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Alexandre Kirchhofer Pereira

The association between sleep duration in pediatric ages and the risk for overweight: A systematic review with practical suggestions

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Prof. Doutor António José Mónica da Silva Guerra

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Projecto de Opção do 6º ano - DECLARAÇÃO DE INTEGRIDADE

Eu, Alexandre Kirchhofer Pereira, abaixo assinado, nº mecanográfico 040801005, aluno do 6º ano do Mestrado Integrado em Medicina, na Faculdade de Medicina da Universidade do Porto, declaro ter actuado com absoluta integridade na elaboração deste projecto de opção.

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Faculdade de Medicina da Universidade do Porto, 01/04/2010

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The association between sleep duration in pediatric ages and the risk for overweight: A systematic review with practical suggestions

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List of abbreviations

AFA – Arm Fat Area

BF – Body Fat

BMI – Body Mass Index

CDC – Centers for Disease Control and Prevention

CI – Confidence Interval

GH – Growth hormone

IOTF – The International Obesity Task Force

OR – Odds Ratio

SES – Socio-Economical Status

WC – Waist Circumference

WHtR – Waist to Height Ratio

Abstract

Context: In recent years, several epidemiological studies showed that short sleep duration in pediatric ages may be linked to an increased risk of overweight and obesity.

Objective: To systematically review the published observational results relating childhood or adolescent sleep duration and the risk for overweight, to suggest guidelines for future research, and to alert pediatricians for the importance of sleep duration assessment and counseling.

Methods: A systematic screening for articles indexed in PubMed, EMBASE, Scopus, ISI Web of Knowledge, EBSCO and Science Direct online databases from inception to end September 2009 was performed. Studies with less than 200 subjects of initial population, or paper written in any other languages than English, French, Portuguese, Spanish or Italian where excluded from the review. Risk estimates and confidence intervals were directly retrieved or, when not available, calculated according paper's provided data.

Results: From the 1292 identified publications, 36 were included for complete analysis (6 prospective cohort, 4 case-control and 26 cross-sectional studies). The majority of studies described a significant association between short sleep duration and an increased risk for overweight or obesity, but greatly differed in aspects such as obesity definition, considered sleep categories and number of subjects. Also, most of sex-stratified data pointed to more important correlation in boys, compared to girls. Only one paper mentioned that short sleep was a significant protecting factor for overweight.

Conclusion: Chronic reduced sleep is associated to a higher risk for overweight and obesity in pediatric populations, regardless of ethnical origins, age, sex or overweight definition. The relation seems to be causal and dose-dependent, but more

prospective studies are required, which need to be design upon common criteria and definitions. Finally, checking and counseling about sleep habits should be part of every pediatric consult and corrections of sleep duration ought to be integrate in overweight's treatment.

Key-words: Obesity, Overweight, Sleep, Child, Adolescent, Review

Resumo

Contexto: Nos últimos anos, vários estudos epidemiológicos demonstraram que um número de horas de sono reduzido durante idades pediátricas podia estar associado a um risco aumentado de excesso de peso e obesidade.

Objectivo: Rever sistematicamente todos os resultados observacionais publicados sobre a associação entre a duração do sono durante a infância ou adolescência e o risco de excesso de peso, sugerir directrizes para investigação futura, e alertar os pediatras para a importância da determinação do número de horas de sono e correcto aconselhamento.

Métodos: Foi realizada uma pesquisa sistemática nas bases de dados on-line da PubMed, EMBASE, Scopus, ISI Web of Knowledge, EBSCO e Science Direct, desde os artigos mais antigos até finais de Setembro de 2009. Os estudos com menos de 200 indivíduos de população inicial e aqueles que se encontravam escritos noutras línguas que não o inglês, francês, português, espanhol ou italiano foram excluídos da revisão. As estimativas de risco e seus intervalos de confiança foram directamente extraídos e, quando tal não foi possível, foram calculados tendo por base as informações contidas nos artigos.

Resultados: Foram identificados 1292 artigos, dos quais 36 foram incluídos na análise final (6 estudos prospectivos, 4 de casos e controlos e 26 transversais). A maioria dos artigos descreveu uma associação significativa entre uma curta duração de sono e um risco aumentado de excesso de peso e obesidade, mas grandes diferenças em termos de definição de obesidade, categorias de sono e número de indivíduos, foram encontradas. Adicionalmente, a maioria dos estudos com resultados estratificados por sexo constatou que a associação é mais forte nos rapazes, que nas raparigas. Somente

um artigo mencionou que a curta duração do sono é um factor significativo de redução de risco da obesidade.

Conclusão: Em populações pediátricas, uma redução crónica do número de horas de sono está correlacionada a um aumento do risco de excesso de peso e obesidade, independentemente das suas origens étnicas, idade, género, ou da definição de excesso de peso. A associação parece ser causal e dependente da dose, mas são necessários mais estudos prospectivos, cujo planeamento deverá basear-se em critérios e definições comuns. Por último, a verificação e o aconselhamento sobre o número de horas de sono devem fazer parte de qualquer consulta pediátrica e a correcção do número de horas de sono deveria estar integrada nos esquemas de tratamento do excesso de peso.

Palavras-Chave: Obesidade, Excesso de Peso, Sono, Criança, Adolescente, Revisão

Introduction

In the last three decades, obesity and overweight became one of the major health problems in children worldwide[1-4], dramatically increasing obesity-related diseases[5-6], such as insulin resistance, type 2 diabetes, metabolic syndrome, hypertension and adult obesity, and leading to a significant growth in economic costs[7]. Furthermore, the annualized increasing rates of childhood obesity are themselves rising in Europe[8], similarly to what occurred in the USA, independently of the definition for obesity[9], and despite the efforts to control classic obesity risk factors like hypercaloric diet and sedentary lifestyles.

On the other hand, sleep patterns among western children and adolescents have been changing during the same period, leading to a decrease of daily sleep duration[10]. This reality, as well as the association of short sleep and sleep deficit with endocrine and metabolic changes, as reduced leptin[11-13], elevated ghrelin[13] and glucose intolerance[11], encouraged the research in sleep's association with overweight and obesity in pediatric ages, which created an appreciable amount of data .

To my knowledge, two meta-analyses[14-15] and a systematic review[16] summarized this information, concluding that short sleep increased the risk for obesity, but noting that more studies were needed. However, they only used Pubmed as primary online database[14, 16] or didn't address exclusively to children and adolescents[15-16]. Additionally, several important studies were published in the meantime.

The aim of this systematic review is to analyze all eligible papers assessing the association between sleep duration in pediatric age and the risk for overweight or obesity; to propose some aspects of a common methodology for future studies on this subject, thus allowing an easier interpretation and confrontation of results; and to alert pediatricians for the importance of correct sleep counseling.

Methods

Systematic literature search

A systematic search for journal publications using PubMed, EMBASE, Scopus, ISI Web of Knowledge, EBSCO and Science Direct online databases from inception to 31st July 2009, using no language restrictions, was conducted. In all six databases I used (childhood OR infant OR children OR adolescent OR pediatric OR paediatric) AND (sleeping time OR sleeping hours OR sleeping hour OR sleeping pattern OR sleeping habits OR sleeping hygiene OR sleep deprivation OR sleeping duration) AND (obesity risk OR obesity OR overweight OR weight gain OR weight loss OR body weight changes OR body mass index) as query. Additionally, I used ("Sleep"[Mesh] AND "Obesity"[Mesh] AND (“Infant”[Mesh] OR “Child, Preschool”[Mesh] OR "Child"[Mesh] OR “Adolescent” [Mesh])) OR ("Sleep"[Mesh] AND "Overweight"[Mesh] AND (“Infant”[Mesh] OR “Child, Preschool”[Mesh] OR "Child"[Mesh] OR “Adolescent” [Mesh])) only in PubMed. The same procedure was repeated to include journal articles available until 30th September 2009. The full texts of all eligible articles were retrieved for further study and all of their references were screened using the bellow described criteria. Furthermore, the bibliographies from several reviews[14-20] were also analyzed. When I had doubts about the inclusion of an article, an independent and exterior second opinion was asked.

S*tudies eligibility criteria*

Papers that didn’t address the association between childhood or adolescence sleeping hours and the risk for overweight or obesity, or didn’t refer to observational studies, were excluded from the review in the first evaluation. By this criteria, those who analyzed the effect of sleep hours on body mass index (BMI) changes, without

presenting data regarding overweight or obesity specifically, weren't considered. Additionally, only papers with measures of odds ratios (OR) or relative risks, and with confidence intervals (CI), or with enough data to calculate risk parameters, were included in the analysis.

When two or more longitudinal studies published results from the same population, only the article referring to the longest follow-up was described in this review. Results were included even if the obesity risk was analyzed in adulthood, as long as the sleep data referred to childhood. As for transversal studies based on the same population, at the same age, only the data from the one presenting more stratified results was retrieved, but, if they measured outcomes at different ages, they were considered as independent papers.

