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MORTALITY

Smoking Habit and Mortality: A Meta-analysis

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Cigarette smoking leads to excess mortality risk. Although it is well known that the risk increases with the number of pack-years of smoking – that is, how much a person smokes, or ''habit'' – there is apparently no published studies that organize and synthesize the evidence on this topic. This paper provides a meta-analysis of the latest published findings relating to cigarette smoking habit and excess mortality. A combined estimate of the relative risk (RR) of death for smokers, stratified by habit (light, medium, or heavy smoking), compared with non-smokers is provided.

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INTRODUCTION

Cigarette smoking leads to excess mortality risk.[1–9] There are literally thousands of studies documenting this finding. Although it is well known[10–22] that the risk increases with the number of pack-years of smoking – that is, how much a person smokes, or ''habit'' – there do not appear to be any published studies that organize and synthesize the evidence on this topic.

Our purpose here is to present a meta-analysis on the latest published findings relating cigarette smoking habit and excess mortality. In addition, we report on original analyses of data from 3 large databases of persons aged 50 and over. Our goal was to compute a combined estimate of the relative risk (RR) of death for smokers, stratified by habit (light, medium, or heavy smoking), compared with non-smokers. We were further interested to see whether and how these RRs varied with age and sex.

METHODS

Using keywords ''smoking'' and ''mortality,'' we searched the National Center for Biotechnology Information (NCBI) website of journal articles (PubMed.gov). We then restricted attention (using the ''Limits'' feature) to those articles (1) about humans, (2) published in English-only journals, and (3) identified as meta-analyses, yielding 110 studies. Of these, none quantified the all-cause mortality risk due to smoking by pack-years or habit. It was this paucity of evidence that prompted the present investigation. [Note: Three meta-analyses[6–8] did review cause-specific mortality due to smoking (eg, death to cancer, or injury), but none looked at all-cause mortality.]

The starting point for our own meta-analysis was the recent study of Doll et al.[9] Regarding this, PubMed listed 901 studies as ''related articles.'' After restricting attention to those articles (1) of humans only research, (2) published in English-only journals since 1990, (3) dealing with cigarette smoking, rather than pipe or cigar, and (4) with results based on the current smoking habits, we identified 13 published articles.[10–22]

From these 13 we excluded 2, Ostbye and Taylor (2004)[10] and Murakami et al (2007),[11] because both presented life expectancies rather than increased risks of death such as a relative risk (RR). Additional considerations were that (1) the results of Ostbye and Taylor[10] were based on a model that controlled for a number of covariates, some of which might properly have been thought to be outcome variables due to smoking, and (2) RRs implicit in Murakami et al[11] were provided in an earlier study of the same data.[12]

This left 11 studies that addressed the effect of smoking habits on mortality in men, and 9 studies in women. All of these concerned the effect of current habit on subsequent survival; none dealt with the effect of the number of pack-years. Only one of the studies[12] excluded persons with pre-existing medical conditions. Some information about the studies we relied upon, and additional calculations we required, are given in Appendix A.

As can be seen in Appendix A, each study had its own definition of ''light,'' ''medium,'' or ''heavy'' smoking. ''Light'' was defined as less than 10 cigarettes/day in 5 studies, as less than 15 cigarettes per day in 5 studies and as less than 21 in 1 study. ''Heavy'' was defined mostly as 20+ or 25+ cigarettes/day. ''Medium'' was thus most often in the range of 10 to 25 cigarettes/day.

We also carried out original analyses of longitudinal mortality data from (1) the Cardiovascular Health Study (CHS), (2) the Health and Retirement Study (HRS), and (3) the Third National Health and Nutrition Examination Survey (NHANES III).[23–25] These data and the methods we used are described in Appendix A.

For each study (or data set) we recorded the relative risks (relative to never-smokers) for each smoking habit: light, medium, or heavy. Because these same studies often reported on the effect for former smokers, we included this as well.

Our goal was to compute a combined estimate of the RR for each smoking habit. Heuristically, one might think of this as a weighted average of the individual estimates given in the various studies, with the weights based on the ''confidence'' we place on each estimate. In practice one cannot simply average the RRs. Rather, one must first obtain the underlying parameter estimates, then average these, and then finally convert this back to the overall estimate of RR. Technical details are given in Appendix B.

