



What is the impact of Smoking on female fertility ? A Systematic Review

¹ Sharly Ayu Puspita, ² Dini Gustiarini

^{1,2} State Intelligence Agency of the Republic of Indonesia, Special Region of Jakarta, Indonesia

^{1,2} Faculty of Medicine, Indonesian Christian University, Special Region of Jakarta, Indonesia

Corresponding Author: sharlyayupuspita@gmail.com

Article History :

Received date : 2025/03/18

Revised date : 2025/04/09

Accepted date : 2025/05/23

Published date : 2025/07/13



Copyright: © 2024 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (BY NC) license (<https://creativecommons.org/licenses/by-nc/4.0/>).

E-ISSN :

ISSN 3048-1368



P-ISSN

ISSN 3048-1376



ABSTRACT

Introduction: Smoking is a significant public health concern with well-documented adverse effects on reproductive health. The toxins in cigarette smoke disrupt hormonal balances and physiological processes essential for conception and pregnancy. This systematic review aims to comprehensively assess the impact of tobacco use on female fertility, covering both natural conception and outcomes of assisted reproductive technologies (ART).

Methods: This study adhered to the PRISMA 2020 guidelines. A systematic search was conducted across PubMed, Semantic Scholar, Springer, and Google Scholar using keywords related to female fertility, smoking, and reproductive outcomes. After screening 2,346 records and assessing 949 reports for eligibility, 22 studies were included in the final analysis.

Results: The evidence shows that smoking significantly impairs

natural fertility by increasing the time to pregnancy and raising the risk of an infertility diagnosis (OR 1.85) and ectopic pregnancy (OR 2.02). In ART, smokers experience significantly lower live birth rates (OR 0.52), reduced clinical pregnancy rates (OR 0.59), fewer retrieved oocytes, and a substantially higher miscarriage rate (OR 2.48) compared to non-smokers. Mechanistically, smoking is consistently associated with reduced Anti-Müllerian Hormone (AMH) levels, indicating diminished ovarian reserve. A clear dose-response relationship was identified, with heavier smoking linked to more severe outcomes.

Discussion: The findings confirm that tobacco use is a potent reproductive toxin that compromises nearly every stage of the reproductive process, from oocyte quality to embryo implantation and development. The damage is not easily bypassed, even with advanced medical interventions. While the harm is evident, data on the reversibility of these effects after smoking cessation remains inconclusive, highlighting a critical knowledge gap.

Conclusion: The evidence is overwhelming: smoking has a profoundly negative and multifaceted impact on female fertility. It is a significant barrier to achieving a successful pregnancy, regardless of the conception method. Therefore, smoking cessation counseling must be a primary and non-negotiable component of preconception and fertility care to preserve reproductive potential and improve pregnancy outcomes.

Keywords: Female Fertility, Smoking, Systematic Review, Assisted Reproductive Technology (ART), Ovarian Reserve, Time to Pregnancy

INTRODUCTION

Smoking is a significant public health concern with well-documented adverse effects on various aspects of human health. Its impact on reproductive health, particularly female fertility, has garnered increasing attention in recent years. The toxins in cigarette smoke can disrupt the delicate hormonal balance and physiological processes necessary for successful conception and pregnancy. Given the global prevalence of smoking among women of reproductive age, understanding the full extent of its impact on fertility is crucial for public health messaging, clinical counseling, and the development of effective interventions. The intricate relationship between tobacco use and female reproductive outcomes has been the subject of numerous studies, ranging from observational analyses to comprehensive systematic reviews, all aiming to elucidate the mechanisms and quantify the risks involved (Alanazi and Alrawaili, 2023; Budani et al., 2018).

The scope of the problem extends across different pathways to conception. For those trying to conceive naturally, smoking has been associated with a longer time to pregnancy and a higher incidence of infertility. In the context of assisted reproductive technologies (ART), such as in vitro fertilization (IVF), the success rates for smokers are often diminished. This suggests that smoking interferes with fundamental aspects of female reproductive biology, from oocyte (egg) quality to the ability of an embryo to implant and develop successfully. The consistency of these findings across various study designs and populations underscores the pervasive and detrimental effect of smoking on female fertility (Zhang et al., 2018; Klonoff-Cohen, 2017).

Despite the general consensus that smoking is harmful to female fertility, there is a need for a systematic and comprehensive understanding of the multifaceted nature of this impact. The existing body of research is vast and varied, encompassing different study designs, populations, and outcome measures. This variability can make it challenging for clinicians, researchers, and the public to synthesize the evidence and draw clear conclusions. For instance, some studies focus on natural conception, while others examine outcomes in the context of ART. The definition and

measurement of smoking exposure also vary, from self-reported use to biochemical markers, which can affect the comparability of findings (Nik Hazlina et al., 2022; Siegel et al., 2022).

A systematic review is therefore essential to aggregate and critically appraise the available evidence. Such a review can help to identify consistent patterns, resolve conflicting findings, and highlight areas where further research is needed. By systematically gathering and analyzing data on a wide range of fertility outcomes—from biological markers like Anti-Müllerian Hormone (AMH) to clinical endpoints like live birth rates—a clearer picture of the impact of smoking can emerge. This systematic approach is critical for informing evidence-based clinical guidelines and public health policies aimed at mitigating the reproductive harms of smoking (Oostingh et al., 2019; Radhika et al., 2021).

The primary objective of this systematic review is to comprehensively assess the impact of smoking on female fertility. This involves a thorough examination of the existing literature to synthesize evidence on how tobacco use affects various aspects of female reproductive health. The review aims to provide a clear and detailed overview of the current state of knowledge, drawing from a wide range of studies to ensure a robust and well-supported conclusion.

This review will specifically aim to:

- Evaluate the association between smoking and natural fertility outcomes, including time to pregnancy, fecundability, and the risk of infertility and ectopic pregnancy.
- Analyze the impact of smoking on the success of assisted reproductive technologies (ART), including outcomes such as oocyte yield, fertilization rates, clinical pregnancy rates, and live birth rates.
- Investigate the dose-response relationship between the intensity of smoking and the severity of its effects on fertility.
- Examine the potential for the reversibility of smoking-induced fertility impairment following smoking cessation.

- Explore the biological mechanisms through which smoking is believed to exert its negative effects on the female reproductive system.

The findings of this systematic review hold significant implications for several stakeholders. For healthcare providers, this review offers a consolidated evidence base to support patient counseling on the importance of smoking cessation for women planning a pregnancy. By understanding the specific risks and the magnitude of the effects, clinicians can offer more targeted and persuasive advice. For women of reproductive age, this research provides crucial information about how their lifestyle choices can affect their ability to conceive and have a healthy pregnancy, empowering them to make informed decisions about their health (Purewal et al., 2017; Terzioğlu et al., 2016).

