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# Risk of Gynecological and Breast Cancers in Workers Exposed to Diesel Exhaust: A Systematic Review and Meta-Analysis of Cohort Studies

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**Keywords:** Gynecological Cancers; Breast Cancer; Diesel Exhaust; Occupational Health; Occupational Risk

## ABSTRACT

**Background:** *This study aimed to explore the association between occupational exposure to diesel exhaust (DE) and gynaecological and breast cancers.* **Methods:** *A systematic review was performed to identify cohort studies reporting results on the association between occupational exposure to DE and risk of gynaecological and breast cancers. STROBE guidelines and PECOS criteria were followed. We identified 6 studies for breast cancer (BC), 4 for cervical cancer (CC), 4 for endometrial cancer (EC) and 7 for ovarian cancer (OC). Random-effects meta-analyses were conducted on the relationship between DE exposure and BC, CC, EC, and OC risk; 95% Confidence Intervals (CI) and prediction intervals (PI) were reported. We investigated between-study heterogeneity and potential publication bias using Egger's test.* **Results:** *No associations were observed between occupational DE exposure and risk of BC [RR=0.93; CI: 0.77-1.13; PI:0.50-1.73, $I^2$=80.31% (CI: 21.72-95.05%)], EC [RR=0.89; CI: 0.75-1.05; PI:0.61-1.30, $I^2$=0.78% (CI: 0-85.57%)], and OC [RR=1.08; CI: 0.89-1.32, PI: 0.76-1.56, $I^2$=11.87% (CI: 0-74.42%)]. A weak association was observed for CC [RR=1.41; CI: 1.17-1.17; PI:0.85-2.30, $I^2$=6.44% (CI: 0-86.40%)]. No between-study heterogeneity or publication bias was detected.* **Conclusions:** *This study identified an association between DE exposure and CC, which was not adjusted for potential confounders. No evidence of an association was found with BC, EC, and OC.*

## 1. Introduction

Diesel engines are used in a wide range of industrial applications and, therefore, occupational exposure to diesel exhaust (DE) is common. Exposed workers include mechanics, warehouse workers, professional drivers, shipping, and railroad workers, as well as miners and construction workers and other industries where diesel-powered vehicles and tools are applied [1].

DE is primarily composed of gases (e.g., carbon monoxide and nitrogen oxides), vapours, aerosols, and particulate matter consisting of solid carbonaceous particles which may become chemically active when are adsorbed to metallic particles and polycyclic aromatic hydrocarbons (PAH), in particular nitro-PAH [2]. Exposure to these pollutants may lead to a variety of symptoms and diseases, from acute manifestations (e.g.: eyes, nose, throat and lung irritation, headache, dizziness, coughing, phlegm, and

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nausea) to chronic ones (cardiovascular diseases, respiratory infections, and lung cancer) based on duration and intensity of exposure. However, the relative importance and underlying mechanisms of the different constituents of DE to the observed effects have not yet been fully understood.

According to the International Agency for Research on Cancer (IARC) evaluation in 2012, DE is classified as a Category 1 carcinogen to humans based on evidence in epidemiological studies that occupational exposure is associated with an increased risk for lung cancer [3]. DE is also suspected to be linked to other cancers, including cancers of the bladder, larynx, stomach, liver, pancreas, and ovary [4-8]. However, DE carcinogenicity in humans has not yet been fully investigated [3].

While there are suggestions in the scientific literature that occupational exposure to DE may increase the risk of early-onset estrogen receptor-negative breast cancer (BC) in women [2, 9, 10] and that of ovarian cancer (OC) [11], it is not yet clear if DE exposure can be considered an occupational risk factor for these and other gynecological cancers such as cervical cancer (CC), endometrial cancer (EC), fallopian tube cancer (FTC) and vaginal and vulvar cancer (VVC).

To our knowledge, no meta-analyses have been conducted on occupational DE exposure and female cancers. For this reason, considering the limited information available, we conducted a systematic review and metanalysis aimed at investigating the association between occupational exposure to DE and risk of BC and gynaecological cancers, including CC, EC, OC, FTC and VVC.

## 2. Methods

### 2.1 Identification and Selection of Studies

We conducted a systematic review in accordance with the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [12]. A study protocol was registered in the PROSPERO database (Registration No. 352729). The inclusion criteria for study selection followed the PECOS framework (Population; Exposure; Comparators; Outcomes; Study Design) [13].

Our search strategy implied first the inclusion of the publications listed in the most recent IARC Monograph on Diesel Engine Exhaust (DE) [3]. In addition, we searched the PubMed database for studies published subsequent to the IARC report, focusing on research concerning occupational exposure to DE and its association with various types of cancer, excluding lung cancer. The PubMed search was conducted independently by two authors (GC, FT) using the search string *"(diesel OR miner OR garage OR railway OR ((truck OR bus) AND driver) OR (heavy equipment OR docker)) AND (cancer OR neoplasm)"* to identify industry-based studies reporting results on the risk of cancer among workers exposed to DE in sectors such as railway, transportation, construction, and mining. Furthermore, we supplemented our search with reports found in the reference lists of the identified articles. When multiple studies were based on the same population, we included only the most informative one, typically the one reporting the largest number of cases or deaths. An overlap of less than 10% was considered acceptable, and therefore studies with minimal overlap were treated as independent. We excluded studies lacking references to DE exposure, those involving non-occupational exposure, those lacking data on cancers other than lung cancer, and those with a design other than cohort or case-control nested in a cohort (Figure 1).

### 2.2 Data Extraction

Data were extracted into pre-defined forms. The following information was pulled from the studies:

- Sociodemographic factors;
- Occupation and industry type;
- Person-years of observation;
- Type of cancer – including ICD code with version;
- Measure of association, such as odds ratio (OR), risk ratio, rate ratio, standardized mortality ratio (SMR), or standardized incidence ratio (SIR), collectively referred to as relative risk (RR), with corresponding 95% Confidence Intervals (CI);
- Factors adjusted for in the analysis;

