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Review Article

Second-hand tobacco smoke exposure in Israel: A systematic review and meta-analysis of prevalence data, 2012-2024

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ABSTRACT

Objectives: Exposure to second-hand tobacco smoke (SHS) remains a significant global public health concern. Although previous studies have estimated the prevalence of SHS exposure in Israel, a systematic synthesis has not been performed. This study aims to identify and describe the different studies performed in Israel to ascertain the prevalence of exposure to SHS.

Study design: Systematic review and meta-analysis.

Methods: A systematic literature review was conducted using Ovid Medline, Embase, and Web of Science, covering publications between 2012 and 2024. All studies reporting data on the prevalence of exposure to SHS in Israel were included. Data were extracted, summarised in tables, and differentiated by type of population (adults vs. children). A qualitative and quantitative synthesis of the results was performed. For the quantitative synthesis, a random effects model was used. Quality assessment was performed using a modified version of the Newcastle-Ottawa Scale.

Results: Eighteen studies met the inclusion criteria. The prevalence of exposure to SHS ranged from 20.5% to 94.9% among adults, and the respective range among children was 29.0% to 85.6%. Among adults, the pooled prevalence of SHS exposure was 56.0% (95% CI: 54.0% to 57.0%) by self-report and 51.0% (95% CI: 47.0% to 55.0%) by biomarker assessment. The corresponding estimates among children were 74.0% (95% CI: 73.0% to 75.0%) and 55.0% (95% CI: 50.0% to 60.0%). Heterogeneity was high in all analyses (I^2 >90%).

Conclusions: The prevalence of exposure to SHS in Israel varies significantly due to differences in population type, definition of exposure, and assessment methods.

1. Introduction

It is estimated that at least 500 million people are exposed to second-hand tobacco smoke (SHS) worldwide[1] and that around 1.3 million deaths per year are attributed to diseases related to such exposure.[2] Recently, a meta-analysis concluded that exposure to SHS increased the risk of lung cancer, ischemic heart disease, stroke, type 2 diabetes mellitus, otitis media, asthma, lower respiratory infections, breast cancer, and chronic obstructive pulmonary disease in the non-smoking population.[3,4] Infants and children are considered especially at risk of suffering from diseases derived from SHS exposure, including asthma, pneumonia, cardiac diseases, and sudden infant death syndrome.[5,6] Therefore, exposure to SHS is considered a global health problem, with no safe exposure threshold.[7]

Protecting populations from exposure to SHS is a key element in the fight against the tobacco epidemic. In Israel, progress began with the taxation of tobacco products in 1952.[8] The Restriction on Smoking in Public Places Act of 1983 banned smoking in enclosed public spaces such as buses, taxis, pharmacies, libraries, and hospitals. The Act implemented marketing and advertising restrictions on tobacco products, including a TV and radio advertising ban and a health warning label covering 30% of the tobacco package.[8,9] In 2007, smoking bans were extended to include bars and pubs, though enforcement remains limited.[8] By 2012, restrictions were broadened to include entrances to

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medical facilities, bus stops, train stations, centres of religious worship, and outdoor swimming pools.[8] That same year, taxes on tobacco products were significantly increased, accounting for 79% of the retail price.[8] A landmark act followed in 2018, introducing a near-total ban on advertising and implementing additional marketing restrictions, including an increase in warning label area from 30% to 65%.[9] However, full implementation has been hindered by the lack of a clear enforcement mandate and tobacco industry pressure.[9]

Monitoring the prevalence of smoking and SHS exposure could also play a vital role in tobacco control. In Israel, smoking prevalence remains high at 20.5% as of 2023, with higher rates among men (28.1%) than women (13.1%) and among Arab-Israelis (23.0%) than Jews (19.9%). Among Arab-Israeli men, the smoking prevalence reached 39.0%.[10] Several data sources are available to assess the prevalence of exposure to SHS in the Israeli population, including epidemiological studies.[11–15] However, no systematic synthesis has been conducted to summarise these findings comprehensively, a gap previously identified by Ein-Mor et al.[16] Conducting a systematic synthesis of existing evidence is essential for identifying vulnerable populations, understanding sources of heterogeneity, and evaluating the effectiveness of tobacco control measures at the population level.