If a study provided results with different degrees of adjustment for potential confounders, only results adjusted for the largest number of confounders were retrieved. Finally, this review was restricted to articles written in English, French, Portuguese, Spanish or Italian and comprising an initial sample size ≥200, as the population's size is an objective quality criteria, and lesser populations presumably wouldn't allow enough statistical power to detect the association in review.

For simplicity and coherence, through this paper the term overweight always includes the obese children as well, as proposed by IOTF's definition[21], except when stated otherwise. Also, the CDC's overweight group[22] is considered to be equivalent to the term obesity.

Data extraction

Each included study was analyzed using a standardized data extraction form and characterized according to year of publication, country of origin, population's origin,

type of study, length of follow-up (only longitudinal studies), participant's number, age and sex, definition of obesity, sleep hours reference, obesity's and sleep's method of measure, risk estimates (if not provided in the original paper the information was computed according to existing data) and confounders taken into account. Sex-specific and age-specific results were extracted whenever available, in detriment of non stratified estimates. The database was constructed in a Microsoft Excel 2007® file and EpiInfo 6® was used to calculate missing risk values.

Results

The original search retrieved 1292 articles, resulting in 53 eligible articles after review of references, as detailed in Figure 1. Seven[23-29] studies were excluded because they assessed an initial population of less than 200 individuals, six[30-35] where duplicates or reported to other papers and four[36-39] weren't examined due to language restrictions.

Tables 1, 2 and 3 summarize the results of the systematic review, divided by prospective cohort[40-45], case-control[46-49] and cross-sectional[50-75] studies (and annexed Figures 2 to 5 show it graphically). From the 36 included articles, ten were conducted in the European Union (EU), ten in North America, seven in Eastern Asia, four in Oceania and five in other locations, resulting in a great variety of subject's origin and cultural background.

Most assessments of sleep duration were made by self or parent-reported questionnaire, save for three investigations[44, 61, 64] that used diaries, and other two[62, 72] which used objective methods. All included papers measured the anthropometric values, with the exception of one[67]. Although a major part of studies assessed the weight status using IOTF references[21] or CDC charts[22], several[45-47, 49, 53-54, 69, 75] used national references or distinct cut-offs.

Every one of the six cohort studies[40-45] assessed sleeping hours of pre-teen populations, and found an association between reduced sleep and an increased risk for obesity. The population number ranged from 785 to 7758 children and the normal follow-up was from 3 years to 5 years, although Landhuis *et al.*[40] analyzed long term consequences of childhood short sleep, concluding that the existence of reverse causation isn't probable, meaning that it's not likely that the children slept less because they were already overweight. Reilly *et al.*[45] followed 7758 children during four years, with 5493 included in the final adjusted model, and verified that sleep duration was

independently associated with obesity (OR = 1.45; 95% CI: 1.10-1.89 for those who slept <10.5h vs >12h/day), also showing a dose-response effect. Beside the longitudinal approach, Lumeng *et al*.[43] also performed a transversal examination, rendering similar, although weaker, results (OR = 0.80; 95% CI: 0.65-0.98 [transversal] vs OR = 0.60; 95% CI: 0.36-0.99 [longitudinal] risk of obesity for each additional hour of sleep). Finally, Snell *et al*.[44] found that the effect of sleep in the risk of overweight is greater in younger children, and Touchette *et al*.[42] suggested that a cumulative effect of short sleep's duration on BMI exists.

Case-control populations varied from 343 and 1322. Only Ochoa's[46] study didn´t find a statistically significant reverse association between sleep duration and obesity, and included teenagers in their sample. He *et al*. concluded that the protective effect of sleeping ≥12h/day was greater in 3-6.9 year old children (OR = 0.56; 95% CI: 0.43-0.74) than in the younger offspring (OR = 0.88; 95% CI: 0.58-1.35).

Among cross-sectional surveys, observed populations varied from 270 and 13450 children and adolescents, with a majority of papers reporting more than 1000 subjects. The results generally pointed to an association (which causation cannot be inferred due to this studies' design) of reduced sleep and obesity. However, Osama Awad *et al*.[65] were the only who found a protective effect of reduced sleep on the risk for overweight. Several results[56-57, 61, 66, 68, 70-71, 74] showed a greater association in males, compared to females, while Sun *et al*.[58] reported a stronger correlation in females. On the other hand, two recent studies[50, 52] didn't find significant differences among genders. Age-related differences of the correlation are difficult to determine with the retrieved data, yet, Eisenmamm *et al*.[70] found stronger associations in older males, as well as in younger females, and one study[55] found no association in children aged 11-17 years old

(OR = 0.99; 95% IC: 0.9-1.1), opposite to those aged 3-10 years old (OR = 0.89; 95% IC: 0.8-1.0), when considering sleep as a continuous variable (not showed in table 3) .

Some articles presented interesting data, because they were differently stratified. Ievers-Landis *et al*.[61] demonstrated no significant difference in assessing sleep duration by sleep journal rather than questionnaire, contrary to Knutson & Lauderdale[64] that only found significant associations using data collected by questionnaire. Lastly, Duncan *et al*.[60] observed that weekend sleep duration wasn't correlated with obesity, in opposition to weekday sleep duration.

Due to different definitions of overweight and obesity, diverse sleep references (even within the same age group), irregular stratification methods and great variation of accounted confounders, no meta-analysis was attempted, as it would not represent a pooled risk estimate with the needed accuracy.

Discussion

Result analysis, controversies and review limitations

In general, included studies point to an association between short sleep duration and an increased risk for overweight in pediatric subjects. Additionally, as all six included prospective studies were based on multi-adjusted models and presented similar conclusions, it seems likely that children became heavier as consequence of the lack of sleep and not the other way around. Also, sleep duration appears to play an independent role in increasing the risk for overweight or obesity. However, the majority of reviewed articles were cross-sectional; therefore no causal relations can be extracted from them.

The association is consistent even considering the observed great inter-study design variability. For example, children of the same age could be categorized according different sleep duration references[52, 59] and subjects belonging to distinct age groups could be considered unstratified and compared to the same sleep reference[50, 56, 60, 64, 69], regardless of age-specific needs of sleep.

Included articles represent many different populations, with distinct ethnical, cultural and social origins. As the association was consistent across populations, it seems that cultural and ethnical aspects don't play a significant role in the establishment of this correlation. Nevertheless, these variables should always be taken into account as potential confounders.

As previously highlighted, and detailed in tables 1, 2 and 3, studies greatly differ in key-aspects, as sleep references or overweight definitions, turning real comparison between papers prone to biases, as well as increasing inter-study heterogeneity. Even so, it appears that the increased risk of overweight in reduced sleepers is statistically significant, although not very strongly. Also, as a dose-response relationship seems to

exists, the clinical increasing prevalence of childhood overweight may be more correlated to childhood chronic lack of sleep than risk estimates seem to express.

A majority of sex-stratified studies reported that boys were more negatively affected by reduced sleep hours than girls[56-57, 61, 66, 68, 70, 74], whereas only Sun *et al.*[58] showed divergent results. Although no evidence-based explanation for this phenomenon exists to my knowledge, Jonathan Wells[76] arguments that, in general, natural selection acts in a way that, during earlier life years, environmental aggressions affect males more severely than females, thus, reduced sleep (interpreted as a stress factor) could result in more deleterious consequences in boys, when compared to girls. On the other hand, at this time and taken only into account age-stratified results, it isn't possible to determine if the association is stronger in younger or older children, so further research should try to determine age-specific risks.

Regarding Osama Awad's[65] results, which are inconsistent with all other included studies, it's possible that several biases occurred, as he only studied a small population (270 subjects) and the presented OR are non-adjusted. For example, it's likely that short sleeper children living in Sudan spent only a minor part of their awaken time with sedentary activities, contrary to most European or North American children. Anyway, independently of any possible explanation for these results, the importance of multi-adjustment needs to be emphasized, as it allows to control the effect provided from external variables.

Some authors[77-78] argue that systematic searches on this subject may be prone to limitations because sleep and body mass variables are frequently reported in potential confounder tables or as secondary results. For this reason, they state that publication bias and selection bias is expected to occur, thus restraining the conclusions about sleep's association with overweight. Due to the consistency of this review's results and

the fact that a very sensible query was used, I do not think that this limitation significantly applies to pediatric population, though I agree that more and larger prospective studies are needed in order to clarify the real impact of reduced sleep in the increased risk of overweight.

The sleep's role upon obesity seems to be important, as only minor changes in sleep duration may influence the overweight risk. However, despite these results, advocating an increased sleep period for children and adolescents shouldn't be interpreted as the miracle solution for the world's obesity epidemics, because overweight and obesity are multifactorial problems and we still lack the knowledge to fully understand these disorders. In consequence, to prevent or treat overweight, clinicians need to integrate classical approaches like increasing physical exercise and diminishing caloric intake, alongside with sleep recommendations.

This study was undertaken by only one author, which may be an important limitation, as one can conclude by Pai's work[79]. However, I used six different article indexes and created a query with high sensitivity, which didn't occur in previously published reviews. Furthermore, all papers previously included in other systematic reviews were analyzed and the reference list obtained after multi-database search was screened twice. Also, an external opinion was asked when doubts about the inclusion of an article or data retrieval occurred. Therefore, it's unlikely that important articles or information were missed and that more reviewers would conduct to distinct results and conclusions. Finally, as many of the included studies were published in the time between the last review and this one, much of the presented data was never integrated in a global analysis.