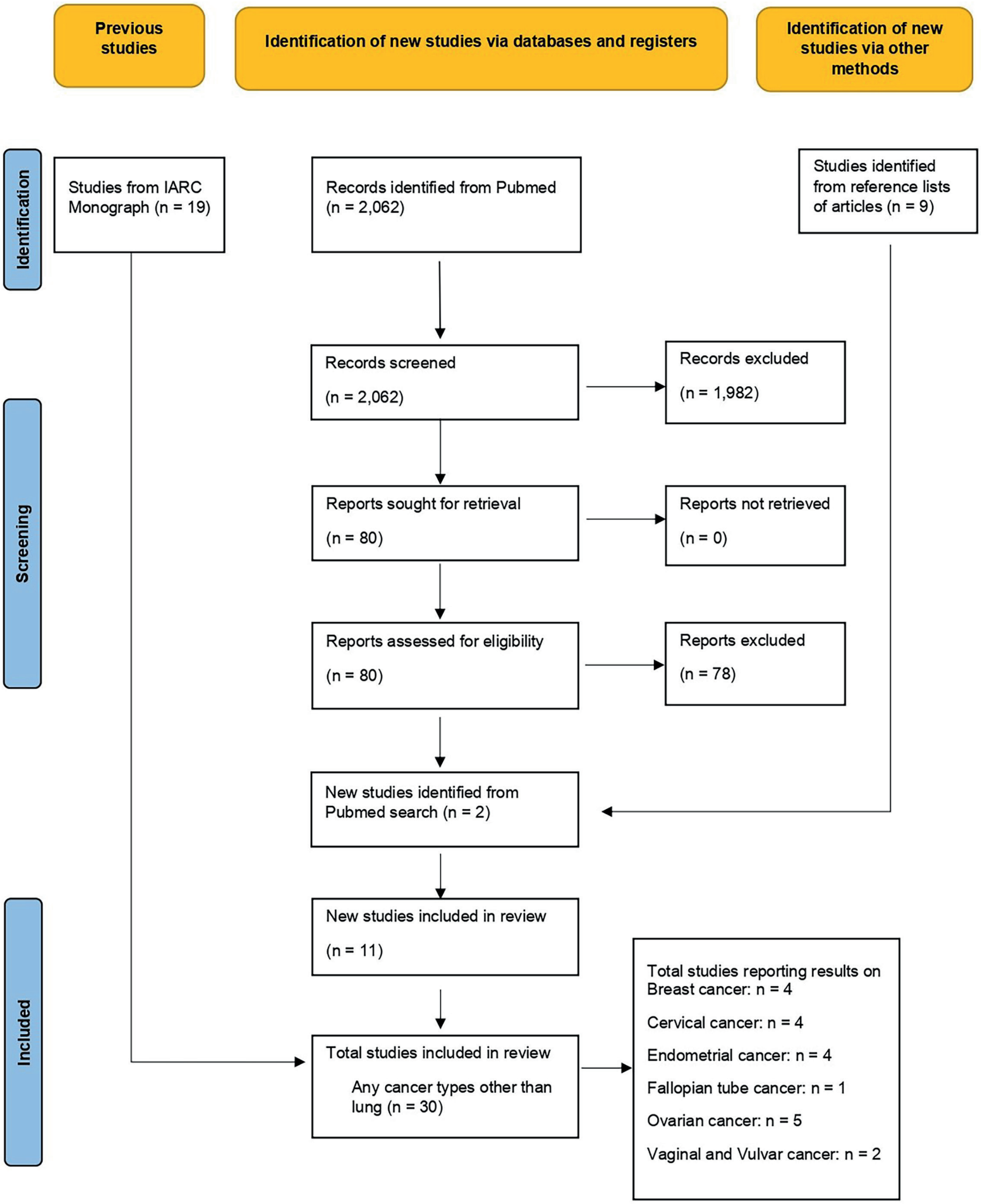


**Figure 1.** Flow diagram of the study selection process.

- Characteristics of the study population, such as the number of subjects included and the number of cases).

The dataset was then organized by type of cohort study (historical vs. prospective), follow-up period, geographic region, and outcome (incidence vs. mortality). Additionally, when available, we extracted results on dose-response analysis for various indicators of DE exposure.

### 2.3 Statistical Analysis

We conducted a quality assessment of the included studies using the CASP checklist [14], consisting of 11 items totalling 14 points. The final score was determined by averaging the results obtained independently by two authors (GC and FT). We generated a dichotomous variable, categorizing studies scoring less than 10 as "low quality" and those scoring 10 or higher as "high quality".

While the systematic literature review was performed to identify cohort studies on occupational DE exposure and risk of cancers other than lung, the subset of studies included in this analysis pertains specifically to gynecological and breast cancers. We conducted a series of meta-analyses of non-overlapping studies to calculate pooled estimates with 95% CI for BC, CC, EC, and OC, while FTC and VVC were not analysed due to the small number of studies available (Figure 2). Also, further stratified meta-analyses for any cancer type were not feasible due to the paucity of studies. We utilized the Random-Effects Sidik–Jonkman model for statistical analysis [15], reporting RRs with 95% CI. We considered p-values <0.05 as statistically significant. Moreover, 95% Prediction Intervals (PI) were provided [16]. To assess study heterogeneity, we employed the inconsistency index ($I^2$ statistic) along with its 95% CI [17], interpreting values as follows: 0-30% for low, 31%-60% for moderate, 61%-75% for substantial, and 76%-100% for considerable heterogeneity [18]. Furthermore, we conducted sensitivity analyses using multiple leave-one-out meta-analyses. Publication bias was evaluated using the Egger test and visual inspection of funnel plots [19] and Galbraith plots [20].

All statistical analyses were performed using STATA, version 17.0 (Stata Corp LLC, College Station, TX, US). Meta-analyses were reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [14]. The PRISMA checklist is available in Table S1.

## 3. Results

### 3.1 Study Search and Study Characteristics

First, 19 reports were identified in the IARC monograph [3] and included in the systematic review. The PubMed literature search to include studies reported after the publication of the IARC monograph resulted in 2,062 articles, of which 1,982 articles were excluded based on title and abstract, and 78 were excluded after review of the full text. Therefore, 2 new studies were included in the review, together with 9 non-overlapping reports identified from the reference lists of the papers identified in the preceding steps. A final number of 30 articles underwent full review, and 5 of them were included in the final analysis regarding gynecological and breast cancer. Among the 5 studies included for systematic review, 4 reported risk estimates for BC, CC, and EC, 1 for FTC, 5 for OC and 2 for VVC (Figure 1). Four studies were conducted in Europe, specifically in the Nordic countries, and one was conducted in the USA. Selected characteristics of the studies included in the review and meta-analysis are presented in Table 1. Risk of FTC and VVC were not further investigated due to the small number of studies available.