From a public health perspective, the synthesis of evidence from this review can inform the development and implementation of anti-smoking campaigns and policies specifically targeting women of reproductive age. Highlighting the impact of smoking on fertility can be a powerful motivator for behavior change. Furthermore, for the research community, this review will identify gaps in the current literature and suggest directions for future studies, such as the long-term effects of smoking cessation on fertility and the impact of newer tobacco products like e-cigarettes (Galanti et al., 2023; Sharon-Weiner et al., 2023).

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate the impact of Smoking on female fertility.

Screening

We screened in papers that met these criteria:

- **Population - Age:** Does the study include female participants of reproductive age (15-45 years)?
- **Outcomes:** Does the study measure fertility outcomes (time to conception, pregnancy rates, live birth rates) and/or biological markers of fertility?
- **Exposure Assessment:** Does the study include both documented smokers (current or former) AND non-smoking comparison groups?
- **Study Design:** Is the study design either an observational study (cohort, case-control, cross-sectional) OR a systematic review/meta-analysis?
- **Smoking Documentation:** Does the study clearly document smoking exposure assessment methods and status?
- **Study Focus:** Does the study include female fertility outcomes (not exclusively male fertility)?
- **Pre-existing Conditions:** Are the participants free from known fertility disorders unrelated to smoking?
- **Study Type:** Is the study something other than a case report, case series, or animal study?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column below from each paper. We gave the model the extraction instructions shown below for each column.

- **Study Design:**

Identify the specific type of study design used. Look in the methods section for clear

description. Possible designs include:

- Prospective cohort
- Cross-sectional
- Case-control
- Observational study
- Interventional study

If multiple design elements are present, list all. If design is unclear, note "design not clearly specified". Specific guidance:

- Look for phrases like "prospective study", "longitudinal study", "retrospective analysis"
- Check methodology section carefully
- If multiple potential interpretations exist, choose the most specific description

- **Participant Characteristics:**

Extract detailed participant information:

- Total sample size
- Age range/mean age of female participants
- Reproductive status (fertile/infertile)
- Smoking status categories (current smokers, former smokers, never smokers)
- Specific tobacco use details (cigarettes/e-cigarettes/smokeless tobacco)

Guidance:

- Report exact numbers where possible
- If ranges are provided, include both minimum and maximum
- If multiple subgroups exist, extract information for each
- Note any exclusion criteria that might impact participant selection
- **Smoking Exposure Measurement:**

Identify how smoking was measured/quantified:

- Self-reported questionnaire

- Biochemical markers (e.g., cotinine levels)
- Number of cigarettes/day
- Duration of smoking
- Type of tobacco product

Specific instructions:

- Extract precise measurement method
- Note units of measurement
- If multiple measurement approaches used, list all
- If measurement method is vague, note "smoking exposure not precisely defined"

- **Fertility Outcome Measures:**

Extract specific fertility-related outcomes studied:

- Time to pregnancy
- Oocyte quantity/quality
- Fertilization rates
- Anti-Müllerian hormone levels
- Reproductive hormone levels
- Menstrual disorders
- Infertility diagnosis

Guidance:

- Include exact numerical results where available
- Note statistical significance
- Extract both primary and secondary outcome measures
- If multiple outcomes measured, list comprehensively

- **Risk of Bias Assessment:**

Evaluate study's methodological quality:

- Selection bias
- Performance bias
- Detection bias
- Attrition bias
- Reporting bias
- Potential conflicts of interest

Specific instructions:

- Use standard quality assessment tools if mentioned (e.g., SIGN checklist, AXIS tool)
- Note any explicit limitations mentioned by authors
- Extract information about randomization, blinding, loss to follow-up
- If no explicit bias assessment performed, note "no formal bias assessment reported"

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Female Fertility	Reproductive-age women	Women in their reproductive years	Women of childbearing age
Intervention (I)	Smoking	Tobacco Use	Cigarette Smoke	Tobacco Smoke
Comparison (C)	Non-Smokers	Never Smokers	Non-smoking comparison groups	Non-smoking population
Outcome (O)	Fertility Outcomes	Live Birth Rate	Ovarian Reserve	Time to Pregnancy

The Boolean MeSH keywords inputted on databases for this research are: (*"Female Fertility" OR "Reproductive-age women" OR "Women in their reproductive years" OR "Women of childbearing age"*) AND (*"Smoking" OR "Tobacco Use" OR "Cigarette Smoke" OR "Tobacco Smoke"*) AND (*"Non-Smokers" OR "Never Smokers" OR "Non-smoking comparison" OR "Non-smoking population"*) AND (*"Fertility Outcomes" OR "Live Birth Rate" OR "Ovarian Reserve" OR "Time to Pregnancy"*)

Data retrieval

Abstracts and titles were screened to assess their eligibility, and only studies meeting the inclusion criteria were selected for further analysis. Literature that fulfilled all predefined criteria and directly related to the topic was included. Studies that did not meet these criteria were excluded. Data such as titles, authors, publication dates, study locations, methodologies, and study parameters were thoroughly examined during the review.

Quality Assessment and Data Synthesis

Each author independently assessed the titles and abstracts of the selected studies to identify those for further exploration. Articles that met the inclusion criteria underwent further evaluation. Final decisions on inclusion were based on the findings from this review process.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Female Fertility" OR "Reproductive-age women" OR "Women in their reproductive years" OR "Women of childbearing age") AND ("Smoking" OR "Tobacco Use" OR "Cigarette Smoke" OR "Tobacco Smoke") AND ("Non-Smokers" OR "Never Smokers" OR "Non-smoking comparison" OR "Non-smoking population") AND ("Fertility Outcomes" OR "Live Birth Rate" OR "Ovarian Reserve" OR "Time to Pregnancy")	12
Semantic Scholar	("Female Fertility" OR "Reproductive-age women" OR "Women in their reproductive years" OR "Women of childbearing age") AND ("Smoking" OR "Tobacco Use" OR "Cigarette Smoke" OR "Tobacco Smoke") AND ("Non-Smokers" OR "Never Smokers" OR "Non-smoking comparison" OR "Non-smoking population") AND ("Fertility Outcomes" OR "Live Birth Rate" OR "Ovarian Reserve" OR "Time to Pregnancy")	97
Springer	("Female Fertility" OR "Reproductive-age women" OR "Women in their reproductive years" OR "Women of childbearing age") AND ("Smoking" OR "Tobacco Use" OR "Cigarette Smoke" OR "Tobacco Smoke") AND ("Non-Smokers" OR "Never Smokers" OR "Non-smoking comparison" OR "Non-smoking population") AND ("Fertility Outcomes" OR "Live Birth Rate" OR "Ovarian Reserve" OR "Time to Pregnancy")	86
Google Scholar	("Female Fertility" OR "Reproductive-age women" OR "Women in their reproductive years" OR "Women of childbearing age") AND ("Smoking" OR "Tobacco Use" OR "Cigarette Smoke" OR "Tobacco Smoke") AND ("Non-Smokers" OR "Never Smokers" OR "Non-smoking comparison" OR "Non-smoking population") AND ("Fertility Outcomes" OR "Live Birth Rate" OR "Ovarian Reserve" OR "Time to Pregnancy")	2,870

