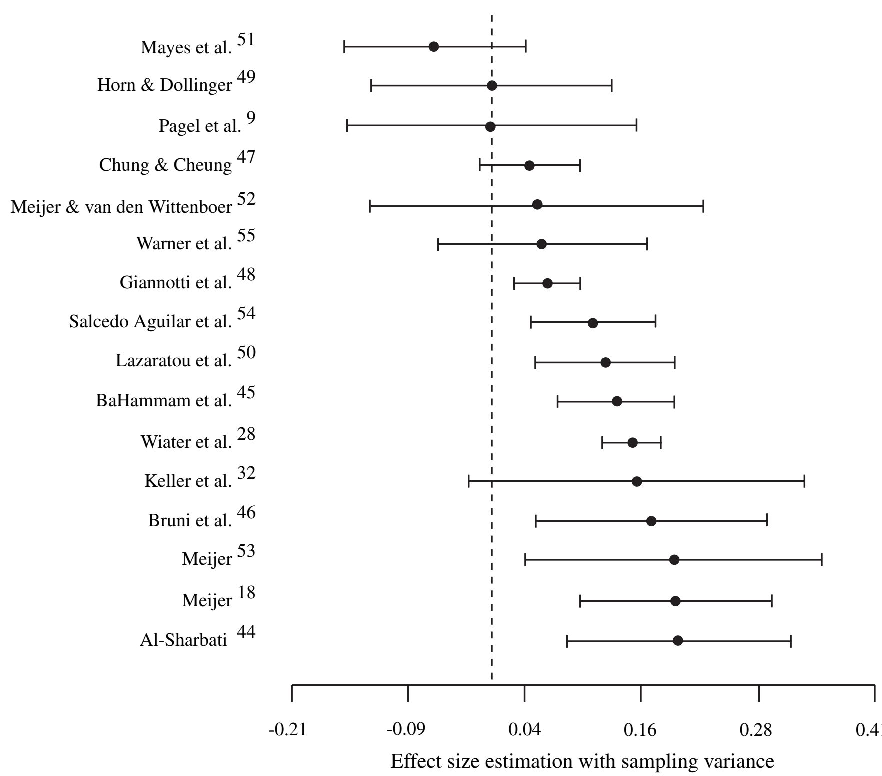



**Fig. 2.** Forest plot of studies investigating the relationship between sleep quality and school performance.

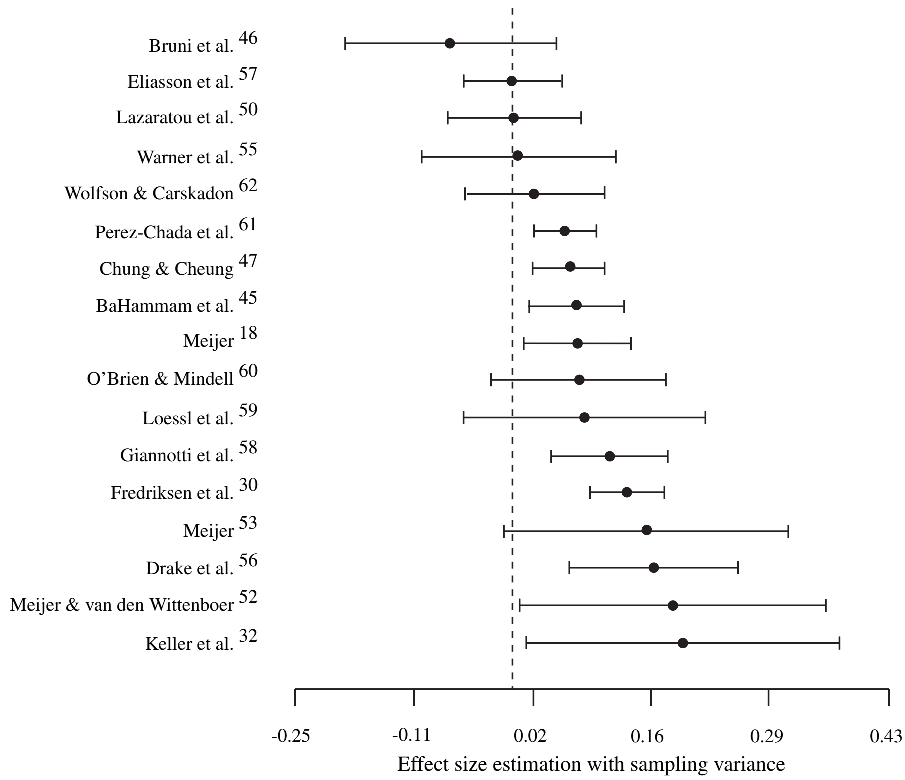



**Fig. 3.** Forest plot of studies investigating the relationship between sleep duration and school performance.

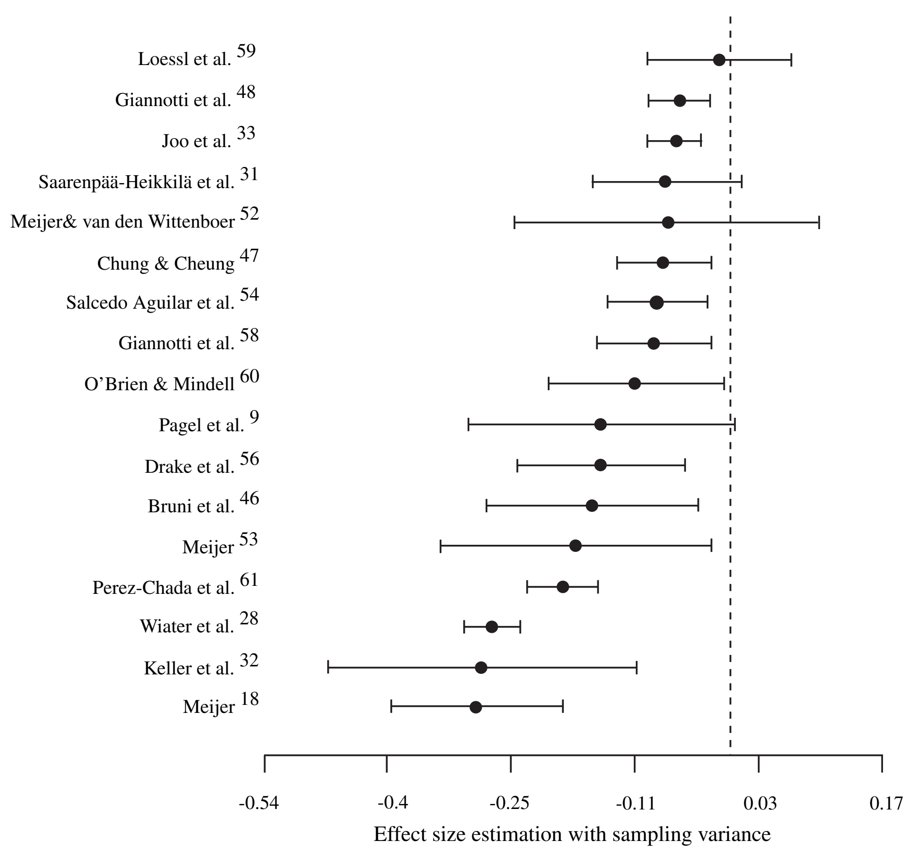



**Fig. 4.** Forest plot of studies investigating the relationship between sleepiness and school performance.

**Table 4**
Moderators of effect sizes for studies on sleep quality.

| Moderator | k | r | β | Qb | Qw |
|---|---|---|---|---|---|
| Age | | | | | |
| Fixed | 16 | 0.100 | −0.501** | 11.290** | 33.770** |
| Random | 16 | 0.096 | −0.222 | 0.349 | 16.909 |
| Gender (% boys) | | | | | |
| Fixed | 15 | 0.080 | 0.226 | 1.63 | 30.319** |
| Random | 15 | 0.089 | 0.169 | 0.446 | 15.145 |
| Age*gender | | | | | |
| Fixed | 15 | 0.080 | | 2.732 | 29.214** |
| Age | | | −0.262 | | |
| Gender | | | 0.154 | | |
| Age*gender | | | −0.184 | | |
| Random | 15 | 0.090 | | 0.674 | 12.411 |
| Age | | | −0.133 | | |
| Gender | | | 0.150 | | |
| Age*gender | | | −0.182 | | |
| Objectivity of sleep assessment | | | | | |
| Fixed | 16 | 0.100 | −0.390** | 6.836** | 38.224** |
| Random | 16 | 0.096 | −0.393 | 2.754 | 15.038 |
| Objectivity of school performance assessment | | | | | |
| Fixed | 16 | 0.100 | −0.185 | 1.545 | 43.515** |
| Random | 16 | 0.096 | −0.127 | 0.258 | 15.859 |