Internationally, systematic reviews and meta-analyses of SHS exposure are well established and provide critical insights for public health policy. These studies have examined a wide range of populations, including children in household settings, pregnant women in low- and middle-income countries, and general populations. Their results have consistently identified substantial variability in exposure prevalence, ranging from 30% to over 75%, driven by demographic and socioeconomic factors (age, education, income), residential settings, and assessment methods.[17–20]

Therefore, the objective of this study was to ascertain the prevalence of exposure to SHS in Israel by type of population, assess their characteristics, and detail the current exposure situation.

2. Methods

2.1. Study design

A systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and registered in PROSPERO (ID: CRD42024504251).[21,22]

2.2. Literature search

A literature search was performed using the search databases Medline (Ovid), Embase, and Web of Science (WoS). The search strategy included the terms “second-hand smoke”, “SHS”, “passive smok*”, “tobacco smoke incursion”, “environmental tobacco smoke”, “ETS”, and “tobacco smoke pollution [Mesh]” (Appendix 1). The search was restricted to studies published between January 1st, 2012, and November 1st, 2024, due to legislation and taxation in 2012.

2.3. Inclusion and exclusion criteria

Studies estimating the prevalence of SHS exposure among the Israeli population, both general and specific (e.g., Arab-Israelis, Jews, newborns, adolescents, and pregnant women) were included, regardless of exposure setting or assessment method (questionnaires and/or biomarkers). We included all studies that met the following PECOS (Population, Exposure, Comparator, Outcome, Study design) question:[23] “Among the Israeli population, what is the prevalence of SHS exposure? Population: Israeli population of all ages, stratified by children (0-17 years) and adults (18+); Exposure: SHS in different settings; Comparator: Not applicable; Outcome: Self-reported or biomarker-assessed prevalence of SHS (%); Study design: Cross-sectional, cohort and case-control studies that provided data on the prevalence of SHS (%) in Israel”.

Studies were excluded if they exclusively assessed exposure to second-hand aerosol from e-cigarettes or Hookah. We also excluded conference abstracts, letters to the editor, opinion articles, preprints, reports, narrative reviews, simulation studies, and retracted publications. Studies published in languages other than English or Hebrew were excluded.

2.4. Study selection, data extraction, and analysis of results

Titles and abstracts of the records retrieved through the search were revised. Potential studies that met the inclusion/exclusion criteria were read in full text. The selection of studies was carried out independently by two researchers. Discrepancies were resolved by consensus.

Of the studies that met the eligibility criteria, the following data were extracted by two researchers independently in a standardised Excel sheet: study period; study design; sample size; study area (national studies include those using nationally representative samples or national health registries, whereas non-national studies encompass all other study types, including hospital-based, single-centre, or specific municipality studies); study representativeness (yes or no); survey name (if applicable); population characteristics (age, sex, race, ethnicity and tobacco use (smokers or non-smokers)); type of population (adults or children); exposure settings (home, work, or other settings); assessment of SHS (self-report, biomarkers or both) and definition of exposure; self-report method (if applicable); biomarker assessment method (if applicable); prevalence of smoking among participants (if applicable); and prevalence of exposure to SHS. The complete Excel spreadsheet with the extracted data is available in the supplementary material (Supplementary Data File 1).

A narrative description of the results was provided. Additionally, meta-analyses were conducted separately for each type of population (adults and children) and assessment method (self-report and biomarkers). Meta-analyses were stratified by assessment method (self-report vs biomarkers) as these methods capture different dimensions of exposure. Self-report reflects perceived exposure and recalled behaviours, while biomarkers detect total nicotine/cotinine exposure, including third-hand smoke and environmental contamination.[24,25]

To perform the meta-analyses, the prevalence of SHS exposure was extracted from the included studies. Due to the possible heterogeneity between studies, a random-effects model was chosen, based on the assumption that results could vary depending on factors such as age, ethnicity, or exposure setting. Proportions were pooled using a logit transformation. Prediction intervals were calculated to illustrate the expected range of true effects in similar future studies. Forest plots were generated. Heterogeneity across the studies was assessed using the I^2 index statistic.[26] Heterogeneity was considered substantial when I^2 was greater than 50%.[27] Publication bias was assessed using funnel plots and Egger's test regression intercepts.[28] Sensitivity analyses were performed by sequentially excluding each study to assess its influence on the obtained results for the self-reported studies. Data were statistically analysed using the R program and RStudio.[29]

2.5. Study quality assessment

To assess the study's risk of bias, we used a modified version of the Newcastle-Ottawa Scale (NOS), which assigns a summative score to each study[30] (Appendix 2). The score on this scale ranges from 0 to 8, with 0-3 indicating low quality, 4-5 indicating medium quality, and 6-8 indicating high quality.