An important consideration was the extent to which each study (a) excluded persons with pre-existing medical conditions, perhaps those due to smoking, and (b) controlled for various co-morbid factors, such as age, sex, race, education, weight, cholesterol, blood pressure, heart disease, and cancer. Studies that excluded persons with medical conditions due to smoking, or controlled for factors related to smoking (eg, blood pressure), would be expected to find lower RRs. Conversely, studies that did not account for sufficient confounding factors (such as age or weight) might find higher RRs. We return to this issue in the results and discussion.

RESULTS

Table 1 lists the articles and databases included in the final meta-analysis. Most of

Table 1. Summary of Studies and Results

Males

#	Study	Sample Size	Average Age	Light			Medium			Heavy			Former		
				RR	95% CI	Weight	RR	95% CI	Weight	RR	95% CI	Weight	RR	95% CI	Weight
1	Hummer 1998	21936	60	1.30	(1.04, 1.63)	0.03	1.96	(1.57, 2.45)	0.03	2.62	(2.1, 3.28)	0.03	0.98	(0.78, 1.23)	0.03
2	Prescott 1998	13423	48	1.90	(1.7, 2.2)	0.10	2.40	(2.1, 2.7)	0.08	2.60	(2.3, 3.0)	0.09	1.30	(1.06, 1.59)	0.04
3	Jacobs 1999	12763	50	1.30	(1.17, 1.43)	0.16	1.80	(1.65, 1.93)	0.20	1.94	(1.87, 2.27)	0.16	1.10	(0.78, 1.65)	0.01
4	Qiao 2000	1496	50	1.15	(0.93, 1.42)	0.04	1.76	(1.48, 2.09)	0.04	1.98	(1.65, 2.37)	0.05	1.09	(0.82, 1.44)	0.02
5	Lam 2001	7760	59	1.51	(1.23, 1.86)	0.04	2.01	(1.63, 2.47)	0.03	3.31	(2.69, 4.07)	0.04			0.00
6	Bronnum-Hansen 2004	8345	30	1.38	(1.25, 1.53)	0.16	1.85	(1.67, 2.05)	0.12	2.55	(2.08, 3.14)	0.04	1.19	(1.08, 1.31)	0.16
7	Doll 2004	24321	36	1.79	(1.62, 1.98)	0.16	2.17	(1.96, 2.40)	0.12	2.61	(2.36, 2.88)	0.15	1.31	(1.19, 1.45)	0.15
8	Hozawa 2004	18945	52	1.50	(1.22, 1.84)	0.04	1.71	(1.44, 2.03)	0.04	1.80	(1.51, 2.14)	0.05	1.38	(1.12, 1.70)	0.03
9	Ueshima 2004	3972	51	1.14	(0.91, 1.44)	0.03	1.30	(1.03, 1.71)	0.02	1.55	(1.17, 2.04)	0.02	1.17	(0.90, 1.52)	0.02
10	Vollset 2006	25034	43	2.24	(1.99, 2.53)	0.11	2.60	(2.35, 2.87)	0.13	3.04	(2.71, 3.40)	0.12	1.31	(1.18, 1.46)	0.13
11	Ekberg-Aronsson 2007	13888	46	1.43	(1.23, 1.67)	0.07	2.02	(1.83, 2.23)	0.13	2.31	(2.10, 2.54)	0.17	1.05	(0.95, 1.17)	0.14
12	CHS	2462	65+	1.24	(0.78, 1.96)	0.01	2.13	(1.65, 2.73)	0.02	2.84	(2.02, 3.99)	0.01	1.25	(1.09, 1.44)	0.08
13	HRS	11093	50+	1.55	(1.25, 1.93)	0.03	2.23	(1.82, 2.74)	0.03	2.25	(1.96, 2.58)	0.08	1.24	(1.12, 1.37)	0.15
14	NHANES III	1939	50+	1.43	(0.98, 2.09)	0.01	1.83	(1.37, 2.43)	0.02	2.77	(1.90, 4.04)	0.01	1.18	(0.97, 1.44)	0.04
Weighted average				1.47			2.02			2.38			1.21		