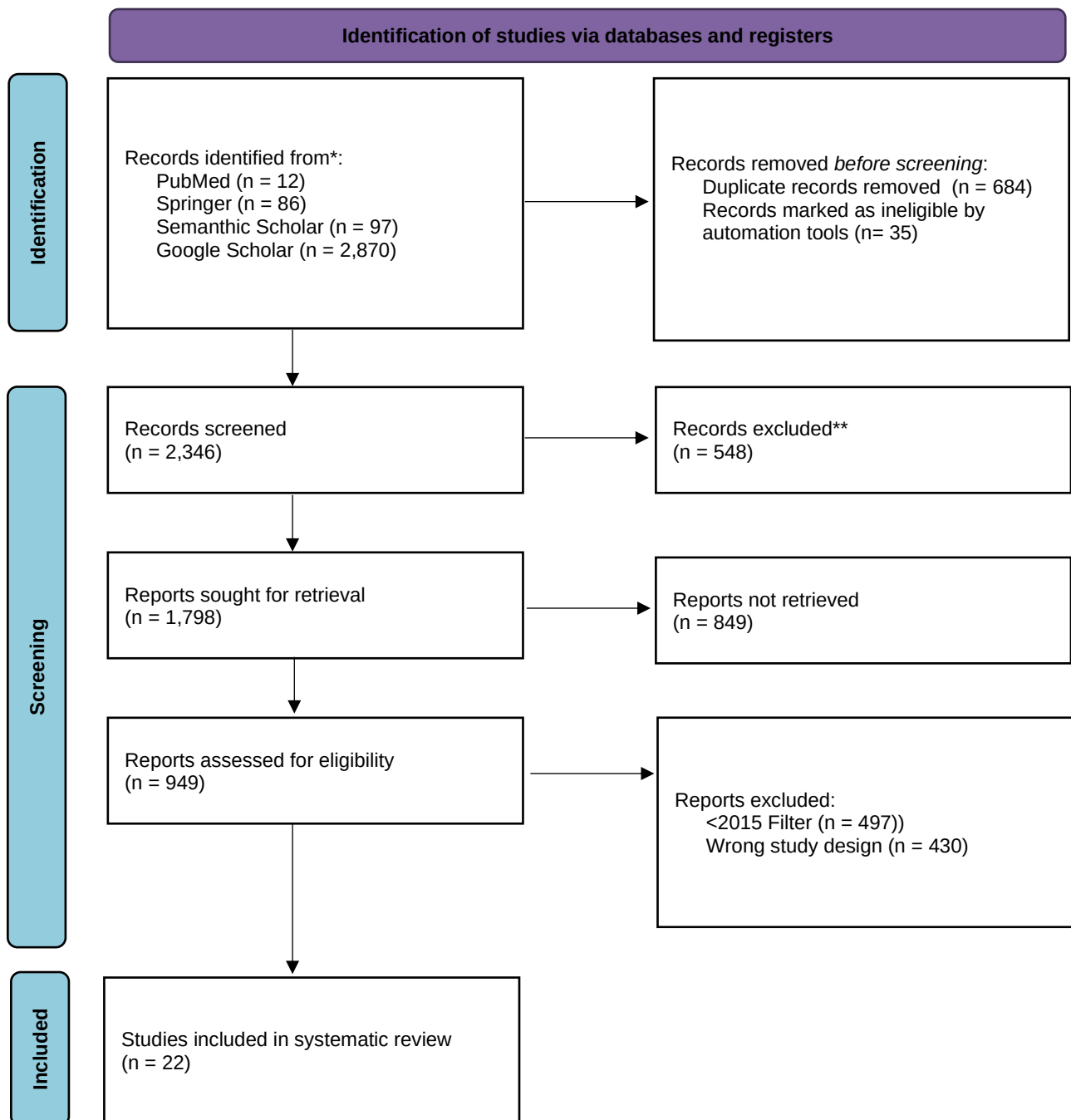


Figure 1. Article search flowchart

JBI Critical Appraisal									
Study	Bias related to temporal precedence Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Bias related to selection and allocation Was there a control group?	Bias related to confounding factors Were participants included in any comparisons similar?	Bias related to administration of intervention/exposure Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Bias related to participant retention Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Statistical conclusion validity Was appropriate statistical analysis used?
Neog, 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Abdoli et al., "Adverse Quality of Life Style and Risk of Infertility"	✓	✓	✓	✗	✓	✗	✓	✓	✓

Esfandiari et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Nik Hazlina et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Siegel et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Oostingh et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Radhika et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Menon et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
Purewal et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Ng et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Terzioglu et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Radhika et al., "Smokeless Tobacco Use and Reproductive Outcomes", 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓

Abdoli et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Klonoff-Cohen, 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Rogne et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sharon-Weiner et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Alanazi and Alrawaii, 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Zhang et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Budani et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Galanti et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Werner et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Agudo et al., "Does Tobacco Affect Follicular and Embryo Health?"	✓	✓	✓	✗	✓	✗	✓	✓	✓

RESULTS

Characteristics of Included Studies

Study	Study Design	Population Characteristics	Smoking Definition	Primary Outcomes
Neog, 2020	Systematic review	31 articles, global	No mention found	Oocyte quality, hormone levels, menstrual disorders, infertility
Abdoli et al., "Adverse Quality of Life Style and Risk of Infertility"	Systematic review	60 studies, various	No mention found	Reproductive/infertility parameters
Esfandiari et al., 2019	Retrospective	935 ART cycles, mean female age 34.4, infertile couples	No mention found	Semen parameters, oocyte yield, fertilization, embryo development, pregnancy

Study	Study Design	Population Characteristics	Smoking Definition	Primary Outcomes
				outcomes
Nik Hazlina et al., 2022	Systematic review/met a-analysis	124,556 women, community and health institution settings	No mention found	Infertility prevalence, risk factors, psychological impact
Siegel et al., 2022	Systematic review	33 articles, various populations, focus on air pollution/Second hand Smoke (SHS)	No mention found	Time to pregnancy (TTP), fecundability
Oostingh et al., 2019	Systematic review	49 studies, periconceptional women	No mention found	Fecundity, TTP, miscarriage
Radhika et al., 2021	Systematic review	501 (cohort), 192 (cross-sectional), reproductive-age women	Biochemical (urinary cotinine)	TTP, menstrual disorders, infertility diagnosis