3. Results

3.1. Literature search

The literature search yielded 277 records, of which 146 were

Table 1
Description of studies assessing prevalence of exposure to SHS in Israeli adults.

Study	Study period	Study design	Population under study (years)	Study area	Exposure settings	Representative of the study population	Assessment of exposure	Prevalence of smokers (%)	Newcastle-Ottawa score (0-8)
Berman et al., 2013[32]	Feb-Jun 2011	Cross-sectional	Adults aged 20-74	National	NA	Yes	Biomarkers (Urine cotinine)	Non-smokers	5
Peles et al., 2014[34]	Jun 2011-Jan 2012	Cross-sectional	Pregnant women	Non-national	Home (Spouse)	No	Self-report (self-administered questionnaires)	10.5%	3
Novack et al., 2015[36]	Jun 2012-Dec 2013	Prospective longitudinal	Pregnant Bedouin women	Non-national	Home (Spouse)	No	Self-report (Face-to-face interviews)	NS	3
Landau et al., 2015[35]	2010-2013	Cross-sectional	Pregnant Bedouin women	Non-national	Home (Spouse)	No	Self-report (Face-to-face interviews)	Non-smokers	3
Awawdi et al., 2016[37]	Jan 2008-Dec 2011	Case-control	Arab women aged 35-70 after acute coronary event and healthy controls	Non-national	Home (Parental) + Home (Spouse)	No	Self-report (Face-to-face interviews)	Non-smokers	6
Berman et al., 2018[12]	2015-2016	Cross-sectional	Adults aged 18-64	National	Home, work or another location	Yes	Self-report (Telephone interview) & Biomarkers (Urine cotinine)	Non-smokers	5
Regev-Avraham et al., 2018[38]	2008-2013	Case-control	Arab women aged 30-70 with breast cancer	Non-national	NS	No	Self-report (Face-to-face interviews)	Non-smokers	4
Ein-Mor et al., 2019[16]	Sep 2012-Mar 2016	Prospective longitudinal	Pregnant women	Non-national	Home (Spouse)	No	Self-report (Face-to-face interviews) & Biomarkers (Urine cotinine)	Non-smokers	4
Regev-Avraham et al., 2020[13]	NS	Case-control	Women aged 45-85	Non-national	Home (Spouse)	No	Self-report (Face-to-face interviews)	Non-smokers	4
Leiter et al., 2022[39]	2014	Case-control	Ultra-orthodox women and general population aged 18-74	National	NS	NS	Self-report (Anonymous self-administered questionnaires)	NS	5
Velosa et al., 2022[41]	NS	Nested case-control	Adults born 1964-1976	Non-national	Home (Parental)	No	Self-report (NS)	NS	3
Theitler et al., 2023[42]	Aug-Dec 2017	Cross-sectional	Hebrew-speaking adults aged ≥18	National	Home	Yes	Self-report (Mobile phone interviews)	23.5%	7

Abbreviations: **NA**: Not applicable; **NS**: Not specified; **SHS**: Second-hand smoke.

Table 2
Results of studies assessing prevalence of exposure to SHS in Israeli adults.