### 3.2 Breast Cancer

This meta-analysis included 4 studies, which reported 6 risk estimates (4 regarding BC in women and 2 regarding BC in men). The forest plot is shown in Figure 2. Overall, the RR of BC was 0.93 [95% CI: 0.76-1.12, 95% PI: 0.50-1.72]. The leave-one-out meta-analysis indicated that no single study exerted a disproportionately large influence on the estimation of the overall effect size when compared

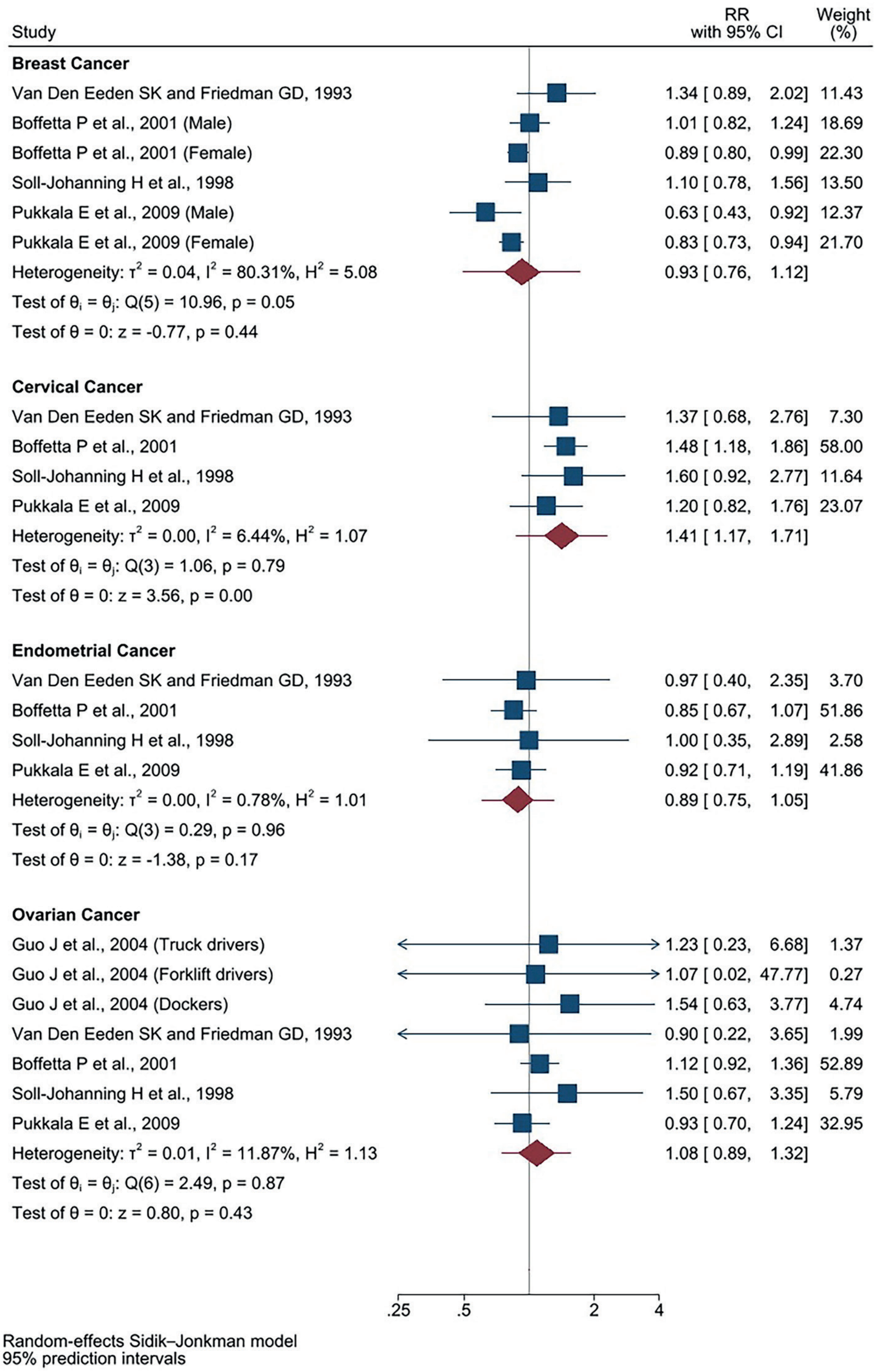


**Figure 2.** Forest plot of a meta-analysis of cohort studies on occupational exposure to diesel exhaust and breast, cervical, endometrial, and ovarian cancer with a 95% prediction interval.

**Table 1.** Selected characteristics of the studies included in the review and meta-analyses.

| Study | Cancer | Country | Cohort Type | Follow-Up | Population | Person-years | Industry | Number of cases | Adjustments | CASP Assessment |
|---|---|---|---|---|---|---|---|---|---|---|
| [4] | BC<br>CC<br>EC<br>OC | Denmark | Retrospective<br>Prospective | 1943-92 | 16 023 men<br>1967 women | 386 395 | Bus drivers and tramway employers | BC (Female): 29<br>CC: 14<br>EC: 4<br>OC: 7 | - | 9.5 - Low Quality |
| [6] | OC | Finland | Retrospective | 1971-95 | Economically active Finns born between 1906 and 1945 | 30 million | (1) Miners, quarry workers, no metal ore<br>(2) Engine (locomotive) drivers<br>(3) Road-building vehicle drivers<br>(4) Truck drivers<br>(5) Forklift drivers, NEC<br>(6) Excavation machine operators<br>(7) Road-building machine operators<br>(8) Construction machine operators, NEC<br>(9) Dockers, stevedores | OC (1): 0<br>OC (2): -<br>OC (3): 0<br>OC (4): 2<br>OC (5): 1<br>OC (6): 0<br>OC (7): 0<br>OC (8): 0<br>OC (9): 6 | Socioeconomic status, BMI, number of children, age, and calendar period | 12 - High Quality |
| [21] | BC<br>CC<br>EC<br>OC<br>VVC | USA | Retrospective | 1964-88 | 160 230 | - | People of the KPMCP with self-reported exposure, no job or industry titles | BC (Female): 2507<br>CC: 714<br>EC: 772<br>OC: 329<br>VVC: 125 | - | 12 - High Quality |
| [22] | BC<br>CC<br>EC<br>OC | Sweden | Prospective | 1971-89 | Employed Swedish adult population | Over 7 640 000 (exposed men)<br>Over 240 000 (exposed women) | Different job and industry titles (farmers excluded) | BC (Female): 360<br>BC (Male): 95<br>CC: 79<br>EC: 77<br>OC: 106 | - | 11 - High Quality |
| [23] | BC<br>CC<br>EC<br>FTC<br>OC<br>VVC | Denmark<br>Finland<br>Iceland<br>Norway<br>Sweden | Prospective | 1961-2005 | 15 million (NOCCA cohort) | 385 million | Engine operators | BC (Female): 255<br>BC (Male): 29<br>CC: 29<br>EC: 59<br>FTC:<br>OC: 49<br>VVC: 10 | Age | 12.75 - High Quality |