Females

#	Study	Sample Size	Average Age	Light			Medium			Heavy			Former		
				RR	95% CI	Weight	RR	95% CI	Weight	RR	95% CI	Weight	RR	95% CI	Weight
1	Hummer 1998	21936	60	1.47	(1.18, 1.84)	0.05	2.60	(2.08, 3.25)	0.05	3.74	(2.99, 4.68)	0.09	1.85	(1.48, 2.31)	0.04
2	Prescott 1998	17386	48	2.20	(2.0, 2.5)	0.22	2.70	(2.4, 3.1)	0.15	3.60	(2.9, 4.5)	0.10	1.20	(0.98, 1.47)	0.05
3	Al-dalaimy 2001	3542	62	1.43	(0.96, 2.14)	0.02	1.64	(1.24, 2.17)	0.03	2.19	(1.32, 3.65)	0.02	1.31	(1.11, 1.55)	0.07
4	Lam 2001	7864	59	1.47	(1.19, 1.81)	0.06	1.84	(1.49, 2.27)	0.05	2.63	(2.14, 3.24)	0.11			0.00
5	Bronnum-Hansen 2004	8345	30	1.36	(1.23, 1.50)	0.27	1.84	(1.66, 2.03)	0.24	2.50	(2.04, 3.05)	0.12	1.18	(1.07, 1.30)	0.22
6	Hozawa 2004	17107	51	1.47	(1.04, 2.08)	0.02	1.44	(1.06, 1.94)	0.03	1.35	(0.81, 2.26)	0.02	1.10	(0.56, 2.16)	0.00
7	Ueshima 2004	4957	50	1.31	(0.99, 1.74)	0.03	1.31	(0.99, 1.74)	0.03	1.32	(0.54, 3.22)	0.01	1.21	(0.76, 1.92)	0.01
8	Vollset 2006	24505	43	1.80	(1.59, 2.04)	0.17	2.03	(1.82, 2.26)	0.20	2.62	(2.20, 3.12)	0.15	1.25	(1.11, 1.42)	0.14
9	Ekberg-Aronsson 2007	8499	49	1.74	(1.38, 2.18)	0.05	2.44	(2.07, 2.87)	0.09	2.42	(2.00, 2.92)	0.13	1.26	(1.04, 1.52)	0.06
10	CHS	3323	65+	1.78	(1.23, 2.58)	0.02	1.75	(1.4, 2.19)	0.05	4.05	(2.61, 6.27)	0.02	1.20	(1.03, 1.4)	0.09
11	HRS	13447	50+	1.60	(1.28, 1.99)	0.06	1.90	(1.56, 2.33)	0.06	2.27	(1.95, 2.64)	0.20	1.20	(1.09, 1.31)	0.25
12	NHANES III	3259	50+	1.33	(0.90, 1.96)	0.02	1.57	(1.18, 2.08)	0.03	3.17	(2.10, 4.78)	0.03	1.16	(0.97, 1.37)	0.07
Weighted average				1.50			2.02			2.66			1.23		

the data came from the United States, although there were several each from Asia and Europe. The combined (meta-) estimates of the relative risks for light, medium, and heavy smoking in men were 1.47, 2.02, and 2.38, respectively. The values for women were quite similar, at 1.50, 2.02, and 2.66, respectively.

The values for former smokers were 1.21 for men and 1.23 for women. The results did not vary significantly if the last 3 results (CHS, HRS, and NHANES III) were excluded. A plot (not shown) of the RRs against age for the various studies listed in Table 1 did not reveal any trend, in either direction, for either sex.

The 6 studies that included 11+ cigarettes/day in the ''light'' group did not yield uniformly higher RRs than the ones with lower limits (1–10). Nor did the studies with a higher threshold for ''heavy'' yield uniformly higher RRs than those of the other studies. This suggests that the results are rather robust to the definitional choices.

The one study that excluded persons with pre-existing conditions (cardiovascular disease),[12] reported lower RRs than all of the other studies. Most of the studies reported RRs based on (Cox) models that controlled for age, sex, and various co-morbid factors (eg, weight, cholesterol, blood pressure). The few studies that did not control for the co-morbid factors – that is, control was made only for age and sex – reported relatively higher RRs.[9,13,14,17] We found the same to be true in our own analyses of the CHS, HRS, and NHANES databases: The models that included co-morbid factors yielded lower RRs than the ones without these factors.

Exclusion of the 5 studies footnoted in the preceding paragraph (ie, references 9, 12–14, and 17) did not appreciably alter the overall findings. For example, the RRs for medium smoking changed from 2.02 to 1.98 in males and from 2.02 to 1.92 in females.

In our analysis of the CHS and NHANES databases, we also determined the effect of smoking stratified by pack-years of smoking.