Study	No. of participants (Sample size)	No. of participants exposed to SHS (Prevalence %)	Assessment of SHS (self-report method/detection by biomarkers)	Definition of SHS exposure	Factors associated with exposure to SHS
Berman et al., 2013[32]	153	96 (**62.7**)	Measured by cotinine levels in urine samples and creatinine-adjusted urinary cotinine geometric means (GM)	> LOQ (1.0 μg/L)	Not mentioned
Peles et al., 2014[34]	210	78 (**37.1**)	NS	Spouse or partner current smoker	Husband/ partner smoking
Novack et al., 2015[36]	275	261 (**94.9**)	NS	Spouse or partner current smoker	Frequent male smoking
Landau et al., 2015[35]	773	687 (**88.9**)	Maternal (participant) & Paternal smoking during pregnancy	NS	Frequent male smoking
Awawdi et al., 2016[37]	146	106 (**72.6**)	Estimated by a questionnaire based on 9 questions assessing SHS as a dichotomous variable in childhood and in adulthood during the past 5 years (especially after marriage)	The extent of exposure to SHS at home, workplace, and place of study, defined by estimated average hourly exposure period during past year in these places	Husband/ partner smoking
Berman et al., 2018[12]	133	Self-report: 87 (**65.4**); Urine cotinine: 84 (**63.2**)	Measured by cotinine levels in urine samples and creatinine-adjusted urinary cotinine geometric means (GM); limit of quantification (LOQ) ≥1 μg/l	> LOQ	Gender and ethnicity
Regev-Avraham et al., 2018[38]	411	297 (**72.3**)	Having one or more adults at the household in each life period who regularly smoked	NS	Frequent male smoking
Ein-Mor et al., 2019[16]	265	Self-report: 142 (**53.5**); Urine cotinine: 100 (**37.7**)	Maternal self-report of SHS	NS	Husband/ partner smoking
Regev-Avraham et al., 2020[13]	211	97 (**46.0**)	Having one or more adults in the household who regularly smokes	NS	Frequent male smoking
Leiter et al., 2022[39]	1993	932 (**46.8**)	NS	General: Self-reported exposure from 2014 to 2016 MABAT 18–64 and the 2014–2015 MABAT Gold	Level of religiosity
Velosa et al., 2022[41]	625	128 (**20.5**)	Mother's smoking status at the time of birth from the JPS's post-partum interview subset	NS	Not mentioned
Theitler et al., 2023[42]	284	144 (**50.7**)	"Have you ever seen, felt, or smelled tobacco smoke which penetrates your home as a result of someone smoking in a nearby apartment, in the hallway, or in the area of your building? "	Self-reported exposure to TSI	Residency in multi-unit housing

Abbreviations: **JPS**: Jerusalem Perinatal Study; **GM**: Geometric means; **LOQ**: Limit of quantification; **NS**: Not specified; **SHS**: Second-hand smoke; **TSI**: Tobacco smoke incursion.

duplicates, and two could not be retrieved. Overall, 129 records were assessed; after selection by title and abstract, 68 were read in full text. Of these, 18 studies were eligible for inclusion in the systematic review (Supplementary Fig. 1).[11–16,31–42] These studies were published between 2012 and 2023. For those studies that reported their study period, this ranged from 2003 to 2018.

Among the 18 studies included, eleven assessed the prevalence of exposure to SHS solely among adults,[12,13,32,34–39,41,42] six assessed the prevalence solely among children,[11,14,15,31,33,40] and one assessed the prevalence including both.[16]

3.2. Characteristics of studies assessing the prevalence of exposure to SHS among adults

Twelve studies assessed the prevalence of exposure to SHS in Israel among adults (Table 1). Five were cross-sectional studies,[12,32,34,35,42] five were case-control studies (including one nested),[13,37–39,41] and the remaining two were prospective longitudinal studies.[16,36] The number of participants in these studies varied between 133 and 1993. Of the 12 studies, four were carried out at the national level.[12,32,39,42]

Eight studies were conducted among women.[13,16,34–39] Of these, four referred exclusively to pregnant women, one to Arab women after an acute coronary event, and one to Arab women diagnosed with breast cancer. Six studies referred exclusively to current non-smokers.[12,13,16,32,37,38]

Eight studies assessed exposure to SHS at home based on smoking by a spouse or parents.[13,16,34–37,41,42] Another study assessed exposure at home, at work, and in unspecified other locations,[12] and the exposure settings in another two studies were not stated.[38,39]

Nine studies used self-report data to assess prevalence,[13,34–39,41,42] and two others used both self-report data and biomarker measurement (urine cotinine) for assessment.[12,16] Another study used biomarker measurement solely.[32] Regarding self-report data, six studies used face-to-face interviews,[13,16,35–38] two used telephone interviews,[12,42] and two used self-reported questionnaires.[34,39] Another study did not specify the source of self-reported data.[41]

3.3. Prevalence of exposure to SHS among adults

The prevalence of exposure to SHS varied widely between studies, from 20.5% to 94.9% (Table 2). In studies conducted on women, the prevalence ranged from 37.1% to 94.9%; the range was identical among pregnant women. Among Arab-Israelis, the prevalence ranged from 72.3% to 94.9%.[35–38] Prevalence differed when measured by self-report and biomarker levels (urine cotinine) in the same study, as higher exposure was obtained from self-report data.[12,16] In studies carried out in the non-smoking population (n = 6), the prevalence of exposure varied between 35.5% and 72.6%.[12,13,16,32,37,38]

National studies (n = 4) showed a prevalence range from 46.8% to 65.4%, while non-national studies (n = 8) ranged from 20.5% to 94.9%, with the highest prevalence in Arab-Israeli populations. Regarding the exposure setting, studies that assessed exposure at home showed a prevalence rangingr from 20.5% to 94.9%.