Physiological bases and lifestyle factors relating short sleep to obesity

Recent experimental works[11, 13] demonstrated that sleep plays a substantial role in the neuroendocrine control of appetite. Short sleepers tend to present reduced serum levels of leptin, as well as increased ghrelin levels, thus having an augment appetite and leading to excessive caloric intake, especially in societies where food is highly available and parents can't (or won't) control their children's consumption habits. Likewise, it's well documented that growth hormone (GH) is clearly elevated during sleep, especially in males; consequently short sleeping children will secrete less GH and have their growth development restrained, which can result in an higher BMI index, even if they have an appropriate weight for their specific age. Furthermore, chronic partial sleep loss modify prolactin, cortisol and thyrotropin secretion, altering hormonal interactions[80]. These modifications are not only correlated with sleep duration, but also with sleep quality[80]. It is then fundamental to assess the quality of subject's sleep when performing sleep duration studies.

Additionally, children in developed countries occupy a considerable part of their waken time on sedentary activities, namely watching television or playing video games. Such behaviors are frequently associated to increased snaking and ingestion of high caloric food. It's then possible to argument that most of the lost sleeping hours of a children or adolescent will be engaged in unnecessary food consumption, which increases the risk of overweight. Obviously, this conclusion is simplistic, as behavioral factors are very complex, but allows an insight on the explanation for the association of lower than recommended sleep duration and an increased risk for overweight.

Future studies and methodology proposal

As detailed above, most of the studies assessing the association of childhood and adolescent sleep duration and the risk for overweight are cross-sectional and no causal inferences can be established with them. On the other way, the few existing prospective works normally don't follow the subjects in order to determine long term consequences of sleep reduction. Furthermore, many questions still remain unanswered: What is the real impact of reduced sleep in the risk of overweight or obesity? Are females really less affected by the lack of sleep? How does the observed relationship evolve with the child's age? Which hormones are affected by sleep deprivation, and how do they affect the children's BMI? How does BMI evolve if sleep duration is actively increased? When can one consider that the association is similar to the one observed in adults? What's the importance of this information in establishing public health programs? Among others. Considering this aspects and the fact that a considerable amount of data has already been produced by cross-sectional observational studies, future investigation should privilege large prospective cohort studies with long term follow-ups and regular risk determinations, trying to answer these, and other, pertinent questions.

Another important problem is the existence of a great variability among studies' criteria, cut-off points, reference values and definitions, turning it very difficult to compare different papers. It's then important to create some methodological bases that should become the common ground for all future works.

Magee *et al.*[81] reviewed adult studies, outlined their major methodological limitations and provided some practical recommendations to ensure more objective and comparable results in future reports. Based on their findings, as well as the articles included in this review, authors of pediatric studies addressing sleep and obesity should agree to a common definition of pediatric obesity sleep reference values, measurements

strategies, data stratification and addressed confounders, as resumed in table 4, in order to allow comparison between results.

Having this in mind, I suggest to always measure the anthropometric variables, however, if that's not possible, self-reported or parent-reported height and weight are acceptable for teens[82], but not self or parent-reported overweight/obesity status[82], as this aspect tends to be biased by subjective perception.

Overweight/obesity status is difficult to assess because easily accessible methods as BMI or waist circumference (WC) have important limitations[81] and more accurate methods are costly or unpractical to adopt in large observation studies[81]. Therefore, a single index combining BMI and the waist to height ratio (WHtR) should be used, considering that a child is obese if he corresponds to the BMI or to the WHtR definition. This requires the construction of WHtR charts. Furthermore, as several BMI-related charts and obesity definition exists, I recommend using both CDC[22] and IOTF[21] charts simultaneously. Thus, a child with a BMI $\geq 85^{th}$ percentil (CDC) or included in the overweight group by IOTF criteria should be considered overweighed, the same applying for children with BMI $\geq 95^{th}$ percentil (CDC) and obesity, as detailed in table 4. Using this system will allow less variation of these definitions according to the population's evolution, which is inevitable when using percentile-based interpretations, and permits to classify as obese those children that the IOTF (in opposition to CDC) doesn't consider as such.

Although actigraphy should be the preferred method to measure sleep duration[81], because it's an inexpensive and objective way to assess this parameter, evidence shows that sleep journals reports demonstrate high correlation with actigraphy records[83-84]. Also, when clinicians need to recommend sleep durations, they'll base their judgments on information concerning bed time and wake time so, in a practical point of view, sleep

journal could be more adequate. Either way, measurements should be done over a whole non-vacation week. Additionally, subjective sleep quality scales, as Pittsburgh Sleep Quality Index[85] or Epworth Sleepiness Scale[86] should be used[81] in adolescent's studies.

When defining sleep references, researchers ought to be aware of an age-related evolution of sleep duration requirements and use age-specific references. Table 5 summarizes a references proposal. Note that these sleep intervals shouldn't be interpreted as individual sleep recommendations, but rather as generic values allowing easy comparisons. Also, as sleep patterns have been changing and different populations get different amounts of sleep[10], this common reference values should be revised when the definition of adequate sleep becomes unanimous.

Because obesity is a complex and multi-variable pathology, many confounding variables should be taken into account. A non-exhaustive list includes: age, sex, screen time, physical activity, birth weight, birth height, parental BMI, SES, breastfeeding, sleep quality, alcohol consumption, smoking, alcohol drinking during pregnancy, pregnancy smoking, prematurity status, snaking, irregular eating, parental educational level, regular breakfast and ethnicity. It's also preferable to present data stratified by age and sex, as a minimum.

Lastly, interventional observation, where sleep schedules and duration are actively modified, will be necessary to establish the real impact of increasing sleep duration on the individual's or population's BMI.

Clinicians' role in counseling better sleep

Clinicians in general, and pediatricians in special, should be alert to sleeping problems and insufficient sleep, since it's of major importance to ensure an adequate sleep, with an adequate duration, to all children and adolescents. This is fundamental

not only due to the increasing prevalence of obesity and the potential benefits of longer sleep, but specially because inadequate sleep, in quality or quantity terms, is related to multiple problems, such as inattention[87], psychiatric symptoms[87], depression[88], school problems[88] and aggressively[88], among others.

In consequences, sleep habits must be assessed in every doctor's visit, and adequate age-adjusted sleep duration should be proposed, as well as simple actions to increase sleep quality[89]: remove all televisions, gamming consoles and computers from the bedroom; avoid screen-watching, homework doing, exercise practice and hanging out with friends before going to bed; provide an adequate temperature (not too warm, or too cold) and a quiet environment to sleep. Ultimately, a regular sleep and wake schedule should be negotiated and adopted[89] and doctors should recommend a sleep's duration of, at least, the 50^{th} percentile of the sleep duration curves[10].

If implemented these simple measures could provide a significant increase in sleep quality and reduce problems associated to poor sleep duration.

Conclusion

Chronic short sleep is associated to a higher risk for overweight and obesity in pediatric populations, regardless of ethnical origins, age, sex or overweight definition. A causal dose-response effect has been observed and it appears that the association is stronger in males, compared to females.

More studies, in particular large prospective ones, are needed to clearly understand the relation between sleep and overweight, as well as the clinical, social and economical consequences of this association. Future analysis should also have a common base of definitions, similar methodological designs and use age-specific references for sleep duration.

Sleep habits evaluation and sleep counseling ought to be a part of every pediatric consult. Also, sleep duration should integrate each overweight prevention or treatment programs, alongside with classic approaches, such as caloric intake restrictions and physical exercise stimulation.

Finally, although promoting increased sleep hours in pediatric populations won't miraculously solve the obesity epidemics, encouraging children and adolescents to sleep more is a simple measure that will likely improve prevention and treatment of obesity.