*BC: breast cancer; CC: cervical cancer; EC: endometrial cancer; FTC: Fallopian tube cancer; OC: ovarian cancer; VVC: vaginal and vulvar cancer; NEC: not elsewhere classified; BMI: body mass index; NOCCA: Nordic Occupational Cancer; KPMCP: Kaiser Permanente Medical Care Program.*

with the others (Figure S1). The reported heterogeneity statistic $I^2$ was 80.31% [95% CI: 21.72-95.05%]. The between-study variance $\tau^2$ is estimated to be 0.04. The Egger test for publication bias was not significant (p=0.61). The corresponding funnel plot and Galbraith plot are reported in Figures S2 and Figure S3. Further stratified meta-analyses could not be performed due to the small number of risk estimates available.

### 3.3 Cervical Cancer

This meta-analysis included 4 studies, corresponding to 4 risk estimates. The forest plot is shown in Figure 2. Overall, the RR of CC was 1.41 [95% CI: 1.17-1.71, 95% PI: 0.87-2.29]. The leave-one-out meta-analysis indicated that no single study exerted a disproportionately large influence on the estimation of the overall effect size when compared with the others (Figure S4). The reported heterogeneity statistic $I^2$ was 6.44% [95% CI: 0-86.40%]. The between-study variance $\tau^2$ is estimated to be <0.01. The Egger test for publication bias was not significant (p=0.87). The corresponding funnel plot and Galbraith plot are reported in Figures S5 and Figure S6. Further stratified meta-analyses could not be performed due to the small number of risk estimates available.

### 3.4 Endometrial Cancer

This meta-analysis included 4 studies, corresponding to 4 risk estimates. The forest plot is shown in Figure 2. Overall, the RR of EC was 0.89 [95% CI: 0.75-1.05, 95% PI: 0.61-1.30]. The leave-one-out meta-analysis indicated that no single study exerted a disproportionately large influence on the estimation of the overall effect size when compared with the others (Figure S7). The reported heterogeneity statistic $I^2$ was 0.78% [95% CI: 0-85.57%]. The between-study variance $\tau^2$ is estimated to be <0.01. The Egger test for publication bias was not significant (p=0.73). The corresponding funnel plot and Galbraith plot are reported in Figures S8 and Figure S9. Further stratified meta-analyses could not be performed due to the small number of risk estimates available.

### 3.5 Ovarian Cancer

This meta-analysis included 5 studies, corresponding to 7 risk estimates. The forest plot is shown in Figure 2. Overall, the RR of OC was 1.08 [95% CI: 0.89-1.32, 95% PI: 0.76-1.56]. The leave-one-out meta-analysis indicated that no single study exerted a disproportionately large influence on the estimation of the overall effect size when compared with the others (Figure S10). The reported heterogeneity statistic $I^2$ was 11.87% [95% CI: 0-74.42%]. The between-study variance $\tau^2$ is estimated to be 0.01. The Egger test for publication bias was not significant (p=0.64). The corresponding funnel plot and Galbraith plot are reported in Figures S11 and Figure S12. Further stratified meta-analyses could not be performed due to the small number of risk estimates available.

## 4. Discussion

To our knowledge, this is the first systematic review and meta-analysis of cohort studies to assess the association between occupational DE exposure and risk of gynecological and breast cancers. While the meta-analysis suggested a positive association between risk of CC and DE exposure, we found no association between DE exposure and risk of BC, EC, and OC. On the other hand, the results we observed on CC supports the design of occupational interventions aimed at increasing the knowledge of HPV infections, and its vaccination and possibly enhancing access to CC screening programs [24, 25].

BC is causally associated with different reproductive factors, such as age at menarche, age at menopause, parity, number of children, age at first birth, and use of oral contraceptives or hormonal substitutive therapy [26-29]. Previous literature reported that night-shift work may represent an occupational risk associated with BC [30]. Several studies among nurses have indicated that this population has a higher risk of developing BC compared to the general female population [31-33]. The investigation of possible risk factors for BC in large female workers cohorts is showing associations with several chemicals, such as benzene, solvents, and metals [34-37]. Limited evidence has been produced around DE exposure. A recent study conducted in Denmark (not included in the meta-analysis since published after the end of the systematic review) found no overall association between BC and DE in female workers, despite an increased risk of early-onset estrogen receptor negative BC in the exposed was suggested [9]. Similar results were also obtained from a study investigating exposure to vehicle traffic, which contains diesel exhaust [38]. All in all, studies currently do not allow to establish any causal relationship between occupational risk factors and BC [37].

Obesity is recognized as a risk factor for EC [39], together with hypertension, oral contraceptive use, and parity [40]. Limited evidence is available regarding occupational EC risks, and findings are not conclusive on any possible hazards in specific occupational settings [41, 42].

OC is causally related to hormonal and reproductive factors, with an increased risk related to BMI and usage of hormone replacement therapy (HRT) and a decreased risk related to parity and the number of live births [43-45], while few publications investigated this disease in association to occupational exposures [46-50].

The studies included in this meta-analysis were not designed to investigate female cancers after occupational DE exposure. Report and publication bias are a possibility in these circumstances. Although the test for publication bias was not significant for any cancer, the small number of studies reduced the power of such tests. Moreover, only two studies adjusted for important confounders such as age. The duration of the follow-up period may also have affected the observed results. Latency is indeed a major factor when considering cohort studies on cancer: the longer the follow-up period, the higher the likelihood of observing the occurrence of epithelial cancers in the population [51]. Three out of 5 studies included in this meta-analysis followed up workers for less than 30 years and more cases of female cancer would have been included if the studies had covered longer periods, with the possibility to detect associations that have remained hidden.

As far as the underlying mechanisms involved in DE carcinogenic effects on female organs are scarcely supported by the available literature [2, 3, 9-11], the lack of association found in this analysis is likely reflecting a real lack of effect.