| Method of sleep assessment | | | | | |
| Fixed | 15 | 0.080 | | 9.13* | 22.818** |
| Self-report (k = 11) | | | Reference | | |
| Parent report (k = 2) | | | 0.374* | | |
| Objective measurement (k = 2) | | | −0.349* | | |
| Random | 15 | 0.088 | | 4.414 | 14.386 |
| Self-report (k = 11) | | | Reference | | |
| Parent report (k = 2) | | | 0.291 | | |
| Objective measurement (k = 2) | | | −0.350 | | |
| Method of school performance assessment | | | | | |
| Fixed | 15 | 0.098 | | 17.226** | 26.547** |
| Self-report (k = 9) | | | Reference | | |
| Parent report (k = 2) | | | 0.619** | | |
| Objective measurement (k = 4) | | | −0.032 | | |
| Random | 15 | 0.092 | | 2.635 | 15.684 |
| Self-report (k = 9) | | | Reference | | |
| Parent report (k = 2) | | | 0.374 | | |
| Objective measurement (k = 4) | | | −0.019 | | |

k = number of studies; r = correlation coefficient, Qb = Q statistic between studies (index of variability between the group means); Qw = Q statistic within studies (index of variability within the groups).
* $p < 0.05$. ** $p < 0.01$.

**Table 5**
Moderators of effect sizes for studies on sleep duration.

| Moderator | k | r | β | Qb | Qw |
|---|---|---|---|---|---|
| Age | | | | | |
| Fixed | 17 | 0.071 | −0.400* | 5.454* | 29.213** |
| Random | 17 | 0.069 | −0.345 | 2.272 | 16.786 |
| Gender (% boys) | | | | | |
| Fixed | 15 | 0.076 | 0.284 | 2.267 | 25.928* |