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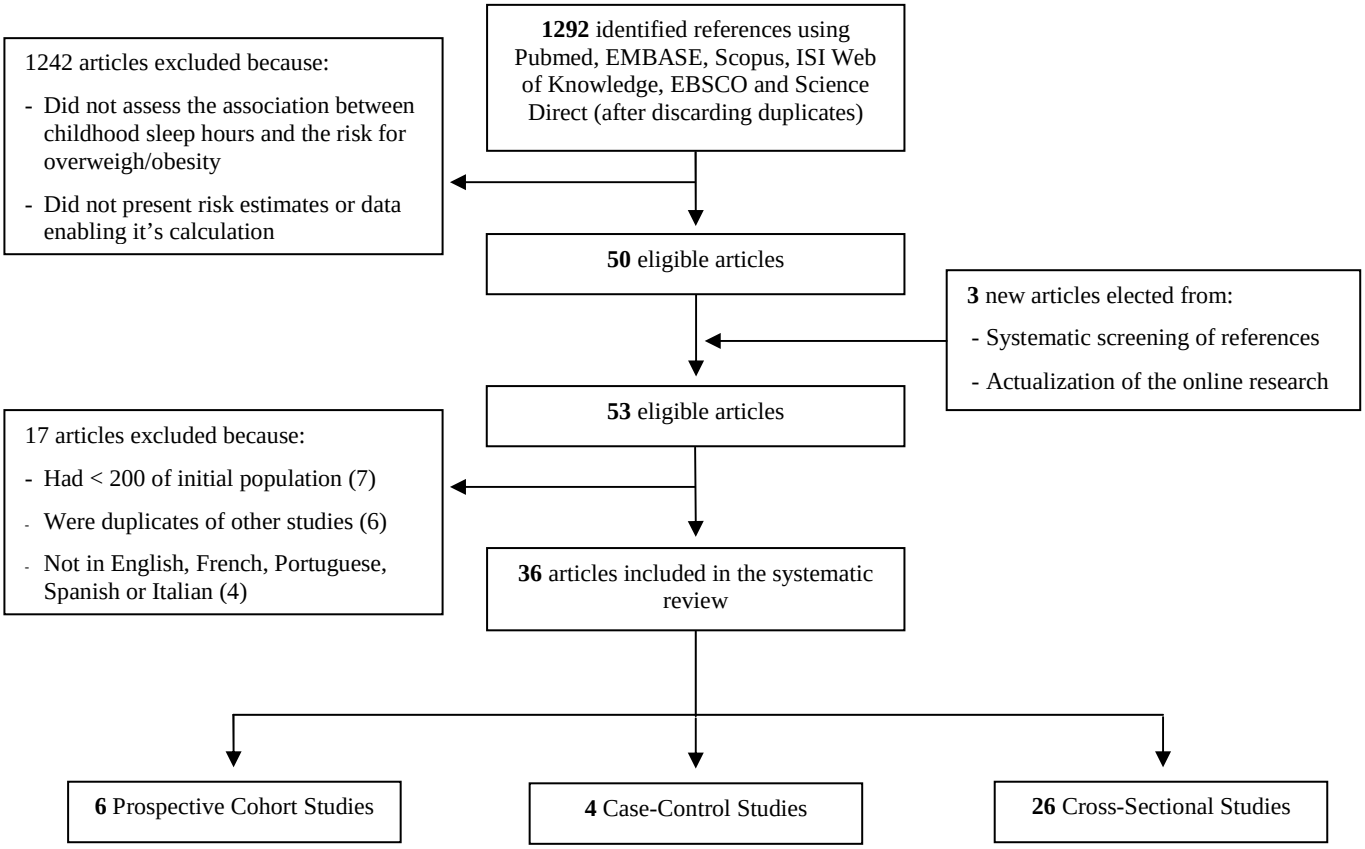

Fig. 1 – Systematic review flow-chart.

Table 1 – Description and main characteristics of prospective cohort studies referring to the association of childhood or adolescence sleep hours and risk for overweight or obesity

First Author, Country, Year Follow-up	No. Subjects Baseline Age Men (%)	Sleep Evaluation	Classification of overweight and obesity	Sleep Reference (hours/day)	OR (95% CI)	Confounders Addressed
Landhuis CE [40] New Zealand, 2008 29 years	1037 (M & F)† 3 years 52.0 %	Questionnaire: parental report (at 5, 7, 9, 11y)	Obesity: BMI ≥ 30 kg/m^2	____	Risk of obesity for each additional sleep hour 0.65 (0.43 – 0.97)*	Sex, SES, Parental BMI, Screen time, Smoking, Parental control, BMI at Age 5y, Early BMI, Adult physical activity, Sleep time at age 32y
Taveras EM [41] USA, 2008 3 years	915 (M & F) 0 years 50.0%	Questionnaire: parental report (at 6m, 1y, 2y)	CDC ref. Obesity: BMI ≥ 95th percentile	≥ 12h	Males & females < 12h: 2.04 (1.07 – 3.91)	Income, Race, Marital status, Maternal education, Prenatal smoking, Breastfeeding duration, Birth weight, Screen time, Daily active play, Weight-for-length z score
Touchette E [42] Canada, 2008 3.5 years	1138 (M & F)† 2.5 years 46.8 %	Questionnaire: parental report (at 2.5y, 3.5y, 4y, 5y & 6y) ‡	IOTF ref. Obesity and overweight	11h	Males & females < 10h: 2.9 (1.0 – 8.5) 10h: 1.5 (0.9 – 2.5)	Birth weight, Prematurity, Low birth weight, Sex, Pregnancy Smoking, Weight at 5 month & 2.5y, Low parental education, Modified family structure, Late cereal introduction, Not breast-fed, Screen time, Immigrant mother, Snaking, Nap-time, Overeating, Eating sweets, Modified family structure, Physical

						activity, Snoring, Income status
Lumeng JC [43] USA, 2007 3 years	785 (M & F)† 9 years 50.0 %	Questionnaire:§ parental report 3rd & 6th grade	CDC ref. Obesity: BMI ≥ 95th percentile	____	Risk of obesity for each additional sleep hour 0.60 (0.36 – 0.99)*	Sex, Race, Maternal education, Changes in sleep duration between 3rd and 6th grades, Weight at 3rd grade
Snell EK [44] USA, 2007 5 years	2281 (M & F)† 3 – 12.9 years ____	Time diary	IOTF ref. Obesity and overweight	9 – 10h	Younger children (3 – 7.9y) ‖ < 8h: 1.09 (0.96 – 1.23) 8 – 9h: 1.04 (0.95 – 1.14) 10 – 11h: 0.94 (0.89 – 1.00) ≥ 11h: 0.85 (0.79 – 0.92)** Older Children (8 – 12.9y) ‖ < 8h: 0.91 (0.83 – 1.00) 8 – 9h: 1.04 (0.96 – 1.11) 10 – 11h: 0.92 (0.86 – 0.98) ≥ 11h: 0.90 (0.80 – 1.01)	Sex, Race, Parental education, Family income, Age at study's start and finish
Reilly JJ [45] UK, 2005 4 years	7758 (M & F)† 2.9 – 4.5 years 50.7 %	Questionnaire: parental report (at 38mo)	UK ref. [90] Obesity: BMI ≥ 95th percentile	> 12h	Males & females < 10.5h: 1.45 (1.10 – 1.89)** 10.5 - 10.9h: 1.35 (1.02 – 1.79) 11 – 11.9h: 1.04 (0.76 – 1.42)	Sex, Maternal education, Energy intake at age 3y

CI – confidence intervals; OR – odds ratio; SES – socio-economical status; BMI – body mass index

† – Lower number of subjects taken into account for results; ‡ – Weight measured at 2.5 and 6 years); § – Weight measured at 3rd & 6th grades;

‖ – Coefficients and standard errors of the original article were converted to OR and IC; * – P < 0.05; ** – P < 0.01. [a] The International Obesity Task Force (IOTF)[21] age-sex specific BMI cut points correspond to a curve that passes through 25 Kg/m^2 (overweight) and 30 Kg/m^2 at age 18 (obesity), obtained by averaged data from six countries. 25 kg/m^2 curve is just below the 91st centile and 30 Kg/m^2 curve is above the 98th centile for both sexes. [b] The CDC Growth Charts[22] defines "at risk for overweight" between the 85th and the 95th percentiles of BMI, and "overweight" (termed "obesity" in this paper) above the 95th percentile of BMI.

Table 2 – Description and main characteristics of case-control studies referring to the association of childhood or adolescence sleep hours and risk for overweight or obesity

First Author, Country, Year	No. Subjects, Age Men (%)	Sleep Evaluation	Classification of overweight and obesity	Sleep Reference (hours/day)	OR (95% CI)	Confounders Addressed
Ochoa MC [46] Spain, 2007	370 (M & F) 6 – 18 years (mean 11.5 y) 53.0 %	Questionnaire: interview	Spanish ref. Obesity: BMI > 97th percentile	____	Risk of obesity for each additional sleep hour 1.05 (0.82 – 1.34)	No adjustments
Hui LL [47] Hong Kong (China), 2003	343 (M & F) 6 – 7 years 49.0%	Questionnaire: interview	Hong Kong ref. [91] Overweight: ‡ >120% of median weight-for-height	< 9h	Males & females 9 – 11h: 0.54 (0.30 – 0.97)* ≥ 11h: 0.31 (0.11 – 0.87)*	Parental obesity
He Q [48] China, 2000	1322 (M & F) 0.1 – 6.9 years 56.6%	Questionnaire: parental report	CDC ref. >120% of mean weight-for-height	< 12h	Younger children (0.1 – 2.9y) ≥ 12h: 0.88 (0.58 – 1.35) Older children (3 – 6.9y) ≥ 12h: 0.56 (0.43 – 0.74)**	Age
Locard [49] France, 1992†	1031 (M & F) 5 years 51.0%	Questionnaire: interview	French ref. Obesity: ≥ 2 SD weight-for-height z-score	≥ 12h	Males & females < 10h: 4.9 (1.9 – 12.7) 10 – 11h: 2.8 (1.2 – 6.3) 11 – 12h: 2.0 (0.9 – 4.4)	Parental overweight for the <11h vs. ≥11h OR

CI – confidence intervals; OR – odds ratio; BMI – body mass index

† – Data retrieved from Chen et al. study[14] and the original study's abstract; ‡ Equivalent to ≥92nd percentile; * – P < 0.05; ** – P < 0.01

[a] The International Obesity Task Force (IOTF)[21] age-sex specific BMI cut points correspond to a curve that passes through 25 Kg/m^2 (overweight) and 30 Kg/m^2 at age 18 (obesity), obtained by averaged data from six countries. 25 kg/m^2 curve is just below the 91st centile and 30 Kg/m^2 curve is above the 98th centile for both sexes. [b] The CDC Growth Charts[22] defines "at risk for overweight" between the 85th and the 95th percentiles of BMI, and "overweight" (termed "obesity" in this paper) above the 95th percentile of BMI.