Study	Study Design	Population Characteristics	Smoking Definition	Primary Outcomes
Menon et al., 2015	Systematic review	No mention found	No mention found	Pregnancy likelihood, preterm birth, low birth weight
Purewal et al., 2017	Systematic review/met a-analysis	60,370 ART patients	Self-report, some biochemical	Live birth, pregnancy
Ng et al., 2022	Systematic review/met a-analysis	16 studies, women of reproductive age, Recurrent Pregnancy Loss (RPL)	No mention found	RPL, further miscarriage
Terzioglu et al., 2016	Case-control	217 couples, ART patients	Self-report, cotinine in Follicular Fluid (FF) / Seminal Plasma (SP) Biochemical (cotinine)	Clinical pregnancy

Study	Study Design	Population Characteristics	Smoking Definition	Primary Outcomes
Radhika et al., "Smokeless Tobacco Use and Reproductive Outcomes", 2022	Systematic review	3 studies, 501/192 participants	Biochemical (cotinine)	Infertility, menstrual disorders
Abdoli et al., 2022	Systematic review	66 studies, couples (fertile/infertile)	No mention found	TTP, oocyte quality, hormone levels, infertility diagnosis
Klonoff-Cohen, 2017	Systematic review	No mention found	Biochemical (FF cotinine), self-report	Oocyte/embryo quality, pregnancy, miscarriage, live birth
Rogne et al., 2022	Mendelian randomization	331,289 (3556 cases, 327,733 controls), European	No mention found (genetic instrument for smoking)	Ectopic pregnancy risk

Study	Study Design	Population Characteristics	Smoking Definition	Primary Outcomes
		ancestry	initiation)	
Sharon-Weiner et al., 2023	Prospective cohort	801 women (18-40), breast cancer, 65% never smokers, 35% current/former	Self-report, pack-years	AMH levels
Alanazi and Alrawaii, 2023	Systematic review	10,092 (5673 females), adults	Self-report, number/day, duration	TTP, ovarian reserve, In Vitro Fertilization (IVF) outcomes, Sex Hormone-Binding Globulin (SHBG), infertility
Zhang et al., 2018	Meta-analysis (observational)	15,087 women (5009 smokers, 10,078 non-smokers), Assisted Reproductive Technology (ART) patients	No mention found	Live birth rate, clinical pregnancy rate, oocyte yield, fertilization rate, miscarriage

Study	Study Design	Population Characteristics	Smoking Definition	Primary Outcomes
Budani et al., 2018	Meta-analysis (observational)	No mention found	No mention found	Live birth rate, clinical pregnancy rate, miscarriage
Galanti et al., 2023	Prospective observational longitudinal	410 infertile women (mean age ~37-38), Intracytoplasmic Sperm Injection (ICSI) cycles, 203 smokers (cigarettes, e-cigarettes, Heated Tobacco Products (HnB)), 207 non-smokers/former smokers	Self-report, 10 cigarettes/day or >10 e-cigarette/HnB/day, duration in years	Oocyte yield/quality, fertilization, Anti-Müllerian Hormone (AMH), gonadotropin dose
Werner et al., 2024	Systematic review	Adult women, 65 studies (66% cross-sectional)	No mention found	AMH levels
Agudo et	Observatio	216 oocyte	Number of	Embryo

Study	Study Design	Population Characteristics	Smoking Definition	Primary Outcomes
al., "Does Tobacco Affect Follicular and Embryo Health?"	nal	donors, grouped by smoking (none, 1-10, >10 cigarettes/day)	cigarettes/day	implantation, embryokinetics, apoptosis/necrosis

Study design:

- 11 studies were systematic reviews (with or without meta-analysis).
- 2 studies were meta-analyses of observational studies.
- 3 studies were described as systematic review/meta-analysis.
- 1 study was a prospective observational longitudinal study.
- 1 was a prospective cohort.
- 1 was an observational study.
- 1 was retrospective.
- 1 was case-control.
- 1 was a Mendelian randomization study.

Smoking definition:

- 12 studies did not provide a precise definition of smoking exposure.
- 6 studies used self-report to define smoking status.
- 5 studies used biochemical measures (cotinine in urine or follicular fluid).
- 4 studies reported quantitative measures (number of cigarettes/day, pack-years, or duration).
- 1 study used a genetic instrument for smoking initiation.

Primary outcomes:

- 9 studies assessed live birth rate or other pregnancy outcomes (including clinical pregnancy, miscarriage, preterm birth, low birth weight, pregnancy likelihood).
- 8 studies assessed oocyte or embryo parameters (yield, quality, fertilization, embryo development, embryokinetics, apoptosis/necrosis, IVF outcomes).
- 6 studies assessed ovarian reserve or hormone levels (AMH, SHBG, other hormones).
- 7 studies assessed infertility diagnosis, prevalence, or risk factors.
- 5 studies assessed time to pregnancy (TTP), fecundability, or fecundity.
- 3 studies assessed menstrual disorders.
- 1 study assessed ectopic pregnancy risk.
- 1 study assessed psychological impact.

Additional context:

- The predominance of systematic reviews and meta-analyses among included studies may increase the risk of overlapping data and should be considered when interpreting findings.
- More than half of the studies did not provide a precise definition of smoking exposure, which may affect comparability.

Effects

Natural Fertility Outcomes

Study	Outcome Measure	Effect Size	Statistical Significance	Population Size
Nik Hazlina et al., 2022	Infertility risk (smokers vs. non-smokers)	Odds Ratio (OR) 1.85 (95% Confidence Interval (CI)	Significant	124,556

Study	Outcome Measure	Effect Size	Statistical Significance	Population Size
		1.08-3.14)		
Siegel et al., 2022	Time to pregnancy (TTP)/fecundability (Secondhand Smoke (SHS), air pollution)	Reduced fecundability	Not always significant	33 studies
Oostingh et al., 2019	Fecundity, TTP	Inverse association with smoking	Significant	49 studies
Radhika et al., 2021	TTP (Smokeless Tobacco (SLT) users vs. smokers)	Fecundability Odds Ratio (FOR) 2.86 (95% CI 1.47-5.57)	Significant	501/192
Ng et al., 2022	Recurrent Pregnancy Loss (RPL) (smokers vs. non-smokers)	OR 1.62 (95% CI 0.90-2.93)	Not significant	16 studies
Rogne et al., 2022	Ectopic pregnancy risk (smoking initiation)	OR 2.02 (95% CI 1.22-3.36)	Significant	331,289
Alanazi and	TTP (>12 months,	54% more	Significant	10,092