| Random | 15 | 0.075 | 0.199 | 0.6627 | 16.017 |
| Age*gender | 15 | 0.076 | | 10.926* | 17.268 |
| Fixed | | | | | |
| Age | | | −0.591* | | |
| Gender | | | −0.237 | | |
| Age*gender | | | 0.587* | | |
| Random | 15 | 0.075 | | 7.870 | 11.558 |
| Age | | | −0.526* | | |
| Gender | | | −0.337 | | |
| Age*gender | | | 0.652* | | |
| Objectivity of school performance assessment | | | | | |
| Fixed | 17 | 0.071 | 0.055 | 0.104 | 34.563** |
| Random | 17 | 0.069 | 0.207 | 0.709 | 15.778 |
| Method of sleep assessment | | | | | |
| Fixed | 16 | 0.070 | | 0.016 | 32.760** |
| Self-report (k = 12) | | | Reference | | |
| Parent report (k = 4) | | | −0.022 | | |
| Random | 16 | 0.067 | | 0.055 | 15.195 |
| Self-report (k = 12) | | | Reference | | |
| Parent report (k = 4) | | | −0.06 | | |
| Method of school performance assessment | | | | | |
| Fixed | 16 | 0.073 | | 0.758 | 28.630** |
| Self-report (k = 11) | | | Reference | | |
| Parent report (k = 2) | | | 0.159 | | |
| Objective measurement (k = 3) | | | 0.062 | | |
| Random | 16 | 0.074 | | 0.867 | 12.540 |
| Self-report (k = 11) | | | Reference | | |
| Parent report (k = 2) | | 0.176 | | | |
| Objective measurement (k = 3) | | 0.217 | | | |

k = number of studies; r = correlation coefficient, Qb = Q statistic between studies (index of variability between the group means); Qw = Q statistic within studies (index of variability within the groups).
* $p < 0.05$. ** $p < 0.01$.