Table 3 – Description and main characteristics of cross-sectional studies referring to the association of childhood or adolescence sleep hours and risk for overweight or obesity

First Author, Country, Year	No. Subjects, Age Men (%)	Sleep Evaluation	Classification of overweight and obesity	Sleep Reference (hours/day)	OR (95% CI)	Confounders Addressed
Bawazeer NM [50] Saudi Arabia, 2009	5877 (M & F) 10 – 19y 55.2 %	Questionnaire: parental report	Obesity: BMI > 95th percentile	> 7	Males ≤ 7h: 1.28 (1.09 – 1.50) Females ≤ 7h: 1.38 (1.02 – 1.89)	No adjustments
Bayer O [51] Germany, 2009	7767 (M & F) 3 – 10y 51.3 %	Questionnaire: parental report	IOTF ref. Obesity and overweight	____	Risk of overweight for each additional sleep hour 0.84 (0.78 – 0.91) Risk of obesity for each additional sleep hour 0.82 (0.70 – 0.95)	Parental SES, Maternal BMI, Birth weight, Screen time, Smoking during pregnancy, Exclusive breastfeeding until 4 month
Cicek B [52] Turkey, 2009	5358 (M & F) 6 – 7y 48.9 %	Questionnaire: self report	Obesity and overweight AFA ≥ 85th percentile	≥ 10h	Males ≤ 8h: 1.79 (1.08 – 2.97) 8 – 9h: 1.83 (1.09 – 3.08) 9 – 10h: 1.30 (0.76 – 2.24) Females ≤ 8h: 1.77 (1.06 – 2.97) 8 – 9h: 1.72 (1.01 – 2.94) 9 – 10h: 1.96 (1.14 – 3.36)	Age, Sex, Residence region, Screen time, Appetite, House size, Elevator use, Household income, Parental education, Transportation style to school, Maternal employment, Computer use
Hitze B [53] Germany, 2009	414 (M & F) 6.1 – 19.9 47.0%	Questionnaire: parental report (< 11y) self report (≥ 11y)	German ref. [92] Obesity: BMI > 97th percentile	Long sleep: ≥10h if < 10y ≥ 9h if ≥ 10y	Females Short sleep: 5.5 (1.3 – 23.5) Note: No OR were given for males	Paternal BMI, Maternal BMI, Birth weight, Variation of weight-SDS from birth to 2y, Breastfeeding duration

Jiang F [54] Shanghai, 2009	1311 (M & F) 3 – 4y 50.3 %	Questionnaire: parental report	Chinese ref. [93] Obesity: BMI ≥ 95th percentile	≥ 11h	Males & females < 9h: 4.76 (1.28 – 17.69) 9h – 9.4h: 3.42 (1.12 – 10.46) 9.5 – 9.9h: 1.78 (0.55 – 5.82) 10h – 10.4h: 2.70 (0.92 – 7.97) 10.5 – 10.9h: 1.70 (0.47 - 6.24)	Age, Sex, Appetite, Birth weight, Mather's age at delivery, Parental & Maternal education, Geographical area, Household income
Kleiser C [55] Germany, 2009	13450 (M & F) 3 – 17y† ____	Questionnaire: parental report (3 – 10y) self report (11 – 17y)	IOTF ref. Obesity and overweight	Highest tertile of sleep	Overweight (M & F) Lowest: 1.24 (1.1 – 1.4) Middle: 0.94 (0.8 – 1.1) Obesity (M & F) Lowest: 1.24 (1.0 – 1.6) Middle: 0.90 (0.7 – 1.1)	Age, Sex
Ozturk A [56] Turkey, 2009	5358 (M & F) 6 – 17y 48.9 %	Questionnaire: parental report	IOTF ref. Obesity and overweight	≥ 10h	Males & females‡ < 8h: 1.48 (1.09 – 2.00)* 8 – 8.9h: 1.54 (1.13 – 2.11)** 9 – 9.9h: 1.55 (1.12 – 2.14)** Males < 8h: 2.06 (1.31 – 3.24) 8 – 8.9h: 1.74 (1.10 – 2.75) 9 – 9.9h: 1.86 (1.17 – 2.97)	No adjustments Note: Results for females alone weren't statistically significant
Padez C [57] Portugal, 2009	4511 (M & F)† 7 – 9y 49.6 %	Questionnaire: parental report	IOTF ref. Obesity and overweight	≥ 11h	Males‡ < 9h: 3.73 (2.13 – 6.56)** 9 – 10h: 1.44 (1.07 – 1.94)* 10 – 11h: 1.28 (0.98 – 1.67) Females‡ < 9h: 2.42 (1.25 – 4.68)** 9 – 10h: 1.10 (0.83 – 1.45) 10 – 11h: 1.02 (0.81 – 1.29)	No adjustments

Sun Y [58] Japan, 2009	5753 (M & F) 12 – 13y 49.4 %	Questionnaire: self report	IOTF ref. Obesity and overweight	8 – 9h	<u>Males</u> < 7h: 1.21 (0.82 – 1.77) 7 – 8h: 0.97 (0.75 – 1.26) ≥ 9h: 0.71 (0.46 – 1.10) <u>Females</u> < 7h: 1.81 (1.21 – 2.72)** 7 – 8h: 1.37 (1.00 – 1.88)* ≥ 9h: 1.53 (0.87 – 2.69)	Age, Paternal overweight, Maternal overweight, Breakfast, Snacking, Nighttime snaking, Eating speed, Eating volume, Physical activity, Screen time
Vanhala M [59] Finland, 2009	855 (M & F)[†] 7.3y (average) 51.0 %	Questionnaire: parental report	IOTF ref. Obesity	> 9h	<u>Males & females</u> ≤ 9h: 2.68 (1.33 – 5.41)*	No adjustments
Duncan JS [60] New Zealand, 2008	1229 (M & F) 5 – 11y 49.1 %	Questionnaire: parental report	Overfat: Males >25% BF Females >30% BF	≥ 12h	<u>Weekday sleep</u> (M & F) < 10h: 7.03 (1.63 – 30.4)** 10 – 10.9h: 4.23 (1.13 – 15.8)* 11 – 11.9h: 3.92 (1.07 – 14.4)* <u>Weekend sleep</u> (M & F) < 10h: 0.85 (0.38 – 1.89) 10 – 10.9h: 1.02 (0.52 – 1.99) 11 – 11.9h: 0.70 (0.35 – 1.43)	Sex, Age, SES, Ethnicity, Physical activity, Active transport, Fast food, Breakfast, Sports participation, Bought lunch, Sugary drinks, Weekday sleep, Weekend sleep
Ievers-Landis CE USA, 2008 [61]	819 (M & F) 8 – 11y 51 %	Questionnaire: parental report & Sleep journal: self report	CDC ref. Obesity: BMI ≥ 95th percentile	____	Risk of obesity for each hour of sleep reduction Question.: 1.41 (1.12 – 1.76)** Sleep jour.: 1.45 (1.09 – 1.94)* Males : 1.69 (1.24 – 2.30)** Females : 1.10 (0.79 – 1.54)	Age, Sex, Preterm status, Median income, Age squared, Psychological & Behavioral problems, Parenting stress
Nixon GM [62] New Zealand, 2008	519 (M & F) 7y 49.5 %	Actigraphy	IOTF ref. Obesity and overweight	≥ 9h	<u>Males & females</u> < 9h: 3.32 (1.40 – 7.87)**	Sex, Maternal stage, BMI & Marital status, Screen time, Season,