Table 2. Relative Risk for Smoking, Stratified by Pack-Years

	Pack-Years		
Database	Low	Medium	High
CHS	1.18	1.46	1.96
NHANES	1.24	1.57	1.80

We used the same models as described in Appendix A. The RRs for current smokers with low (0 to 10 pack-years), medium (10 to 30), and high (greater than 30) are shown in Table 2. In separate models that controlled only for age, sex, race, and smoking (not shown), the resulting RRs were only slightly higher (about 10%).

For general interest we also report the percentage of males aged 40 to 60 in the NHANES data with the various smoking habits: never (22%), light (15%), medium (14%), heavy (6%), and former (42%). For women the figures were 54%, 12%, 9%, 3%, and 22%, respectively. If the RRs for the male smoking groups (1.00, 1.47, 2.02, 2.38, and 1.21) are weighted by these percentages, the composite is 1.37. For females we obtain 1.25. This means, for example, that medium male smokers aged 40 to 60 have 2.02/1.37 =1.47 times the mortality risk of that in the overall group. Such adjustments may be useful when starting with general population or composite mortality data.

DISCUSSION

In the present paper we did not perform a meta-analysis of all smoking studies – that is, studies that did not account for smoking habit but rather relied upon a simple dichotomy: smoking yes/no. A rule of thumb is that the RR for smokers compared with non-smokers is roughly 2, and this comports with the RR for ''medium'' smoking noted above: 2.02.

Indeed, the RRs for smokers vs non-smokers implicit in the VBT 2001 is approximately 2 for persons aged 30–70 at time of underwriting (and for the first few years of the select period).[26] For example, males who smoke have a RR of 2.35 at starting age 60, 2.18 at starting age 70, and 1.85 at starting age 80. The corresponding values for females are 2.35, 1.88, and 1.46.

It is notable that, in the study and data reviewed here, the RRs did not appear to vary significantly by the average study population age or sex. In many conditions we find that females have a higher RR. If a condition confers a constant excess death rate (EDR) to both sexes, then females, who have a lower baseline mortality rate than males, will have a larger corresponding RR (though a lower total mortality risk). But, as can be seen in Table 1, this was not the case here (the rather modest difference in RRs for heavy smoking being the lone exception).

Further, in most chronic conditions, the RR decreases with age,[27,28] sometimes quite dramatically, and thus age is usually a key factor to be accounted for in any meta-analysis. Indeed, the RRs implicit in the VBT 2001 do show a decline with age. First, we see a slight downward trend in the VBT RRs noted above (2.35 to 2.18 to 1.85 in males, and 2.35 to 1.88 to 1.46 in females). Second, with increasing policy duration the imputed RR declines. For example, for males aged 60, the current RR is 2.35, decreasing to 1.97 by duration 10 years and 1.43 by duration 20 years. In nearly every other chronic condition (eg, heart disease, obesity, diabetes) the RR decreases both with initial age and duration. It remains to be determined why we did not observe a similar trend in the RRs reported here.

A related issue concerns the age at which study participants began smoking. Certainly a 60-year-old, pack-per-day, male smoker who began at age 15, say, has a higher risk of death than a pack-per-day smoker who began only at age 50. It is unclear whether among persons with identical pack-years of smoking, the one who started earlier has a higher risk. An implicit assumption in the analyses presented here is that the various populations studied were similar in their respective mixtures of ages of starting smoking. There does not appear to be detailed information on this topic. It is known, however, that most persons begin smoking as young adults. To this extent, therefore, the issue is likely not a major one in explaining the differences between the reported RRs.

The RRs shown here for former smokers may be thought of as averages over (1) those who quit many years in the past, (2) those who quit more recently, and who have an RR close to that of current smokers, and (3) those who quit neither long ago nor recently. It is known that smokers who quit in their youth (eg, 30's) have long-term survival prospects very similar to that of never smokers.[9] In contrast, persons with significant pack-years of smoking, despite quitting many years ago, nevertheless do still experience significant sequelae, such as atheroslcerosis, stroke, or cancer.

Some studies[16,22] reported RRs for former smokers according to (1) pack-years, (2) daily habit when they were smoking, or (3) how recently they had quit smoking. A proper meta-analysis of former smokers should stratify on at least one of these characteristics, much as we have done here for current smokers.

For some applications it might be helpful to have ratings that exclude persons with pre-existing conditions due to smoking; for others it may not. Similarly, for some applications it may be helpful to have ratings that control for many co-morbid factors, while for others it may not. The studies reviewed here were not uniform in their population acceptance criteria or in the number and type of risk factors that were controlled for in the analyses. The reader may thus prefer the relative risks of some selected studies over those presented in others.