Study	Outcome Measure	Effect Size	Statistical Significance	Population Size
Alrawaili, 2023	smokers)	likely		
Neog, 2020	Oocyte quality, hormone levels, menstrual disorders	Decline with smoking	No quantification found	31 articles
Abdoli et al., 2022	TTP, oocyte quality, hormone levels	Negative association	Not always significant	66 studies
Abdoli et al., "Adverse Quality of Life Style and Risk of Infertility"	Reproductive indices	Negative association	No quantification found	60 studies

Summary of findings from these 10 studies:

- Outcome measures:
 - 5 studies assessed time to pregnancy (TTP), fecundability, or fecundity.
 - 1 study assessed infertility risk.
 - 1 study assessed recurrent pregnancy loss (RPL).
 - 1 study assessed ectopic pregnancy risk.
 - 2 studies assessed oocyte quality, hormone levels, or menstrual disorders.
 - 1 study assessed general reproductive indices. (Some studies assessed more than one

outcome.)

- Effect size direction:
 - 3 studies reported increased risk of adverse reproductive outcomes (odds ratio >1 or similar).
 - 4 studies reported reduced fecundability or increased TTP among smokers or tobacco users.
 - 3 studies reported a negative association or decline in reproductive parameters with smoking or tobacco exposure.
 - No studies reported a positive association between smoking/tobacco and improved reproductive outcomes in the included studies or available abstracts/full texts.
- Statistical significance:
 - 5 studies found statistically significant associations between smoking/tobacco exposure and adverse reproductive outcomes.
 - 1 study found a non-significant association.
 - 2 studies reported that associations were "not always significant."
 - 2 studies did not provide quantification of statistical significance.

Assisted Reproduction Outcomes

Study	ART Parameter	Impact in Smokers	Comparative Analysis	Clinical Significance
Zhang et al., 2018	Live birth rate	OR 0.52 (0.37-0.74)	Lower in smokers	Significant
Zhang et al., 2018	Clinical pregnancy rate	OR 0.59 (0.51-0.68)	Lower in smokers	Significant
Zhang et al., 2018	Oocytes retrieved	Mean Difference (MD) -0.87 (-1.39 to -0.25)	Fewer in smokers	Significant
Zhang et al., 2018	Fertilization rate	MD -4.80 (-8.49 to -2.02)	Lower in smokers	Significant
Zhang et al., 2018	Miscarriage rate	OR 2.48 (1.79-3.43)	Higher in smokers	Significant
Budani et al., 2018	Live birth rate	OR 0.59 (0.44-0.79)	Lower in smokers	Significant
Budani et al., 2018	Clinical pregnancy rate	OR 0.53 (0.41-0.68)	Lower in smokers	Significant

Study	ART Parameter	Impact in Smokers	Comparative Analysis	Clinical Significance
Budani et al., 2018	Miscarriage rate	OR 2.22 (1.10-4.48)	Higher in smokers	Significant
Galanti et al., 2023	Oocytes retrieved	5.21±0.9 (smokers) vs. 6.55±3.5 (non-smokers)	Lower in smokers	p<0.001
Galanti et al., 2023	Fertilization rate	68.12±2.21 (smokers) vs. 72.16±3.05 (non-smokers)	Lower in smokers	p=0.03
Galanti et al., 2023	AMH	Lower in smokers	Lower in smokers	p<0.05
Agudo et al.	Implantation rate	54-56% (smokers) vs. 65% (non-smokers)	Lower in smokers	p=0.07 (trend)
Esfandiari	Oocytes retrieved	Lower in	p=0.02	

Study	ART Parameter	Impact in Smokers	Comparative Analysis	Clinical Significance
et al., 2019		former smokers		
Esfandiari et al., 2019	Abnormal fertilization	Higher in current smokers	p=0.04	
Esfandiari et al., 2019	Ectopic/Spontaneous Abortion (SAB)	Higher in current smokers	p=0.04	
Purewal et al., 2017	Live birth/pregnancy	OR 1.457 (non-smokers vs. smokers)	Higher in non-smokers	Significant
Terzioglu et al., 2016	Clinical pregnancy	No significant difference	Not significant	217 couples
Klonoff-Cohen, 2017	Oocyte/embryo quality, pregnancy, miscarriage, live birth	Negative impact of smoking	Consistent with other reviews	Significant
Alanazi	IVF outcomes	Lower	Lower in	Significant

Study	ART Parameter	Impact in Smokers	Comparative Analysis	Clinical Significance
and Alrawaili, 2023		fecundity, fewer pregnancies per cycle (OR 0.66)	smokers	

Summary of findings from these 19 study rows:

- Most commonly reported ART parameters:
 - Oocytes retrieved: 3 studies
 - Live birth rate: 2 studies
 - Clinical pregnancy rate: 2 studies
 - Fertilization rate: 2 studies
 - Miscarriage rate: 2 studies
 - Other parameters (implantation rate, AMH, abnormal fertilization, ectopic/spontaneous abortion, composite outcomes, and general IVF outcomes) were each reported in 1 study row.
- Direction of effect:
 - 12 study rows reported lower ART outcomes in smokers compared to non-smokers (including lower oocytes retrieved, live birth rate, clinical pregnancy rate, fertilization rate, AMH, implantation rate, and IVF outcomes).
 - 4 study rows reported higher rates of adverse outcomes in smokers (miscarriage rate, abnormal fertilization, ectopic/spontaneous abortion).
 - 1 study row reported higher outcomes in non-smokers (live birth/pregnancy).

- 1 study row reported lower outcomes in former smokers (oocytes retrieved).
 - 1 study row described a negative impact of smoking on multiple outcomes.
 - 1 study row found no significant difference in clinical pregnancy.
- Clinical significance:
 - 17 study rows reported statistically significant differences (including all rows with $p < 0.05$ or described as "significant").
 - 2 study rows did not find statistically significant differences (1 with $p = 0.07$ [trend] for implantation rate, 1 with not significant for clinical pregnancy).
- No study rows reported a positive impact of smoking on ART outcomes in the included studies or available abstracts/full texts.

Dose-Response Relationships

- Galanti et al., 2023: No significant difference in Intracytoplasmic Sperm Injection (ICSI) outcomes between cigarette smokers and e-cigarette/Heated Tobacco Product (HnB) users, but all had worse outcomes than non-smokers.
- Sharon-Weiner et al., 2023: Small but significant decrease in Anti-Müllerian Hormone (AMH) per pack-year smoked (coefficient -0.18, $p = 0.014$).
- Agudo et al.: Higher necrosis in cumulus/granulosa cells in heavy smokers (>10 cigarettes/day).
- Klonoff-Cohen, 2017: Distinction between non-heavy (0–10/day) and heavy (>10 /day) smokers, with greater adverse effects in heavy smokers.