Wells JCK [63] Brazil, 2008	4452 (M & F)† 10 – 12y 49.3 %	Questionnaire: self report	IOTF ref. Obesity and overweight	< 9h	Overweight (M & F) 9 – 10h: 1.11 (0.89 – 1.37) > 10h: 0.88 (0.72 – 1.07) Obesity (M & F) 9 – 10h: 1.02 (0.70 – 1.49) > 10h: 0.71 (0.50 – 1.02)	Sex, Birth weight, Birth length, Physical activity, Pregnancy smoking, Alcohol intake during pregnancy, Maternal pregnancy BMI, SES, Screen time, Systolic & Diastolic blood pressure
Knutson & Lauderdale [64] USA, 2007	1546 (M & F) 10 – 19y 49.6 %	Questionnaire: self report & Sleep journal	CDC ref. Obesity: BMI ≥ 95th percentile	> 10h > 9h	Sleep journal < 8.4h: 1.02 (0.57 – 1.84) 8.4 – 9.2h: 1.56 (0.92 – 2.64) 9.2 – 10h: 1.63 (0.96 – 2.78) Questionnaire: Self Report ≤ 7h: 0.88 (0.45 – 1.69) 7 – 8h: 1.85 (1.01 – 3.38)* 8 – 9h: 1.93 (1.10 – 3.37)*	Sex, Age, Physical activity, Screen time, SES
Osama Awad S Sudan, 2007 [65]	270 (M & F) 15 – 18y 45.9 %	Questionnaire: self report	IOTF ref. Obesity and overweight	> 8h	Overweight‡, ‖ < 8h: 0.30 (0.13 – 0.72)** 8h: 0.77 (0.33 – 1.79) Obesity‡ < 8h: 0.30 (0.05 – 1.99) 8h: 1.67 (0.33 – 8.54)	No adjustments
Ramos E [66] Portugal, 2007	2161 (M & F)† 13y 48.4 %	Questionnaire: self report	CDC ref. Overweight: BMI 85th – 95th centile Obesity: BMI > 95th percentile	≥ 9h	Overweight‖ – Males‡ ≤ 8h: 1.73 (0.94 – 3.18) 8 – 9h 1.20 (0.81 – 1.77) Overweight‖ – Females‡ ≤ 8h: 0.99 (0.56 – 1.75) 8 – 9h: 1.04 (0.71 – 1.52) Obesity – Males‡ ≤ 8h: 2.65 (1.31 – 5.36)**	No adjustments

					8 – 9h: 1.72 (1.06 – 2.81)* Obesity – Females[‡] ≤ 8h: 1.03 (0.54 – 1.98) 8 – 9h: 0.69 (0.43 – 1.11)	
Seicean A [67] USA, 2007[§]	529 (M & F)[†] 14 – 18y 49.1 %	Questionnaire: self report	CDC ref. Obesity and overweight : BMI ≥ 85th percentile	> 8h	Males & females < 5h: 7.65 (1.87 – 31.30)* 5 – 6h: 2.80 (1.00 – 7.79) 6 – 7h: 2.55(1.02 – 6.38) 7 – 8h: 1.38 (0.54 – 3.53)	Sex, Age, Health status, Irregular eating, Caffeine intake
Chaput JP [68] Canada, 2006	422 (M & F) 5 – 10y 50 %	Questionnaire: parental report	IOTF ref. Obesity and overweight	12 – 13h	Males 8 – 10h: 5.65 (4.23 – 6.75) 10.5 - 11.5h: 1.28 (0.98 – 1.65) Females 8 – 10h: 3.15 (2.06 – 4.43) 10.5 - 11.5h: 1.69 (1.22 – 2.78)	Age, Sex, Parental obesity, Parental education, Family income, Single parenthood, Breakfast, Screen time, Physical activity, Breastfed
Chen MY [69] Taiwan, 2006	656 (M & F) 13 – 18y 53.2 %	Questionnaire: self report	Taiwan ref. [94] Obesity and overweight: BMI > 85th percentile	6 – 8h	Males & females < 6h: 1.74 (1.3 – 2.4)**	Age, Sex, Number of visits to doctor
Eisenman JC [70] Australia, 2006	6324 (M & F) 7 – 15y 50.6 %	Questionnaire: interview	IOTF ref. Obesity and overweight	≥ 10h	Males (7.5 – 10.9y) ≤ 8h: 2.42 (1.14 – 5.15) 8 – 9h: 1.88 (0.98 – 3.60) 9 – 10h: 1.60 (0.98 – 2.61) Males (11.0 – 13.9y) ≤ 8h: 2.73 (1.53 – 4.85) 8 – 9h: 1.68 (1.01 – 2.81) 9 – 10h: 1.62 (1.04 – 2.50) Males (14.0 – 16.5y) ≤ 8h: 4.85 (1.92 – 12.2)	Age, Sex

					8 – 9h: 2.56 (1.04 – 6.24) 9 – 10h: 1.94 (0.78 – 4.83) <u>Females (7.5 – 10.9y)</u> ≤ 8h: 1.41 (0.47 – 4.25) 8 – 9h: 1.80 (0.97 – 3.35) 9 – 10h: 1.14 (0.71 – 1.82) <u>Females (11.0 – 13.9y)</u> ≤ 8h: 1.24 (0.65 – 2.35) 8 – 9h: 1.15 (0.70 – 1.89) 9 – 10h: 0.90 (0.59 – 1.37) <u>Females (14.0 – 16.5y)</u> ≤ 8h: 0.61 (0.28 – 1.30) 8 – 9h: 0.85 (0.46 – 1.56) 9 – 10h: 0.57 (0.31 – 1.08)	
Knutson KL [71] USA, 2005	4486 (M & F) 15 – 18y 49.0 %	Questionnaire	CDC ref. Obesity: BMI ≥ 95th percentile	____	Risk of obesity for each additional sleep hour Males: 0.90 (0.82 – 1.00)* Females: 1.06 (0.96 – 1.17)	Age, Sex, Race, Parental education, Physical activity, Screen time
Gupta NK [72] USA, 2002	383 (M & F) 11 – 16y 46.3 %	Actigraphy	CDC ref. Overweight & Obesity: BMI > 85th percentile & Males >25% BF Females >30% BF	____	Risk of obesity for each additional sleep hour 0.20 (0.11 – 0.34)**	Age, Sex, Ethnicity, Sexual maturity
Sekine M [73] Japan, 2002	8941 (M & F) 3 – 5y 51.3 %	Questionnaire: parental report	IOTF ref. Obesity and overweight	≥ 11h	<u>Males & females</u> < 9h: 1.57 (0.90 – 2.75) 9 – 10h: 1.34 (1.05 – 1.72) 10 – 11h: 1.20 (0.97 – 1.49)	Age, Sex, Parental obesity, Hours of outdoor playing

Sekine M [74] Japan, 2002	8274 (M & F) 6 – 7y 50.7 %	Questionnaire: parental report	IOTF ref. Obesity and overweight	≥ 10h	<u>Males</u> < 8h: 5.49 (2.20 – 16.7) 8 – 9h: 3.45 (1.86 – 6.37) 9 – 10h: 2.28 (1.25 – 4.15) <u>Females</u> < 8h: 2.13 (1.01 – 4.48) 8 – 9h: 1.28 (0.88 – 2.15) 9 – 10h: 1.23 (0.81 – 1.87)	Sex, Age, Parental obesity, Physical activity, Screen time, Frequency of taking breakfast, Frequency of taking snacks
von Kries R [75] Germany, 2002	6862 (M & F)† 5 – 6y ____	Questionnaire: parental report	German ref. [95] Overweight: BMI > 90th percentile Obesity: BMI > 97th percentile	≤ 10h	<u>Overweight (M & F)</u> 10.5h – 11h: 0.77 (0.59 – 0.99) ≥ 11.5h: 0.54 (0.40 – 0.73) <u>Obese (M&F)</u> 10.5 – 11h: 0.53 (0.35 – 0.80) ≥ 11.5h: 0.45 (0.28 – 0.75)	Parental education, Parental BMI, Birth weight, Weight gain during 1st year, Screen time, Snack taking

CI – confidence intervals; OR – odds ratio; SES – socio-economical status; BMI – body mass index; AFA – arm fat area; BF – body fat

† – Lower number of subjects taken into account for results; ‡ – OR and IC calculated from study's data, unadjusted; § – Weight was assessed by self questionnaire; ‖ – Contrary to the rest of the review, in this article overweight is defined as 85th – 95th percentil; * – P < 0.05; ** – P < 0.01

[a] The International Obesity Task Force (IOTF)[21] age-sex specific BMI cut points correspond to a curve that passes through 25 Kg/m^2 (overweight) and 30 Kg/m^2 at age 18 (obesity), obtained by averaged data from six countries. 25 kg/m^2 curve is just below the 91st centile and 30 Kg/m^2 curve is above the 98th centile for both sexes. [b] The CDC Growth Charts[22] defines "at risk for overweight" between the 85th and the 95th percentiles of BMI, and "overweight" (termed "obesity" in this paper) above the 95th percentile of BMI.

Table 4 – Methodological recommendations for future studies

Anthropometric values	Always measure height, weight and WC
Overweight/Obesity assessment	Use a single index combining BMI (defined by CDC & IOTF) and WC
Overweight definition	$\geq 85^{th}$ percentil by CDC or BMI ≥ 25 Kg/m^2 by IOTF or WHtR $\geq 85^{th}$ percentile †
Obesity definition	$\geq 95^{th}$ percentil by CDC or BMI ≥ 30 Kg/m^2 by IOTF or WHtR $\geq 95^{th}$ percentile †
Sleep measurement	Use actigraphy or sleep journals records representing one complete non-vacation week
Sleep references	Use age-specific sleep references, as detailed in table 5
Confounders addressed	Results should be adjusted for as many confounders as possible ‡
Results' presentation	As a minimum, stratify data by age and sex. If possible, also by overweight and obesity

BMI – body mass index; WC – waist circumference; WHtR – waist to height ratio. † – All three variables should be determined. A child enters the referred category if at least one criterion is met. If a child could be classified as non obese overweighed or as obese, it should be considered obese. Overweight definition also includes obese children and adolescents. ‡ – A non-exhaustive list includes: age, sex, screen time, physical activity, socio-economical status , parental BMI, birth weight, birth height, breastfeeding, sleep quality, alcohol consumption, smoking, alcohol drinking during pregnancy, pregnancy smoking, prematurity status, snaking, irregular eating, parental educational level, regular breakfast and ethnicity.