The significant association between DE exposure and CC should nonetheless be pointed out for several reasons. First of all, other studies have reported a significantly increased occupational risk of CC among female workers [22, 37]. This analysis of CC risk was based on 4 risk estimates, limiting the power of the analysis of heterogeneity and publication bias. We used the Sidik–Jonkman method for estimating the between-study variability ($\tau^2$) rather than the most popular DerSimonian–Laird method [52] due to the known tendency of the latter to underestimate $\tau^2$ when the number of studies is small [53]. We also wanted to relax the assumption that the distribution of random effects is normal. Using the Random-Effects Sidik–Jonkman model, the confidence interval has higher coverage probability than the commonly used interval based on the DerSimonian-Laird method [54], but despite this, the CC risk estimate is still statistically significant. Moreover, 3 out of 4 studies included in this meta-analysis were classified as "high quality", and meta-analysis based on higher-quality studies with robust methodologies tend to provide more reliable evidence while addressing the healthy worker survivor effect as well as potential information bias through appropriate reference selection and lag time analyses. Finally, the consistency among the included studies in terms of the direction and magnitude of the effects adds strength to the conclusions drawn from this meta-analysis, even though, given the small number of studies involved, it was not possible to obtain a precise estimate of the heterogeneity among studies ($I^2$ = 6.44%, 95% CI: 0-86.40%) [55].

However, the CI addresses only the precision of the mean estimate since it reflects only the error of estimation of the mean. The dispersion of true effect sizes is addressed by the PI, which crossed the no-effect threshold, indicating that there are settings where DE exposure will have no effect or even an effect in the opposite direction on CC [16].

Moreover, the lack of information in all the studies included in the analysis about HPV infection status, and about HPV-related factors such as sexual habits, educational level, and screening participation rates was a major limitation. In fact, HPV is the most important risk factor in CC development [37]. On turn, occupational risk may explain part of the disparities observed in women of different social classes. In this sense, the fact that women occupationally exposed to DE result in being more likely to develop CC may be the effect of residual confounding as HPV, physical activity, and cigarette smoking [37, 56]. There is also the possibility that participation in the HPV screening programmes varies by occupational category [57]. With this regard, certain working categories might represent special populations to be targeted with interventions aimed at increasing CC screening participation [24, 25, 58]. Also, the workplace might represent a novel setting for screening initiatives [59-60].

Many studies have reported that socioeconomic disparities may be related to a higher HPV prevalence and poor lifestyle habits in less educated, low-income women, as well as to a higher prevalence in low-income countries where HPV is more widespread [61-63]. For this reason, categories of workers exposed to DE – which often include low-income and blue-collar workers – may be at higher risk of developing cancer independently from their occupational exposure, but rather because of other established lifestyle carcinogens. Therefore, studies including adjustments for potential confounders are warranted to explain the relationship we observed in this meta-analysis.

### 4.1 Strengths and Limitations

This study has several strengths. This is the first systematic review and meta-analysis to investigate the relationship between DE exposure in female workers and the risk of breast and gynecological cancers, providing novel data to better understand the epidemiology of these cancers. Specific workers, such as drivers and engine operators, have generally higher exposure levels than the general population. Most importantly, the exposure assessment among workers is likely to be more valid than that conducted on the general population. For these reasons, we restricted our research specifically to occupational DE exposure, and our data collection focused on working categories who are known to be highly exposed to DE. We also considered only cohort studies since they provide higher-quality data and less opportunity for selection bias compared to case-control or cross-sectional studies [64]. Moreover, the meta-analyses were performed following solid methodological guidelines, and 4 out of 5 studies included were classified as "high quality".

However, the results should be interpreted cautiously, as some limitations should be acknowledged. First, the scarce number of women in working cohorts, next to the low incidence of some of the types of cancers investigated (e.g., OC, VVC, FTC) and the small number of studies included in the analysis, limited the statistical power of the analysis. The small number of studies available for each meta-analysis also resulted in imprecise estimates of the heterogeneity index $I^2$. Second, differences between the studies in the definition of DE exposure and of the working populations might introduce bias, despite not being differential among cases and non-cases. Also, little information was available on the type of DE exposure and the working activities of the populations included, limiting the possibility of interpreting the results. Third, this meta-analysis is based on only 5 studies, 4 of which were conducted in the Nordic countries, limiting the generalization of the results. Finally, as with all meta-analyses, language bias cannot be ruled out entirely as our analysis is based only on published studies written in English.

## 5. Conclusions

This study provided no evidence of an increased risk of BC, OC, or EC in workers exposed to DE. We observed a significant increase in the risk of CC. Potential confounding was not controlled for, and other sources of bias cannot be excluded, which preempts conclusions in terms of causality. However, these results suggest that women employed in work settings where they are exposed to DE may benefit from occupational-based CC screening.

**Supplementary Materials:** The following are available online:

- Table S1: PRISMA checklist
- Figure S1: Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of breast cancer (BC)

- Figure S2: Funnel plot of the analysis on occupational diesel exhaust exposure and risk of breast cancer (BC)
- Figure S3: Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of breast cancer (BC)
- Figure S4: Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of cervical cancer (CC)
- Figure S5: Funnel plot of the analysis on occupational diesel exhaust exposure and risk of cervical cancer (CC)
- Figure S6: Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of cervical cancer (CC)
- Figure S7: Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of endometrial cancer (EC)
- Figure S8: Funnel plot of the analysis on occupational diesel exhaust exposure and risk of endometrial cancer (EC)
- Figure S9: Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of endometrial cancer (EC)
- Figure S10. Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of ovarian cancer (OC)
- Figure S11: Funnel plot of the analysis on occupational diesel exhaust exposure and risk of ovarian cancer (OC)
- Figure S12: Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of ovarian cancer (OC)

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**Informed Consent Statement:** Not applicable.

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**Declaration of Interest:** P.B. acted as expert witness in litigation concerning diesel exhaust exposure and gastrointestinal cancers, unrelated to the present work. No conflicts were reported by the other authors.

**Author Contribution Statement:** PB and GC conceived and designed the study; GC and FT searched the literature, identified relevant articles, and reviewed the full text, with PB assistance; MD conducted the statistical analysis and drafted the manuscript; GC and PB interpreted the data and revised the manuscript.