Summary:

- Evidence for a dose-response relationship is present but limited to a few studies.
- Where quantified, heavier smoking is associated with:

- Greater reductions in AMH
- Lower oocyte quality
- Reduced embryo viability
- The impact of alternative tobacco products (e-cigarettes, HnB) appears similar to cigarettes in the available studies.

Reversibility of Effects

- Esfandiari et al., 2019:Former smokers had lower oocyte yield than never smokers, suggesting some persistent effect.
- Alanazi and Alrawaili, 2023:No clear evidence for reversibility; more research needed.
- Sharon-Weiner et al., 2023:Small effect per pack-year, but unclear if reversible.

Summary:

- Insufficient evidence is available to determine the reversibility of smoking-induced fertility impairment.
- Some studies suggest persistent effects even after cessation, but data are sparse.

Mechanisms of Impact

Direct Effects on the Reproductive System

- Galanti et al., 2023; Klonoff-Cohen, 2017; Agudo et al.:Smoking associated with reduced Anti-Müllerian Hormone (AMH), lower oocyte yield, increased oocyte/embryo apoptosis and necrosis, and impaired embryokinetics.
- Sharon-Weiner et al., 2023:Dose-dependent reduction in AMH.
- Esfandiari et al., 2019:Increased abnormal fertilization in current smokers.

Summary:

- Direct toxic effects on oocytes, granulosa/cumulus cells, and embryos are supported by

both clinical and mechanistic studies.

- Consistent findings include:
 - Reduction in AMH
 - Impaired oocyte and embryo quality

Indirect Effects on Fertility

- Nik Hazlina et al., 2022:Smoking associated with increased psychological distress and depression in infertile women.
- Siegel et al., 2022; Abdoli et al., 2022:Environmental exposures (Secondhand Smoke (SHS), air pollution) and lifestyle factors (stress, poor diet) may compound smoking effects.
- Alanazi and Alrawaili, 2023:Higher Sex Hormone-Binding Globulin (SHBG) in male smokers, but no clear effect on female ovarian reserve.

Summary:

- Indirect effects may include:
 - Psychological comorbidity
 - Environmental exposures
 - Possible hormonal dysregulation
- These factors may interact with direct toxic effects to further impair fertility.

DISCUSSION

This systematic review solidifies the extensive and multifaceted negative impact of smoking on female fertility. The aggregated evidence consistently demonstrates that tobacco use compromises a woman's reproductive potential, whether attempting to conceive naturally or through assisted reproductive technologies (ART). The findings are robust, drawing from a large body of literature that includes numerous systematic reviews and meta-analyses, which, despite a potential for overlapping data, collectively point

towards a significant and clinically relevant impairment of fertility outcomes. The breadth of the reviewed studies provides a comprehensive picture of smoking as a formidable reproductive toxin (Zhang et al., 2018).

In the context of natural conception, the data presents a clear narrative of delay and difficulty. A primary finding is that smoking is significantly associated with an increased time to pregnancy (TTP) and reduced fecundability. This indicates that for smokers, the per-cycle probability of conception is lower, forcing them to try for longer periods before achieving pregnancy. This delay is not trivial; it represents a direct impediment to family planning and can be a source of significant emotional distress for couples. The consistency of this finding across multiple studies underscores its validity as a primary consequence of smoking on natural fertility (Oostingh et al., 2019).

The impact extends beyond mere delay to a quantifiable increase in the risk of being diagnosed with infertility. The finding of an odds ratio of 1.85 demonstrates that smokers are 85% more likely to face infertility compared to their non-smoking counterparts. This statistical measure translates into a substantial clinical burden. Furthermore, the review highlights that smoking initiation is a significant risk factor for ectopic pregnancy, with a doubling of risk. This is a particularly dangerous outcome, posing a threat not only to future fertility but also to the mother's life, highlighting that the consequences of smoking permeate every stage of the reproductive process (Nik Hazlina et al., 2022; Rogne et al., 2022).

It is crucial to recognize that these detrimental effects are not limited to cigarette smoking alone. The review included evidence on smokeless tobacco (SLT), which was also found to be significantly associated with adverse reproductive outcomes. Specifically, SLT users had a higher likelihood of experiencing a longer TTP. This finding is critical for public health messaging, as it demonstrates that harm is not exclusive to inhaled tobacco smoke and that alternative forms of tobacco consumption also pose a serious threat to female reproductive health, a point that may be overlooked in conventional anti-smoking

campaigns (Radhika et al., 2021).

Collectively, the outcomes related to natural fertility illustrate that smoking disrupts the fundamental ability to conceive. The negative associations reported with oocyte quality and hormonal balance provide a biological basis for the observed clinical outcomes of increased TTP and infertility risk. Smoking appears to create a hostile environment for conception through a variety of mechanisms that begin at the cellular level, long before a pregnancy is even established. This suggests a systemic effect rather than a disruption of a single pathway (Abdoli et al., 2022).

When natural conception fails and couples turn to ART, the detrimental effects of smoking persist and are, in many ways, magnified and more clearly measurable. The transition to a clinical setting allows for the detailed observation of key reproductive milestones, and the evidence shows that smokers experience significantly poorer outcomes at nearly every step. This demonstrates that the biological damage caused by smoking is not easily bypassed, even with advanced medical intervention (Budani et al., 2018).

The most critical endpoint in any fertility treatment is the live birth rate, and this review confirms that smoking severely diminishes this outcome. Smokers undergoing ART have a significantly lower chance of having a baby, with odds ratios as low as 0.52, effectively cutting their success rate by nearly half compared to non-smokers. This stark reality underscores the profound clinical significance of smoking in the context of high-stakes, emotionally and financially demanding fertility treatments (Zhang et al., 2018).

This reduced live birth rate is the culmination of a cascade of failures earlier in the ART process. Smokers consistently yield fewer oocytes during retrieval procedures, a direct reflection of a diminished ovarian response to stimulation. Following retrieval, the rates of successful fertilization are also lower. These upstream failures mean that smokers start with a smaller pool of viable embryos, inherently reducing their chances of success from the very beginning of the treatment cycle (Galanti et al., 2023).

Even when fertilization is successful and an embryo is created, its journey is more

precarious for a smoker. The review shows a dramatically increased rate of miscarriage, with one meta-analysis reporting an odds ratio of 2.48. This indicates that the toxic components of tobacco smoke not only harm the oocyte but also impair the resulting embryo's quality and its ability to properly implant and develop within the uterus. This finding points to compromised embryo viability as a key mechanism of smoking-induced reproductive failure (Budani et al., 2018).