Table 5 – Age-specific total sleep reference proposal

Age category (years)	Recommended sleep duration (h)†	Inadequate sleep duration categories (h)†		
		Low sleep	Mild short sleep	Severe short sleep
≤ 1	> 14	]13, 14]	]12, 13]	≤ 12
1.1 – 3	>12.5	]11.5, 12.5]	]10.5, 11.5]	≤ 10.5
3.1 – 6	>11	]10, 11]	]9, 10]	≤ 9
6.1 – 10	>10	]9, 10]	]8, 9]	≤ 8
10.1 – 16	> 9	]8, 9]	]7, 8]	≤ 7
> 16	> 8	]7, 8]	]6, 7]	≤ 6

† – Includes naps. Use sleep journal or actigraphy records of at least one normal activity (non-vacation) week.

Annexes

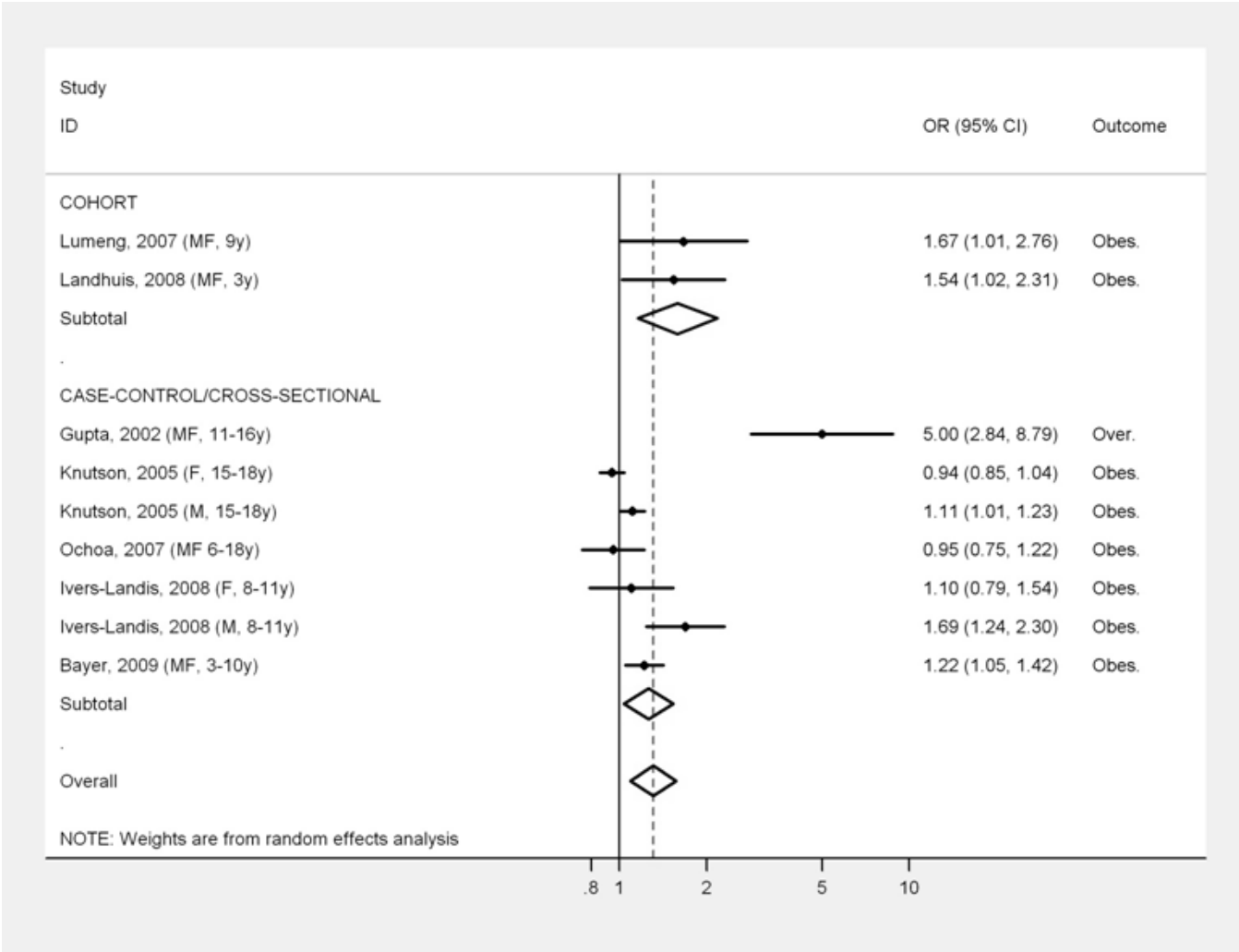

Fig. 2 – The association between short sleep duration and the risk for overweight or obesity as reported by papers considering sleep a continuous variable

OR – Odds ratio. Only the more adjusted estimates were used from each article and obesity-related risk estimates were preferred over overweight-related, if both were available for the same population.

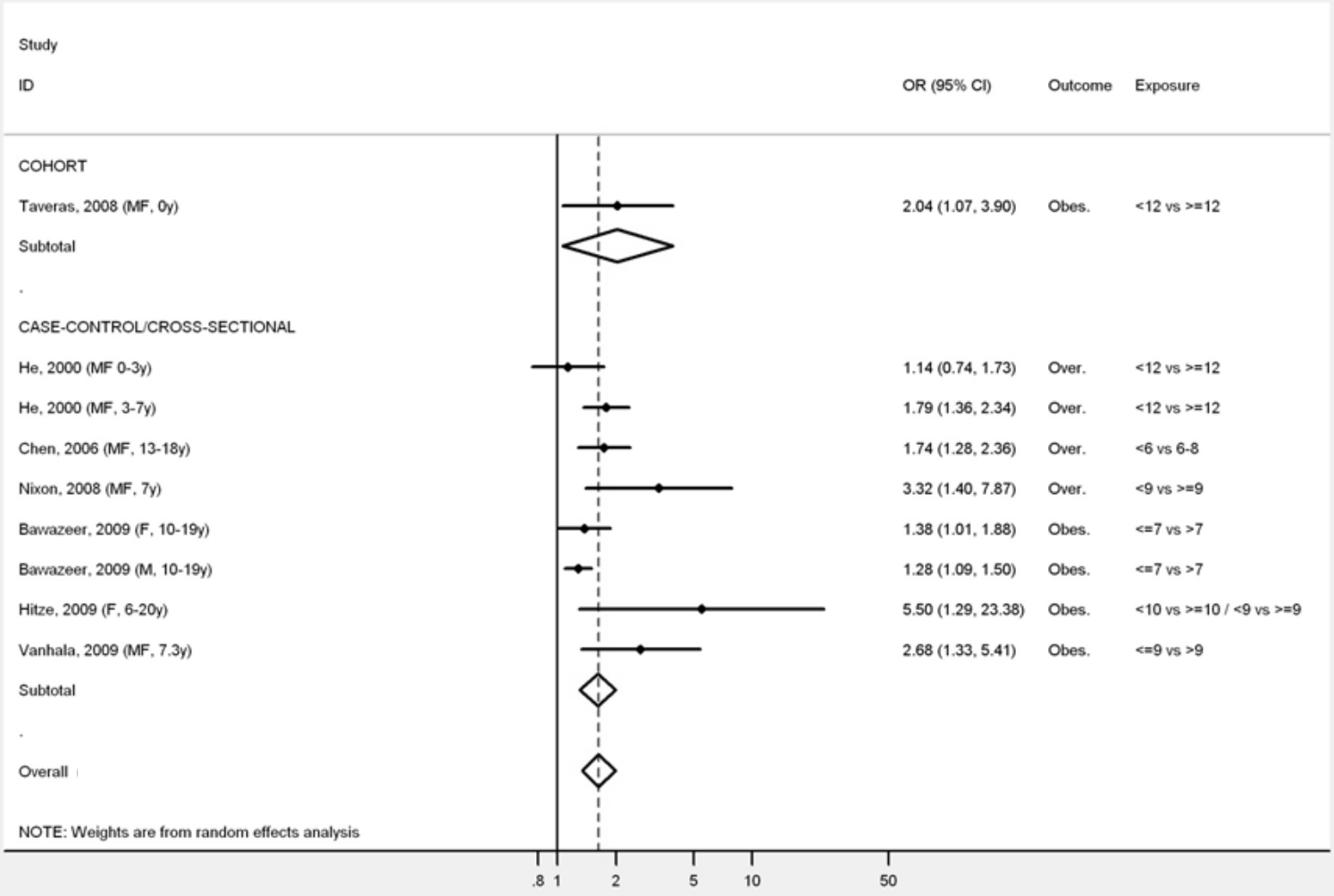

Fig. 3 – The association between short sleep duration and the risk for overweight or obesity as reported by papers considering only two sleep categories

OR – Odds ratio. Only the more adjusted estimates were used from each article and obesity-related risk estimates were preferred over overweight-related, if both were available for the same population.