It is common to rate smoking using a simple yes/no dichotomy. Yet as we have documented, heavy smokers have substantially higher mortality risks than average smokers, and light smokers have substantially lower risks. To the extent that reliable information on a proposed insured's smoking habits is available, it can now be used in underwriting.

Editorial note: The Editor of the *Journal of Insurance Medicine* served as a part-time paid medical consultant to the first author and disqualified himself from evaluating this manuscript. Evaluation was performed by 2 independent external peer reviewers.

APPENDIX A: NOTES ON USE OF THE STUDIES, LISTED BY FIRST AUTHOR AND CALENDAR YEAR.

Hummer 1998:[13] The total number of persons was 21,936. Approximately 3,000 were in our target age range 55–64 (which is why we reported age 60 in the Table). The following mortality rates were given for women (Table 1) and men (Table 2): never smokers, long term former, recent quitter, current light (<10 cigarettes/day), current heavy (25+ cigarettes/day), and overall. We assumed that the medium smoking rates were mid-way between those for light and heavy. We computed relative risks (RR) for smokers compared with never smokers. Confidence intervals (CI) and standard errors of the rates were not given in the study. It can be shown that the standard error of the parameter is approximately 0.11. We used this to construct the CI in the table.

Prescott 1998:[14] Sample sizes are from Table 1, as are the average ages. RRs and CIs were given in Tables 3 and 4. Light smoking was defined as 15 or less g/day, medium = 15–24 g/day, and heavy = 25+ g/day (1 g = 1 cigarette; 3 g = 1 cheroot; 5 g = 1 cigar). CIs for former smokers were derived under the assumption that the sample size was ¼ that of smokers, so the CI was twice as wide, giving a standard error of approximately 2 * 0.05 = 0.10. Separate RRs for former smokers based on habit were shown in Table 3, but were not used here.

Jacobs 1999:[15] RRs and CIs are given in Table 3. Light smoking was defined as 1–9 cigarettes/day, and medium as 10+. The RR for heavy smoking was not given in the study. But the study estimated the RR per pack as 1.7. For the present purposes we assumed that heavy smoking was, on average, 2 packs/day. For simplicity, we also assumed that the RR for heavy smoking was $(1.7)^2 = 2.89$ and that the CI was the square of the CI for medium smoking (it can be shown that this leads to a slight overestimation of the RR for heavy smoking, but that the confidence interval is of the correct width).

Qiao 2000:[16] Light smoking was 1–9/day, avearge 10–19, and heavy 20+. RRs and CIs are given in Table 3. We used the 35-year follow-up period, and for ex-smokers we reported those with medium habits (10–19/day).

Al-dalaimy 2001:[22] All participants were female and had type 2 diabetes. The total sample size was from Table 1 (1986 questionnaire only). Ages were computed using Table 2. Smoking habit was defined as light = 1–14, medium = 15–34, heavy = 35+. For the reader concerned about the inclusion of this unusual study, we note that (a) exclusion did not materially affect the results, and (b) the RRs from this study were rather similar to those of the other studies.

Lam 2001:[17] Smoking habits were defined as light = 1–14, medium = 15–24, and heavy = 25+. Sample sizes were for males age 35–69 (cases plus control) from Table 1. RRs were from Table 5. CIs were not given. We estimated these as follows. For the combined group of males smokers with results shown in Table 3, the standard error of the parameter estimate can be shown to be about 0.06. For the stratified groups, therefore, the sample sizes were about 1/3. Thus, the standard errors are about sqrt(3)*0.06 = 0.10 for males and 0.13 for females.

Bronnum-Hansen 2004:[18] Sample sizes were not given by sex. The total figure was thus divided in two. We based calculations on theirs for age 30, so ''30'' is shown at the age in our Table. Smoking habit was defined in the study as moderate 1–14 g/day (which we placed in our ''light'' group), and heavy 15+g/day (which we took to be ''medium''). RRs were not given in the study; instead, life expectancies were shown in Table 1. By trial and error we found the RR that yielded the desired difference in life expectancy by smoking habit. CIs were not given. For our ''heavy'' group we used the produce of the RRs for the light and medium groups. Because the sample sizes were similar to those in the Prescott study (above), we assumed that the standard error of the parameter estimate was similar as well.