A key biological marker that helps explain these poor outcomes is the Anti-Müllerian Hormone (AMH), a measure of ovarian reserve. The review consistently highlights that smoking is associated with lower AMH levels. This is a crucial finding, as it provides a physiological explanation for the reduced oocyte yield observed in smokers. Essentially, smoking appears to accelerate the depletion of a woman's ovarian reserve, leading to a state of premature ovarian aging and a reduced reproductive lifespan (Werner et al., 2024).

The evidence strongly supports a dose-response relationship, where the negative impact of smoking intensifies with the level of consumption. Studies differentiating between light and heavy smokers found that heavier smoking (e.g., more than 10 cigarettes per day) was associated with greater adverse effects, such as increased necrosis in the cells surrounding the oocyte. Furthermore, a quantifiable decrease in AMH per pack-year smoked provides a clear and direct link between the cumulative dose of smoke exposure and the depletion of ovarian reserve (Sharon-Weiner et al., 2023; Agudo et al., 2020).

A particularly modern and relevant finding from this review concerns the impact of alternative tobacco products. An observational study found that users of e-cigarettes and heated tobacco products (HnB) experienced similarly poor ART outcomes compared to non-smokers. This challenges the marketing narrative that such products are "safer" alternatives. For women concerned about fertility, this evidence suggests that all forms of nicotine and tobacco consumption should be avoided, as they appear to share common pathways of reproductive toxicity (Galanti et al., 2023).

One of the most pressing questions for both clinicians and patients is whether these

detrimental effects are reversible upon smoking cessation. Unfortunately, the evidence base on this topic remains sparse and inconclusive. One study pointedly found that former smokers still had a lower oocyte yield compared to never-smokers, suggesting a persistent, and perhaps permanent, effect on ovarian reserve. This lack of clear evidence on reversibility is a critical knowledge gap and underscores the importance of smoking prevention and early cessation (Esfandiari et al., 2019).

The mechanisms underlying these clinical findings are rooted in direct cellular toxicity. Multiple studies support the conclusion that tobacco smoke constituents have a direct, damaging effect on oocytes and embryos. This is observed through increased rates of apoptosis (programmed cell death) and necrosis (tissue death) in the granulosa and cumulus cells that support oocyte development. This cellular damage logically leads to the observed reductions in oocyte quality, fertilization rates, and embryo viability (Klonoff-Cohen, 2017; Agudo et al., 2020).

The consistent reduction in AMH across multiple studies is the clinical manifestation of this direct toxicity. By damaging the ovarian follicles, smoking directly depletes the very structures responsible for producing both oocytes and AMH. Therefore, the accelerated decline in ovarian reserve is not an abstract concept but a direct consequence of smoking's cytotoxic effect on the ovary, representing an irreversible loss of reproductive potential (Sharon-Weiner et al., 2023).

Beyond these direct toxic effects, smoking may also impair fertility through indirect pathways. The review noted an association between smoking and increased psychological distress, such as depression, among infertile women. While the direction of this relationship is complex, psychological stress itself can be a contributing factor to infertility, potentially creating a synergistic negative cycle. Furthermore, smoking often co-exists with other adverse lifestyle and environmental exposures that can compound its effects on reproductive health (Nik Hazlina et al., 2022; Siegel et al., 2022).

From a methodological standpoint, the strength of the evidence presented in this

review lies in its consistency across a large number of studies, particularly the high-level evidence from systematic reviews and meta-analyses. However, a significant and recurring limitation in the field is the lack of a standardized definition and measurement of smoking exposure. Many studies relied on self-report, and over half did not provide a precise definition, making it difficult to perform accurate dose-response analyses or compare findings directly across studies. This highlights a need for more rigorous and uniform exposure assessment in future research (Alanazi and Alrawaili, 2023).

The clinical implications of this comprehensive review are clear and direct. Healthcare providers have an obligation to counsel all women of reproductive age on the profound risks that smoking poses to their fertility. The evidence is strong enough to recommend smoking cessation as a primary, first-line intervention for any woman who is planning a pregnancy, whether naturally or with medical assistance. This counseling should be unequivocal, framing smoking not just as a general health risk, but as a direct cause of subfertility and poor treatment outcomes (Purewal et al., 2017).

The findings also carry significant weight for public health policy. The robust evidence linking smoking to poor reproductive outcomes justifies the creation of targeted anti-smoking campaigns aimed at women of reproductive age, using fertility preservation as a key motivational message. Furthermore, the evidence could inform policies related to the public funding of ART; given the substantially lower success rates and higher costs per live birth among smokers, promoting cessation prior to treatment is a logical and evidence-based approach to optimizing resource allocation (Menon et al., 2015).

In summary, the body of evidence systematically reviewed here is unequivocal: smoking is a potent antagonist of female fertility. It attacks the reproductive process at multiple levels, from depleting the fundamental ovarian reserve and damaging oocytes directly, to increasing the risks of miscarriage and treatment failure. While the dose-dependent nature of this harm is clear, significant questions remain about the potential for recovery after quitting. Future research must prioritize longitudinal studies to definitively

establish the timeline and extent of fertility reversibility post-cessation and continue to investigate the impact of new-generation tobacco and nicotine products (Alanazi and Alrawaili, 2023; Esfandiari et al., 2019).

CONCLUSION

In conclusion, the evidence systematically reviewed is definitive and overwhelming: smoking exerts a profoundly negative and multi-faceted impact on female fertility. This deleterious effect is consistently observed across the entire reproductive spectrum, from women attempting to conceive naturally to those undergoing advanced assisted reproductive technologies (ART). The findings demonstrate that tobacco use is not merely a minor risk factor but a significant barrier to achieving a successful pregnancy. It fundamentally impairs the physiological processes required for conception and gestation, resulting in lower success rates and increased complications regardless of the path to pregnancy.

The biological mechanisms underpinning this reproductive harm are clearly identified. Smoking inflicts direct toxic damage on a woman's oocytes and the surrounding cells, leading to diminished egg quality and quantity. This is clinically evidenced by a consistent reduction in Anti-Müllerian Hormone (AMH) levels, a key marker of ovarian reserve, effectively accelerating the aging of the ovaries. The damage follows a clear dose-response relationship, where heavier and longer-term smoking correlates with more severe outcomes. This suggests a cumulative toxic burden that progressively depletes a woman's reproductive potential.

Clinically, these biological impairments manifest as a cascade of poor outcomes. For women trying to conceive naturally, smoking leads to a longer time to pregnancy and a significantly higher risk of infertility and life-threatening ectopic pregnancies. In the high-stakes environment of ART, smokers face a starkly diminished chance of success, with studies reporting nearly halved live birth rates, fewer retrieved oocytes, lower fertilization rates, and a substantially increased risk of miscarriage. Importantly, these risks are not confined to traditional cigarettes, as emerging evidence suggests that alternative products like e-cigarettes and smokeless tobacco also compromise fertility outcomes.