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La Medicina del Lavoro

# Risk of Gynecological and Breast Cancers in Workers Exposed to Diesel Exhaust: A Systematic Review and Meta-Analysis of Cohort Studies

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## Supplementary Material

**Table S1 – PRISMA checklist**

| Section and Topic | Item # | Checklist item | Location where item is reported |
|---|---|---|---|
| **TITLE** | | | |
| Title | 1 | Identify the report as a systematic review. | Pag. 1 |
| **ABSTRACT** | | | |
| Abstract | 2 | See the PRISMA 2020 for Abstracts checklist. | Pag. 1 |
| **INTRODUCTION** | | | |
| Rationale | 3 | Describe the rationale for the review in the context of existing knowledge. | Pag. 1-2 |
| Objectives | 4 | Provide an explicit statement of the objective(s) or question(s) the review addresses. | Pag. 2 |
| **METHODS** | | | |
| Eligibility criteria | 5 | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses. | Pag. 2-3 |
| Information sources | 6 | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted. | Pag. 2 |
| Search strategy | 7 | Present the full search strategies for all databases, registers and websites, including any filters and limits used. | Pag. 2 |
| Selection process | 8 | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process. | Pag. 2 |
| Data collection process | 9 | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process. | Pag. 2 |
| Data items | 10a | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect. | Pag. 2-4 |
| | 10b | List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information. | Pag. 2-4 |
| Study risk of bias assessment | 11 | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process. | Pag. 4 |
| Effect measures | 12 | Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results. | Pag. 4 |

| Section and Topic | Item # | Checklist item | Location where item is reported |
|---|---|---|---|
| Synthesis methods | 13a | Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)). | Pag. 2 |
| | 13b | Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions. | Pag. 2 |
| | 13c | Describe any methods used to tabulate or visually display results of individual studies and syntheses. | Pag. 4 |
| | 13d | Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used. | Pag. 4 |
| | 13e | Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression). | Pag. 4 |
| | 13f | Describe any sensitivity analyses conducted to assess robustness of the synthesized results. | NA |
| Reporting bias assessment | 14 | Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases). | Pag. 4 |
| Certainty assessment | 15 | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome. | NA |
| **RESULTS** | | | |
| Study selection | 16a | Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram. | Fig. 1 |
| | 16b | Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded. | Fig. 1 |
| Study characteristics | 17 | Cite each included study and present its characteristics. | Tab. 1 |
| Risk of bias in studies | 18 | Present assessments of risk of bias for each included study. | Tab. 1 |
| Results of individual studies | 19 | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots. | Fig. 1 |
| Results of syntheses | 20a | For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies. | Pag. 4-5 |
| | 20b | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, | Pag. 4-6 |

| Section and Topic | Item # | Checklist item | Location where item is reported |
|---|---|---|---|
| | | describe the direction of the effect. | |
| | 20c | Present results of all investigations of possible causes of heterogeneity among study results. | Pag. 4-5 |
| | 20d | Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results. | Pag. 4-5 |
| Reporting biases | 21 | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed. | Pag. 4-5 |
| Certainty of evidence | 22 | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed. | Pag. 4-5 |
| **DISCUSSION** | | | |
| Discussion | 23a | Provide a general interpretation of the results in the context of other evidence. | Pag. 9-10 |
| | 23b | Discuss any limitations of the evidence included in the review. | Pag. 11 |
| | 23c | Discuss any limitations of the review processes used. | Pag. 11 |
| | 23d | Discuss implications of the results for practice, policy, and future research. | Pag. 9-10 |
| **OTHER INFORMATION** | | | |
| Registration and protocol | 24a | Provide registration information for the review, including register name and registration number, or state that the review was not registered. | Pag. 2 |
| | 24b | Indicate where the review protocol can be accessed, or state that a protocol was not prepared. | Pag. 2 |
| | 24c | Describe and explain any amendments to information provided at registration or in the protocol. | NA |
| Support | 25 | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review. | Pag. 11 |
| Competing interests | 26 | Declare any competing interests of review authors. | Pag. 12 |
| Availability of data, code and other materials | 27 | Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. | Pag. 11 |