Combining data from 11 studies[12,13,16,34–39,41,42] assessing exposure

Table 3
Description of studies assessing prevalence of exposure to SHS in Israeli children.

Study	Study period	Study design	Population under study (years)	Study area	Exposure settings	Representative of the study population	Assessment of exposure	Prevalence of smokers (%)	Newcastle-Ottawa score (0-8)
Ben Noach et al., 2012[31]	2003-2004	Cross-sectional	Adolescents aged 11-19	National	Home, school, entertainment, or another location	Yes	Self-report (Telephone interviews)	14.0%	6
Shani et al., 2013[33]	2008	Cross-sectional	Children and adolescents with Asthma aged 6-18	Non-national	Home (Parental)	No	Self-report (Face-to-face interviews)	NS	4
Berman et al., 2018[11]	2015-2016	Cross-sectional	Children aged 4-11	National	Home (Parental)	No	Self-report (Telephone interviews) & Biomarkers (Urine cotinine)	Non-smokers	4
Ein-Mor et al., 2019[16]	Sep 2012-Mar 2016	Prospective longitudinal	Newborn infants	Non-national	Home (Parental)	No	Self-report (Face-to-face interviews with mothers) & Biomarkers (Urine cotinine)	Non-smokers	4
Laventer-Roberts et al., 2021[14]	Mar-Dec 2014	Case-control	Children aged 3-12	Non-national	NS	No	Self-report (NS)	NS	3
Samuel et al., 2022[40]	2008-2018	Case-control	Children and adolescents with acute mastoiditis aged 0-18	National	Home (Parental)	No	Self-report (Face-to-face interviews)	NS	2
Rosen et al., 2023[15]	2016-2018	Prospective longitudinal	Children aged 0-8	National	NA	No	Biomarkers (Hair nicotine)	NS	4

Abbreviations: **NA**: Not applicable; **NS**: Not specified; **SHS**: Second-hand smoke.

by self-report yielded a pooled prevalence of 56.0% (95% CI: 54.0% to 57.0%) (Supplementary Fig. 2), while combining data from three studies[12,16,32] assessing exposure by biomarkers yielded a pooled prevalence of 51.0% (95% CI: 47.0% to 55.0%) (Supplementary Fig. 3). Heterogeneity was substantial in both analyses (I^2 = 94.2% and I^2 = 98.7%, respectively). Publication bias was evident in the self-report analysis (P = 0.009) (Supplementary Fig. 4), but not in the biomarker analysis (P = 0.148) (Supplementary Fig. 5).

The sensitivity analysis revealed that removing most of the studies resulted in a change in the pooled prevalence of more than two percentage points (Supplementary Table 1).

3.4. Quality of studies

Four studies obtained poor quality scores,[34–36,41] six obtained medium quality;[12,13,16,32,38,39] and two obtained high quality.[37,42] Poor quality studies (NOS≤3, n = 4) showed higher prevalence estimates (37.1% to 94.9%) compared to high quality studies (NOS≥6, n = 2) with prevalence of 50.7% to 72.6%, suggesting potential measurement bias in lower-quality designs.

3.5. Characteristics of studies assessing the prevalence of exposure to SHS among children

Seven studies evaluated the prevalence of exposure to SHS among

Table 4
Results of studies assessing prevalence of exposure to SHS in Israeli children.