phenomenon. It can be explained by the usage of different sleep quality definitions, large individual differences in the experience of sleep quality and finally a subjective sleep quality component (e.g., feeling rested) which might not be captured by objective measurements.[36] The present result empthazizes the need to combine different types of sleep quality measures in future research and compare differences between subjective and objective measurements. The results revealed that studies using parent reports to assess sleep quality showed larger effects on the participants' school performance than studies using self-reports. These effect size differences, being caused by the sleep quality assessment method, support the idea that parental awareness of their child's sleep can be rather limited. It is not possible at present to indicate whether or not similar measurement differences hold for the assessment of sleep duration and sleepiness because no study used an objective sleepiness measurement and only one study assessed sleep duration by using actigraphy. No differences between self-reports and parent reports were found for sleep duration and sleepiness, however, as the number of studies using parent reports was rather small, differences might not be detected. More research is needed in order to answer this question.

Studies examining the association between sleepiness and school performance and sleep quality and school performance reported larger effects when school performance was measured by parent reports than when school performance was measured with self-reports. Objective measurements did not differ from self-reports in all three analyses. As effect size differences between studies using objective measurements or self-reports to assess school performance could not be explained by the assessment method the results indicate that self-reports can be seen as a valid method of measuring participants' school performance. However, again the number of studies using parent reports or objective measurements was rather small. More research, optimally including multi-measure approaches, is needed in order to shed more light on possible differences in effect sizes being caused by school assessment methods.

**Table 6**
Moderators of effect sizes for studies on sleepiness.

| Moderator | k | r | β | Qb | Qw |
|---|---|---|---|---|---|
| Age | | | | | |
| Fixed | 17 | −0.134 | 0.822** | 105.153** | 50.564** |
| Random | 17 | −0.130 | 0.656** | 11.346** | 15.018 |
| Gender (% boys) | | | | | |
| Fixed | 16 | −0.099 | 0.119 | 0.812 | 56.513** |
| Random | 16 | −0.118 | 0.058 | 0.044 | 13.234 |
| Age*gender | | | | | |
| Fixed | 16 | −0.099 | | 24.800** | 32.524** |
| Age | | | 0.695 | | |
| Gender | | | −1.255 | | |
| Age*gender | | | 1.21 | | |
| Random | 16 | −0.115 | | 5.469 | 12.239 |
| Age | | | 0.565 | | |
| Gender | | | −0.161 | | |
| Age*gender | | | −0.108 | | |
| Objectivity of school performance assessment | | | | | |
| Fixed | 17 | −0.135 | 0.137 | 2.938** | 152.779** |
| Random | 17 | −0.133 | −0.149 | 0.215 | 9.427 |
| Method of sleep assessment | | | | | |
| Fixed | 16 | −0.099 | | 0.0262 | 57.298** |
| Self-report (k = 14) | | | Reference | | |
| Parent report (k = 2) | | | −0.021 | | |
| Random | 16 | −0.117 | | 0.007 | 15.091 |
| Self-report (k = 14) | | | Reference | | |
| Parent report (k = 2) | | | 0.022 | | |
| Method of school performance assessment | | | | | |
| Fixed | 16 | −0.135 | | 64.873** | 90.685** |
| Self-report (k = 10) | | | Reference | | |
| Parent report (k = 2) | | | −0.701** | | |
| Objective measurement (k = 4) | | | −0.171 | | |
| Random | 16 | −0.131 | | 1.1233 | 11.459 |
| Self-report (k = 10) | | | Reference | | |
| Parent report (k = 2) | | | −0.221 | | |
| Objective measurement (k = 4) | | | −0.275 | | |

k = number of studies; r = correlation coefficient, Qb = Q statistic between studies (index of variability between the group means); Qw = Q statistic within studies (index of variability within the groups).
* $p < 0.05$. ** $p < 0.01$.