*From:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

**Figure S1.** Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of breast cancer (BC)

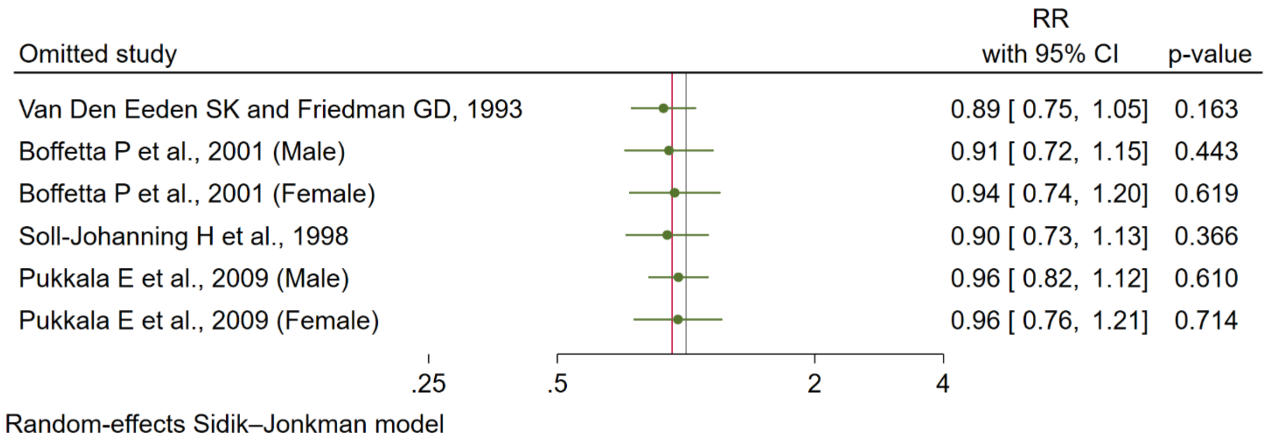



**Figure S2.** Funnel plot of the analysis on occupational diesel exhaust exposure and risk of breast cancer (BC)

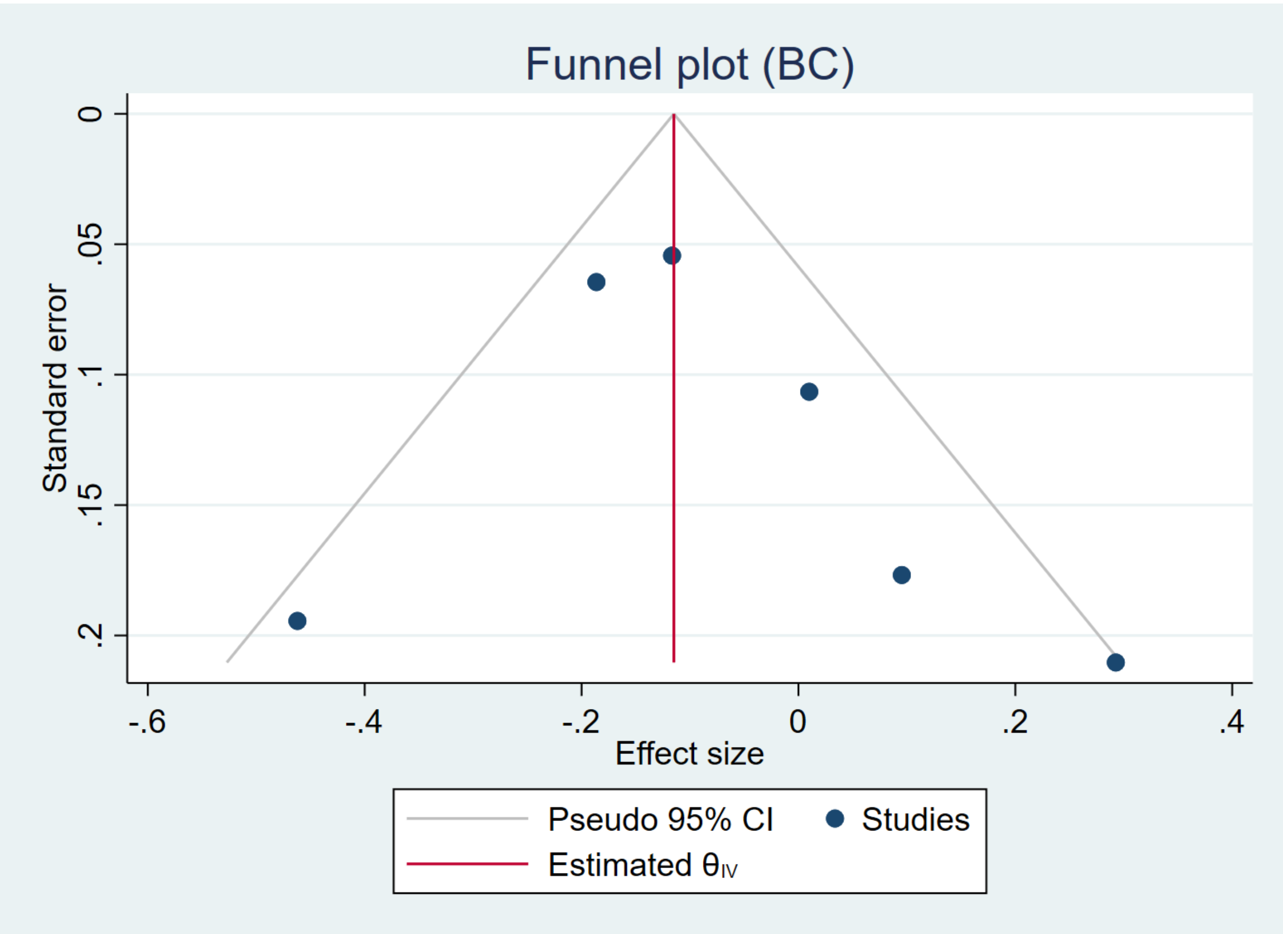


**Figure S3.** Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of breast cancer (BC)

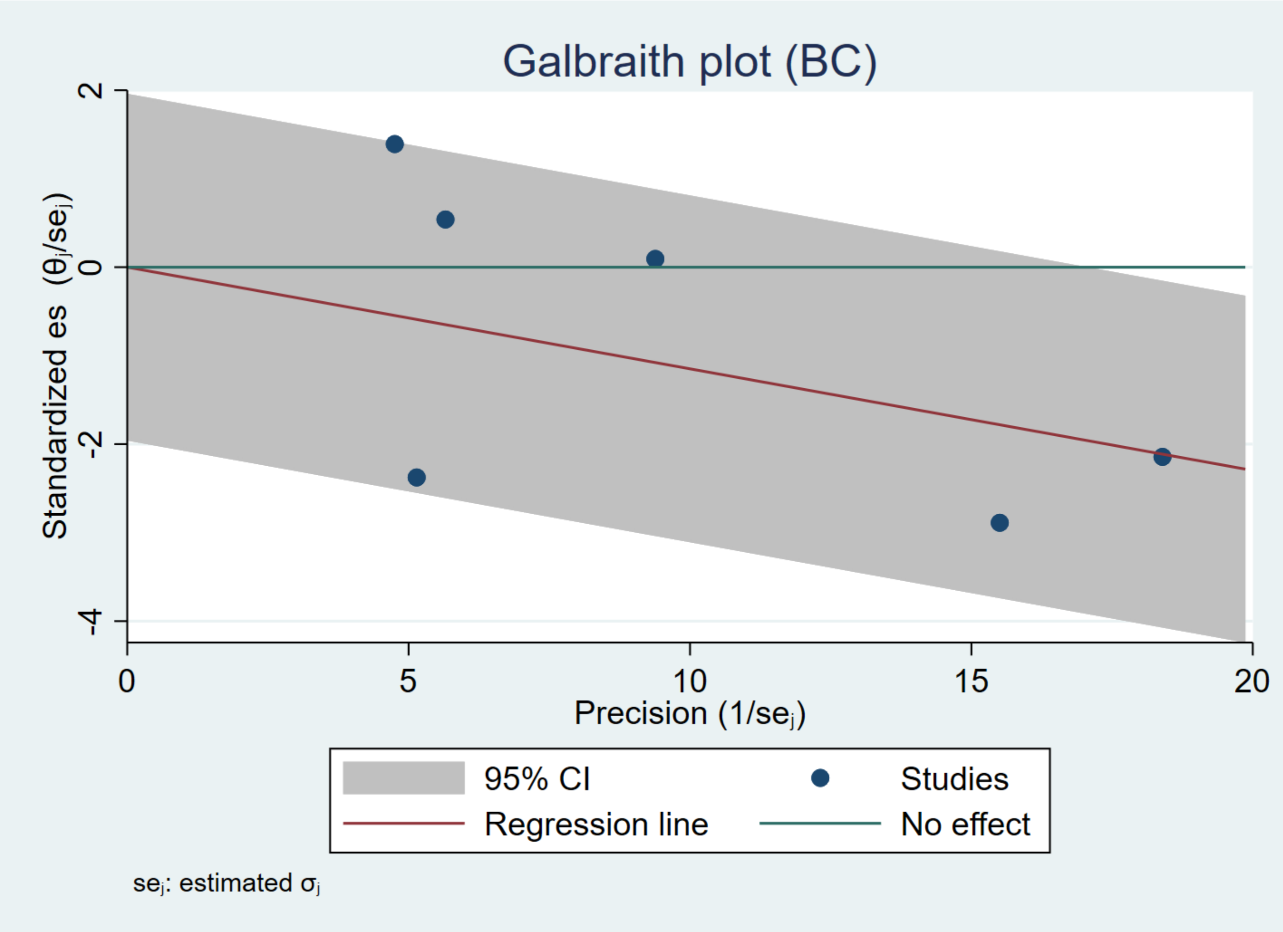