Study	No. of participants (Sample size)	No. of participants exposed to SHS (Prevalence %)	Assessment of SHS (self-report method/detection by biomarkers)	Definition of SHS exposure	Factors associated with exposure to SHS
Ben Noach et al., 2012[31]	6274	5370 (**85.6**)	Do people usually smoke around you (yes/no) in the following areas? (At home, at school, in places of entertainment, in other places)."	Total exposure = smoking in any of those places	Ethnicity
Shani et al., 2013[33]	1217	489 (**40.2**)	% of at least one parent smoking	NS	Ethnicity
Berman et al., 2018[11]	103	Self-report: 40 (**38.8**); Urine cotinine: 65 (**63.1**)	Measured by cotinine levels in urine samples and creatinine-adjusted urinary cotinine geometric means (GM)	> LOQ (1.0 μg/L)	Not mentioned
Ein-Mor et al., 2019[16]	93	Self-report: 47 (**50.5**); Urine cotinine: 27 (**29.0**)	Measured by cotinine levels in urine samples and creatinine-adjusted urinary cotinine geometric means (GM)	> LOQ (1.0 μg/L)	Paternal smoking
Laventer-Roberts et al., 2021[14]	145	90 (**62.1**)	Measured by cotinine and nicotine levels in urine samples	> LOQ (0.1 ng mlˆ-1)	Not mentioned
Samuel et al., 2022[40]	1189	622 (**52.3**)	Parental/Household smoking status	NS	Not mentioned
Rosen et al., 2023[15]	158	103 (**65.2**)	Child hair nicotine (reflecting long-term exposure)	Tobacco smoke exposure-includes both second- and third-hand exposure	Paternal education

Abbreviations: **GM**: Geometric means; **LOQ**: Limit of quantification; **NS**: Not specified; **SHS**: Second-hand smoke.

children in Israel (Table 3). Three were cross-sectional studies,[11,31,33] two were case-control studies,[14,40] and two were prospective longitudinal studies.[15,16] The number of participants varied between 103 and 6274. Of the seven studies, four were carried out at the national level.[11,15,31,40]

One of the studies referred exclusively to newborn infants (and included their mothers),[16] and another exclusively to adolescents (aged 11-19 years).[31] Three studies referred exclusively to young children (aged <12 years),[11,14,15] and the two remaining studies included children of various ages (aged 0 to 18 years).[33,40] Smoking prevalence among participants was reported in one study;[31] two other studies included non-smokers exclusively.[11,16]

Four studies measured SHS exposure at home, based on smoking by parents.[11,16,33,40] One study assessed exposure at home, at school, in entertainment venues, and unspecified other locations,[31] and the exposure settings in another study were not stated.[14]

Four studies used self-report to assess prevalence,[14,31,33,40] and two other studies assessed prevalence using both self-report and biomarker assessment.[11,16] Another study solely used biomarker assessment (nicotine in hair).[15] Regarding self-report data, three studies used face-to-face interviews,[16,33,40] and two used telephone interviews.[11,31] Another study did not specify the source of self-reported data.[14]

3.6. Prevalence of exposure to SHS among children

The prevalence of exposure to SHS varied widely between studies, from 29.0% to 85.6% (Table 4). Among young children (aged >12 years), the prevalence ranged from 29.0% to 65.2%.

National studies (n = 4) showed the prevalence ranging from 38.8% to 85.6%, while non-national studies (n = 3) ranged from 29.0% to 65.2%. Regarding the exposure setting, adolescents exposed in multiple settings (home, school, entertainment venues) showed the highest prevalence (85.6%), while newborns and young children with home-only exposure ranged from 29.0% to 65.2%.

Combining data from six studies[11,14,16,31,33,40] assessing exposure by self-report yielded a pooled prevalence of 74.0% (95% CI: 73.0% to 75.0%) (Supplementary Fig. 6), while combining data from three studies[11,15,16] assessing exposure by biomarkers yielded a pooled prevalence of 55.0% (95% CI: 50.0% to 56.6%) (Supplementary Fig. 7). Heterogeneity was substantial in both analyses (I^2 = 99.6% and I^2 = 93.8%, respectively). Publication bias was evident only in the biomarker analysis (P = 0.241 and P < 0.0001, respectively) (Supplementary Figs. 8–9).

The sensitivity analysis revealed that removing most studies resulted in pooled prevalence changes of less than five percentage points (Supplementary Table 2).

3.7. Quality of studies

Two studies obtained poor quality scores,[14,40] four studies obtained medium quality scores,[11,15,16,33] and one study obtained a high quality score.[31] Quality scores did not show a clear pattern with prevalence estimates in children, though the highest prevalence (85.6%) came from the sole high-quality study measuring multiple exposure settings.