Doll 2004:[9] Sample size was those born since 1900. The average age was at the average start of follow-up. Smoking habit was defined as light = 1–14, medium = 15–24, heavy = 25+. RRs were given in Table 3. CIs were not given. Again, because the sample sizes were similar to those in the Prescott study (above), we assumed that the standard error of the parameter estimate was similar as well.

Hozawa 2004:[19] Sample sizes were in Table 1. Ages were computed from the values in Table 1. Smoking habit was defined as medium = 1–19, heavy = 20+. RRs and CIs were given in Table 2.

Ueshima 2004:[12] Sample sizes were in Table 1. Ages were computed from the values in Table 1. Smoking habit was defined as light = 1–20, heavy = 21+. Values for ''medium'' were assumed to be the average of these. RRs and CIs were given in Table 3.

Vollset 2006:[20] Smoking habit defined as light = 1–9, medium = 10–19, heavy = 20+. RRs and CIs in Table 2.

Ekberg-Aronsson 2007:[21] Sample sizes in Table 2. Age computed from the values in Table 2. Smoking habit defined as light = 1–9, medium = 10–19, heavy = 20+ grams/day (1 g = 1 cigarette, 3 g = 1 cheroot, 5 g = 1 cigar). RRs and CIs in Table 4.

CHS:[23] Begun in 1988, the Cardiovascular Health Study (CHS) is a study of risk factors for development and progression of coronary heart disease and stroke in people aged 65 years and older. A total of 5,888 participants were recruited for this study. In addition to smoking history and status, the final multivariate Cox model adjusted for race, gender, age, weight, and various major medical conditions. The relative risk (RR) for smoking did not appear to vary significantly by age, gender, or other demographic variables. Smoking habit was defined as light = 1–9, medium = 10–20, heavy = 21+.

HRS:[24] Originally started in 1992, the University of Michigan Health and Retirement Study (HRS) is an ongoing survey of more than 22,000 Americans over the age of 50 every 2 years. In addition to smoking history and status, the final multivariate Cox model adjusted for race, gender, age, weight, and various major medical conditions. As above, the relative risk (RR) for smoking did not appear to vary significantly by age, gender, or other demographic variables. Smoking habit was defined as light = 1–9, medium = 10–19, heavy = 20+.

NHANES III:[25] The Third National Health and Nutrition Examination Survey (NHANES III) was conducted between 1988 to 1994 by the National Center for Health Statistics on a nationwide probability sample of approximately 33,994 persons aged 2 months and older. We restricted the data to persons age 50 and older who had a reliable smoking history and pulmonary test. In addition to smoking history and status, the final multivariate Cox model adjusted for race, gender, education, age, weight, and various major medical conditions. Again, the relative risk (RR) for smoking did not appear to vary significantly by age, gender, or other demographic variables. Smoking habit was defined as light = 1–9, medium = 10–20, heavy = 21+.

APPENDIX B: TECHNICAL DETAILS ON THE METHODS

1. For each study we were given (or computed) the relative risk (RR). Denote this as RR_i, i = 1, 2, …

2. Define the underlying parameter as β_i = ln(RRi), or $RR_i = \exp[\beta_i]$, where ''ln'' is the natural logarithm. Note: The values of β are given in statistical output, for example, from a Cox proportional hazard regression model, as are the confidence intervales (CI's) for β.
3. We recorded the 95% CI for each relative risk. If a CI was not available, we estimated one using reasonable assumptions, as indicated in the Appendix.
4. It can also be shown that if a 95% CI for the RR is given by (x,y), then the 95% confidence interval for β_i is $[\ln(x) - 2\sigma_i, \ln(y) + 2\sigma_I]$, where σ_i is the standard error of the parameter estimate.
5. Thus, given the interval (x,y) we can determine the comparable interval for β_i, and also find σ_i^2.
6. The weight to be given to the parameter from the i[th] study was $w_i = (1/\sigma_i^2)/\Sigma(1/\sigma_i^2)$, where $\Sigma(1/\sigma_i^2)$ is the sum of all the inverse variances, and the weights clearly sum to 1. That is, the weight is proportional to the inverse of the variances, as is standard. Hence, a small variance means that the particular parameter is given comparably more weight in the calculations, and conversely. Equivalently, a comparable narrow confidence interval is associated with more weight.
7. We then computed the meta-estimate (B) of the parameter by taking a weighted average of the individual parameter estimates, $B = \Sigma w_i \beta_i$. Finally, we computed the meta-estimate of the relative risk (RR) by taking the exponent of the meta-estimate of the parameter, RR = exp[B].

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