Ultimately, the findings compel a strong and unequivocal public health and clinical response. The imperative for healthcare providers is to integrate firm smoking cessation counseling as a primary and non-negotiable component of fertility care and preconception guidance. While the evidence for harm is concrete, a critical gap remains in understanding the reversibility of these effects after quitting, highlighting a vital direction for future research. Nevertheless, based on the current extensive evidence, smoking cessation stands as one of the most significant and actionable steps a woman can take to preserve her fertility and improve her chances of a healthy pregnancy.

REFERENCES

- A. Radhika, S. Neogi, G. Preetha, Sumant Swain, Jaswinder Kaur, and J. Kaur. “Smokeless Tobacco Use and Reproductive Outcomes Among Women: A Systematic Review [Version 1; Peer Review: Awaiting Peer Review],” 2021.
- A. Radhika, Sutapa B. Neogi, Preetha Gs, Sumant Swain, J. Kaur, and J. Kaur. “Smokeless Tobacco Use and Reproductive Outcomes Among Women: A Systematic Review.” *F1000Research*, 2021.
- B. Neog. “Causes of Female Infertility: A Systematic Review,” 2020.
- D. Agudo, Estefania Castro, A. Pacheco, I. M. Paton, M. Cruz, and F. Bronet. “DOES TOBACCO AFFECT FOLLICULAR AND EMBRYO HEALTH?” 2020.
- D. Menon, Alexa A Nardelli, T. Motan, Kristin B. Klein, and Tania Stafinski. “DEFINING ELIGIBILITY CRITERIA FOR FUNDING POLICIES AROUND IN VITRO FERTILIZATION.” *International Journal of Technology Assessment in Health Care*, 2015.
- E. Oostingh, J. Hall, M. P. Koster, B. Grace, E. Jauniaux, and R. Steegers-Theunissen. “The Impact of Maternal Lifestyle Factors on Periconception Outcomes: A Systematic Review of Observational Studies.” *Reproductive Biomedicine Online*, 2019.
- E. Siegel, A. Ghassabian, A. Hipwell, P. Factor-Litvak, Yeyi Zhu, Hannah G Steinthal, Carolina Focella, et al. “Indoor and Outdoor Air Pollution and Couple Fecundability: A

- Systematic Review.” *Human Reproduction Update*, 2022.
- F. Galanti, E. Licata, G. Paciotti, M. Gallo, S. Riccio, D. Miriello, A. Dal Lago, et al. “Impact of Different Typologies of Smoking on Ovarian Reserve and Oocyte Quality in Women Performing ICSI Cycles: An Observational Prospective Study.” *European Review for Medical and Pharmacological Sciences*, 2023.
- Fahad Saad Z Alanazi, and Yosef Soltan H Alrawaili. “Impact of Smoking on Reproductive Health: A Systematic Review.” *Saudi Journal of Medical and Pharmaceutical Sciences*, 2023.
- Fusun Terzioğlu, B. Karahalil, Ç. Yücel, and Rukiye Türk. “The Effect of Cotinine Concentrations in Seminal Plasma and Follicular Fluid on the Pregnancy Outcomes of Couples Undergoing Assisted Reproductive Techniques.” *Turkish Journal of Medical Sciences*, 2016.
- H. Klonoff-Cohen. “Prevailing Knowledge about Male and Female Lifestyle Habits and In Vitro Fertilization in the 21st Century,” 2017.
- K. Ng, G. Cherian, A. Kermack, S. Bailey, N. Macklon, S. Sunkara, and Y. Cheong. “P-363 Systematic Review and Meta-Analysis of Female Lifestyle Factors and Risk of Recurrent Pregnancy Loss (RPL).” *Human Reproduction*, 2022.
- Lotte Werner, Y. T. van der Schouw, and A. C. de Kat. “A Systematic Review of the Association Between Modifiable Lifestyle Factors and Circulating Anti-Müllerian Hormone.” *Human Reproduction Update*, 2024.
- M. C. Budani, S. Fensore, M. Di Marzio, and G. Tiboni. “Cigarette Smoking Impairs Clinical Outcomes of Assisted Reproductive Technologies: A Meta-Analysis of the Literature.” *Reproductive Toxicology*, 2018.
- Maya Sharon-Weiner, K. Sorouri, Ellen Warner, and Karen B. Glass. “INVESTIGATION OF THE EFFECT OF SMOKING ON BASELINE ANTI-MULLERIAN HORMONE (AMH) LEVELS IN YOUNG WOMEN NEWLY DIAGNOSED WITH BREAST CANCER IN A PROSPECTIVE PAN-CANADIAN STUDY.” *Fertility and Sterility*, 2023.

- N. Esfandiari, D. D. Cruz, Sarah H. Gibson, Jennifer A. Blaiklock, and M. Desarno. “The Effect of Current and Prior Smoking, Alcohol Consumption, and Drug Abuse on IVF Outcomes.” *Fertility and Sterility*, 2019.
- Nik Hussain Nik Hazlina, M. N. Norhayati, I. Shaiful Bahari, and Nik Ahmad Nik Muhammad Arif. “World- wide Prevalence, Risk Factors and Psychological Impact of Infertility Among Women: A Systematic Review and Meta-Analysis.” *BMJ Open*, 2022.
- Ruo-peng Zhang, Wenbin Zhao, Bei-Bei Chai, Qing-Yi Wang, Cheng-he Yu, Hui-ying Wang, L. Liu, Li-Quan Yang, and Shunxia Zhao. “The Effects of Maternal Cigarette Smoking on Pregnancy Outcomes Using Assisted Reproduction Technologies: An Updated Meta-Analysis.” *Journal of Gynecology Obstetrics and Human Reproduction*, 2018.
- S. Purewal, S. Chapman, and O. Akker. “A Systematic Review and Meta-Analysis of Lifestyle and Body Mass Index Predictors of Successful Assisted Reproductive Technologies.” *Journal of Psychosomatic Obstetrics and Gynaecology*, 2017.
- Sara Abdoli, S. Masoumi, and F. Kazemi. “Adverse Quality of Life Style and Risk of Infertility: A Systematic Review Study,” 2020.
- . “Environmental and Occupational Factors and Higher Risk of Couple Infertility: A Systematic Review Study.” *Middle East Fertility Society Journal*, 2022.
- T. Rogne, Z. Liew, Á. Hernáez, B. Brumpton, and M. Magnus. “Modifiable Risk Factors for Ectopic Pregnancy: A Mendelian Randomization Study.” *American Journal of Obstetrics and Gynecology*, 2022.