4. Discussion

This systematic review and meta-analysis provide an updated assessment of SHS exposure in Israel. The prevalence ranged from 20.5% to 94.9% among adults and 29.0% to 85.6% among children. In the self-report meta-analysis among adults, the pooled prevalence was 56.0% (95% CI: 54.0% to 57.0%), while the pooled prevalence for the biomarker meta-analysis was 51.0% (95% CI: 47.0% to 55.0%). Among children, these results were 74.0% (95% CI: 73.0% to 75.0%) and 55.0% (95% CI: 50.0% to 60.0%), respectively. Heterogeneity was high in all analyses. Hence, it is difficult to draw conclusions based on the results of the meta-analyses.

According to the latest International Tobacco Control (ITC) Israel survey, 73.1% of the Israeli adult population, including 68.9% of non-smokers, were exposed to SHS at least a few times a month, 61.7% were exposed at least once a week, and 34.5% were exposed daily.[43,44] While our results align with previous reports, significant variability exists between studies. The main factors possibly explaining prevalence variation include population characteristics, exposure definitions, assessment methods, and study quality scores.

Studies conducted among adult populations have observed the highest prevalence of SHS exposure in Arab-Israeli women. This could be explained by the fact that the prevalence of exposure to SHS in these studies was assessed based on the husbands' smoking behaviour, and the prevalence of tobacco use among Arab-Israeli men is very high. According to the most recent data, the prevalence of tobacco use was 39% among Arab-Israeli men compared to 19.1% among Jewish men. Beyond smoking prevalence, socio-cultural factors could also contribute to higher SHS exposure among Arab-Israeli women. Traditional gender roles in Arab-Israeli society may limit women's ability to enforce smoke-free homes,[45] while extended multigenerational household structures increase the number of potential smokers per residence.[38] Historical reports documented smoking rates of 55% to 74% among Bedouin men,[46] establishing patterns of high household exposure.

On the other hand, all studies conducted among pregnant women, except those involving pregnant Arab-Israeli women, reported a lower prevalence of exposure to SHS. This result is likely due to greater awareness of the effects of SHS on both foetal and maternal health. However, the study reporting the lowest estimated prevalence (20.5%)[41] may have a different explanation related to its design. As it was a case–control study that assessed the mother's smoking status retrospectively at the time of birth, recall bias may have occurred, potentially leading to an underestimation of actual exposure.

Variability in exposure prevalence has also been observed in relation to results for the child population. One study, which included children aged 6 to 19 years, estimated that 85.6% were exposed to SHS. This result differs greatly from those observed in the other included studies, where prevalence ranged from 40% to 65%. This difference may be because this study assessed exposure in multiple settings, while the other studies that provide self-reported data assess exposure exclusively at home. In addition, the lower prevalence observed in studies assessing exposure at home may be related to the common practice of smoking on porches and balconies as a strategy to avoid indoor exposure. However, although these prevalences are lower, they are still high (above 40%), which may be due to tobacco smoke infiltration (TSI), as smoke can easily seep through windows, doors, and ventilation systems when people smoke on balconies. It is estimated that nearly 45% of the Israeli population is affected by TSI.

TSI is a significant problem in multi-unit buildings because smoke can spread between dwellings.[42] Furthermore, the 9-m minimum outdoor distance required to avoid exposure to smoke from a single cigarette[47] is rarely met in Israeli multi-unit buildings, particularly among lower socioeconomic populations who live in smaller dwellings and have higher smoking and exposure prevalence.[11]

Some studies have used biomarkers to determine if there are differences in exposure between children whose parents smoke inside versus outside the home. One study conducted in Israel found that nicotine concentrations in the hair of children whose parents smoked outside were similar to those of children whose parents smoked inside.[15] Similarly, a study in California found that, although nicotine levels in the air and on surfaces differed between homes with direct and indirect exposure, the nicotine levels on the fingers of mothers who smoked outside were virtually identical to those who smoked inside (0.63 and 0.65 μg per cleaning, respectively).[25] Similar results were obtained when analysing cotinine concentrations. A Turkish study found no statistically significant differences in urinary cotinine levels between children whose parents smoked inside versus outside the home (p = 0.286).[48]

Differences in exposure prevalence observed between studies may also be explained by variability in the assessment method. Of the studies included in this review, 16 relied on self-reported information to determine the percentage of the population exposed to SHS. This information was collected using different methods, including face-to-face and telephone interviews, as well as self-administered questionnaires. Methods such as face-to-face or telephone interviews can lead to social desirability bias, as respondents may alter their answers to appear more socially acceptable. This bias is particularly relevant in studies assessing exposure among minors because smoking parents may report lower levels of exposure as a defensive measure of self-justification.[49]