The associations of sleep quality, sleep duration, and sleepiness with school performance were stronger in studies including younger participants than in studies that included older participants. This is in line with prior research that demonstrated that with maturation adolescents experience a decrease in sensitivity to sleep deprivation and extended wakefulness.[37,38] Furthermore, research showed a stronger association between sleep quality and neurobehavioral functioning in younger children than in older children.[39] Higher vulnerability to poor sleep, insufficient sleep and sleepiness could explain the effect size differences as important prefrontal cortex development occur during (early) adolescence.[40] This life time is especially characterized by dramatic prefrontal cortex changes in structural architecture and functional organization that decline throughout adolescence.[40]We can assume that the influence of low sleep quality, insufficient sleep, and sleepiness on prefrontal cortex functions and therefore also on cognitive functioning and school performance is larger during early rather than later adolescence.

An age by gender interaction and a significant main effect for age were found for the relationship between sleep duration and school performance. Larger effects were present for studies including younger participants than for studies including older participants. This age effect was larger if studies included more males than if studies included more females. This finding can be explained by differences in sleep need between males and females due to females' earlier pubertal development.

The present meta-analysis has some limitations: First, as the sample mainly consisted of cross-sectional studies the association between sleep and school performance can be of bidirectional nature. Only the application of an experimental or longitudinal design can address the question of causality. To the authors' knowledge no such study exists examining the effects of different sleep domains on school performance. Results from a previous study[41] revealed that sleep extension and sleep restriction of only 1 hour/night for three days have significant effects on children's neurocognitive functioning and memory. Another study showed that sleep restriction during one school week caused a significant increase in teacher-rated academic problems.[42] These studies indicate that even slight temporary reductions in sleep could have an effect on individuals' school performance. Therefore, experimental and longitudinal designs on this topic can contribute to deeper insight into causal effects of the association between sleep and school performance.

Second, many studies being included in this meta-analysis were not designed to examine the relation between sleep and school performance, which limits the detection of moderating effects. Important moderators that could not be tested were, for instance, socio-economic status, IQ, performance motivation, emotional problems, behavioral problems, or physical health.[1,3,9,18,43] Heterogeneity between studies which remained present even after moderators were included, could be explained by this limitation.

Third, not all moderator effects reached significance in the random effects models. Significance testing in random effects models is based on the total number of studies being included in the analysis, which resulted in low power in the present analyses. This might explain why some significant moderating effects were only found when fixed effects models were fitted to the data but not when random effects models were fitted. The results of fixed effects models have limited generalizabilty, meaning that conclusions concerning parameter assessment and the age effect for sleep quality have to be reduced to the studies that were included in the present study and cannot be generalized to other potential studies.

In summary, it can be concluded that all three sleep domains have a small, but significant effect on children and adolescents' school performance. However, to be able to draw clear conclusions more research is much needed, including experimental and longitudinal studies, within this clinically important scientific field. Only such research can result in the development of programs that might improve school performance by changing children and adolescents' sleep pattern.

**Practice points**

1. Poor sleep quality, insufficient sleep and sleepiness are significantly associated with worse school performance.
2. We recommend educating children, adolescents, parents and schools about the importance of sleep for school performance. As part of this, education about sleep hygiene can be given in order to improves the sleep of children and adolescent and consequently school performance.
3. Attention should be drawn to the development of prevention and treatment programs that focus on the sleep of children and adolescents.

**Research agenda**

1. Treating sleep duration, sleep quality and sleepiness as separate sleep domains has to be considered in studies being conducted in the future.
2. Future research should concentrate on comparing the effects of subjective and objective measurements within the same study in order to investigate possible parameter assessment differences.
3. Examining sleep and school performance within chronologicaly comparable measurement moments.
4. Identification of the role of gender, possibly interacting with age, is needed.
5. Experimental and longitudinal investigation of the effects of sleep on the school performance of children and adolescents is needed. An important goal for future research is to focus on possible long-term effects of sleep on school performance and to develop programs to improve school performance by changing sleep patterns.

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