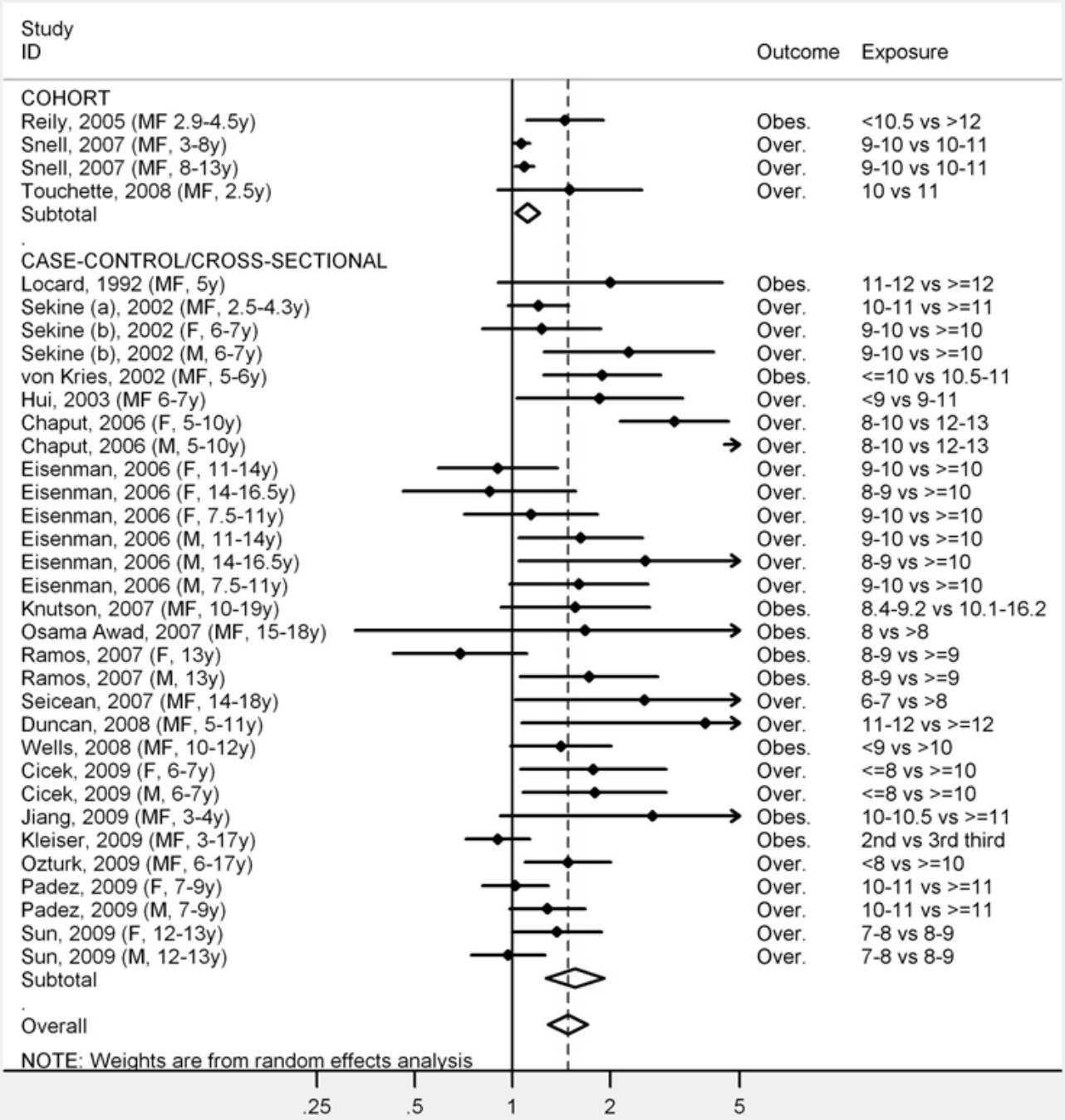

Fig. 4 – The association between short sleep duration and the risk for overweight or obesity as reported by papers considering multiple categories of sleep

OR – Odds ratio. Only the more adjusted estimates were used from each article and obesity-related risk estimates were preferred over overweight-related, if both were available for the same population. When different ORs and 95% CI were presented for the same sex or age group with the same degree of adjustment (different sleep duration exposures), only the estimate corresponding to the narrower CI was considered.

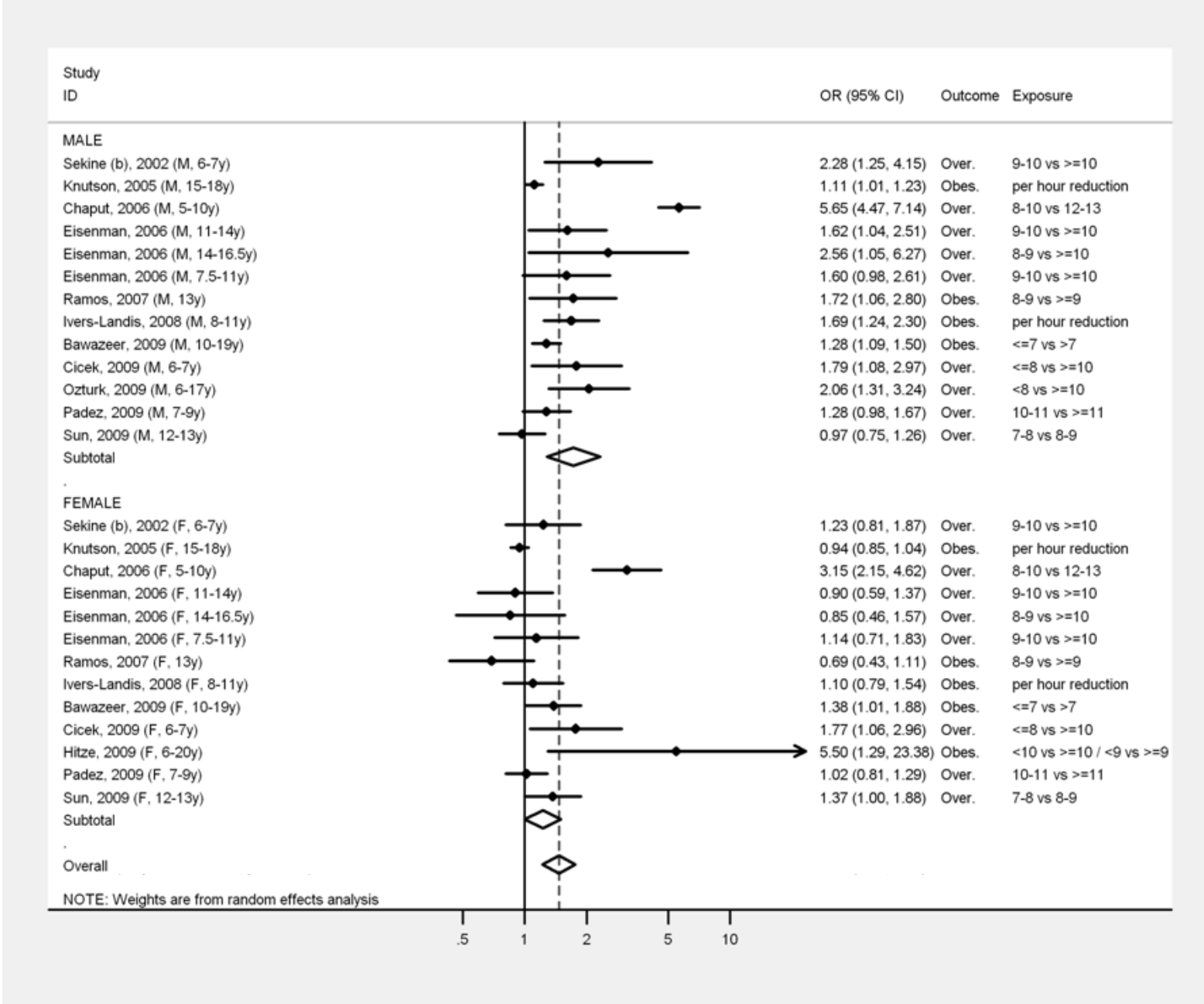

Fig. 5 – The association between short sleep duration and the risk for overweight or obesity stratified by sex, regardless of study design

OR – Odds ratio. Only the more adjusted estimates were used from each article and obesity-related risk estimates were preferred over overweight-related, if both were available for the same population. When different ORs and 95% CI were presented for the same sex or age group with the same degree of adjustment (different sleep duration exposures), only the estimate corresponding to the narrower CI was considered.