On the other hand, 6 out of 18 included studies measured exposure to SHS using biomarkers, mainly by determining cotinine levels in urine (four of these studies assessed exposure using both self-report and biomarkers). Several of the included studies used this measurement as a validation method to compare the concordance between self-reported data and objective assessments. In most studies, biomarker-based prevalence exceeded self-reported exposure. However, Ein-Mor et al. (2019) found lower biomarker prevalence (37.7% above LOQ) than self-reported home exposure (53.5%) among pregnant women. This discrepancy likely reflects methodological factors: using a lower cutoff (LOD = 0.5 μg/L) increased prevalence to 63.8%; timing mismatch occurred between urine collection and questionnaire administration; and this highly educated cohort may have practised intermittent avoidance, which urinary cotinine (reflecting only 2-3 days) would not detect.[16]

Finally, the quality of the studies is another aspect to consider in the variability observed in exposure prevalence in both adult and child studies. Notably, the three studies reporting the highest adult SHS exposure (88.9% to 94.9%) received poor quality scores (NOS = 3),[35,36] suggesting methodological quality and potential measurement bias may influence prevalence estimates. Studies conducted among children in Israel did not follow a similar pattern.

Our study has some limitations. There are differences between studies regarding the definition of exposure to SHS and its assessment, making it difficult to compare. Additionally, regarding biomarkers, the limits of quantification (LOQ), upon which exposure to SHS can be determined, varied across studies (0.1-1.0 μg/L for urinary cotinine) and laboratories, affecting comparability. The levels of the limit of detection, upon which exposure to SHS can be determined, have changed over time and vary from laboratory to laboratory. In addition, different populations were assessed in the studies that were included. Some included Arab-Israeli women or pregnant women only, and some reported the prevalence of exposure among non-smokers, while others included smokers as well. Those differences contributed to the high heterogeneity observed in the results. We conducted meta-analyses stratified by type of population and assessment method, but the heterogeneity was substantial. Therefore, the results obtained in the meta-analyses should be interpreted with caution. Finally, the estimated exposure to SHS included cases in case-control studies; hence, the data may be biased. Exposure to Hookah, a highly prevalent phenomenon with passive smoke risks, was not addressed.[50]

Our study also has several strengths. To our knowledge, this is the first systematic review and meta-analysis of the prevalence of exposure to SHS in Israel. We included all studies reporting the prevalence of exposure to SHS in Israel published from 2012 to 2024. Studies were included regardless of the population under study.

5. Conclusions

The prevalence of exposure to SHS in Israel varies widely across studies. Methodological differences in study design, exposure settings, and assessment methods contribute to this variability. Despite this variability, most studies report SHS exposure prevalence above 50% in adults and children, underscoring a major public health concern. Therefore, it is necessary to standardise data collection methods and exposure definitions to improve comparability and strengthen evidence for tobacco control efforts.

Ethical statement

This study utilized publicly available, de-identified data and did not involve human participants, an intervention, or personally identifiable information. Therefore, institutional review board (IRB) approval was not required. The authors have complied with the Principles of Ethical Practice in Public Health.

Author contributions

YA, JRB, LVL, LJR and MPR contributed to the conception and design; YA and JRB were responsible for data extraction; YA, JRB and MPR were responsible for data analysis; YA, JRB, LVL, LJR, GG, CCP, AT and MPR contributed to the interpretation of the results; YA, JRB and MPR drafted the paper; YA, JRB, LVL, LJR, GG, CCP, AT and MPR contributed to revising the paper critically for intellectual content; YA, JRB, LVL, LJR, GG, CCP, AT and MPR agreed to be accountable for all aspects of the work.

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Declaration of competing interest

The authors have no relevant financial or non-financial interests to disclose.

List of abbreviations

GM	Geometric Means
ITC	International Tobacco Control
JPS	Jerusalem Perinatal Study
LOQ	Limit of Quantification
NA	Not Applicable
NS	Not specified
PECOS	Population, Exposure, Comparator, Outcome, Study design
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
SHS	Second-hand Smoke
TSI	Tobacco Smoke Infiltration
WoS	Web of Science

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2026.106218.

Data availability

The data used in this study is available in supplementary files.

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