**Figure S4.** Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of cervical cancer (CC)

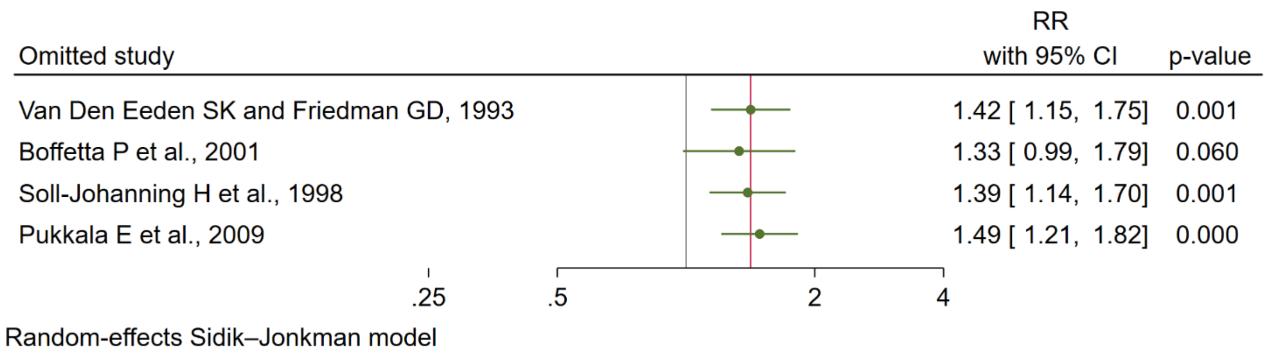


**Figure S5.** Funnel plot of the analysis on occupational diesel exhaust exposure and risk of cervical cancer (CC)

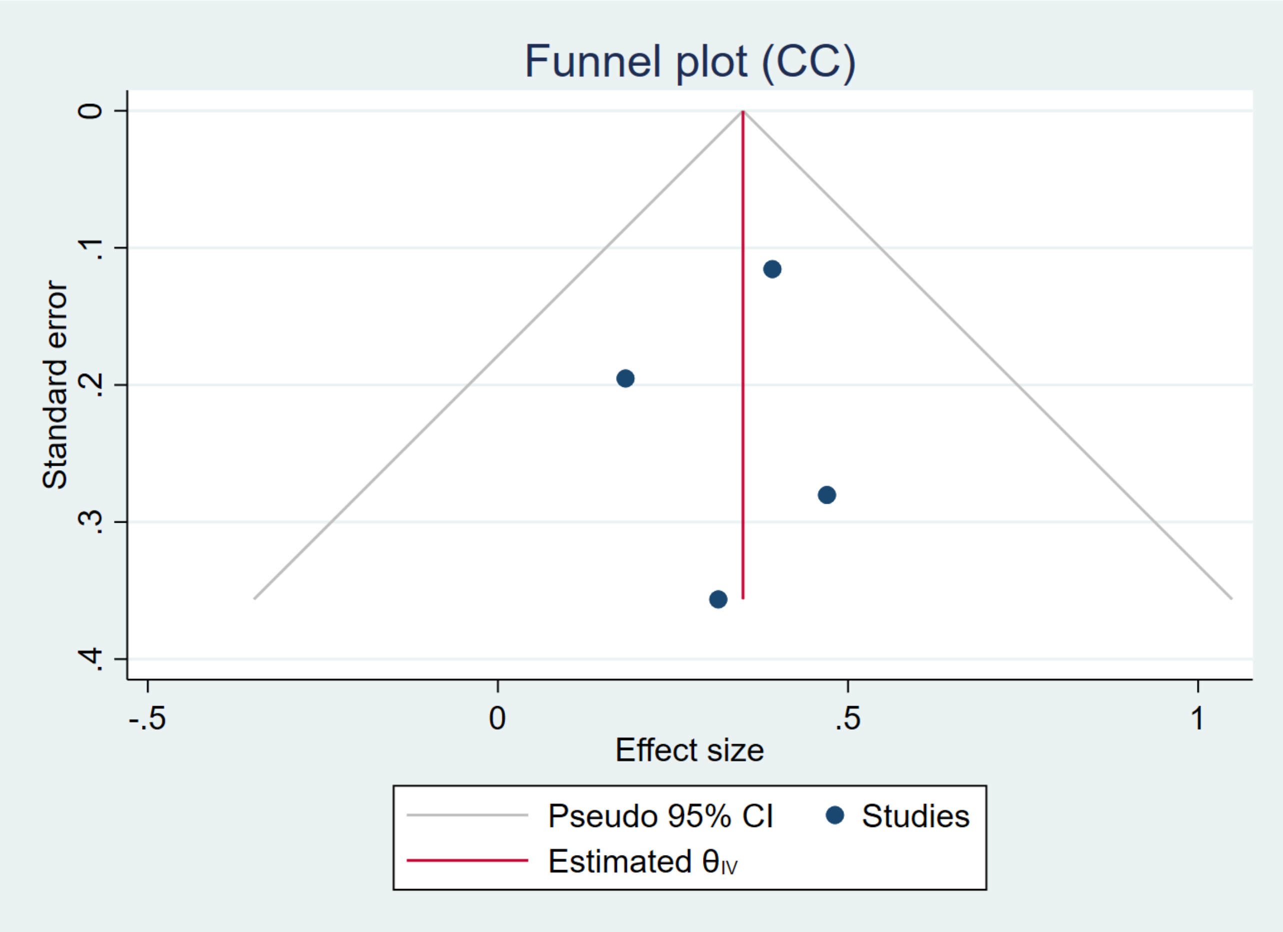



**Figure S6.** Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of cervical cancer (CC)

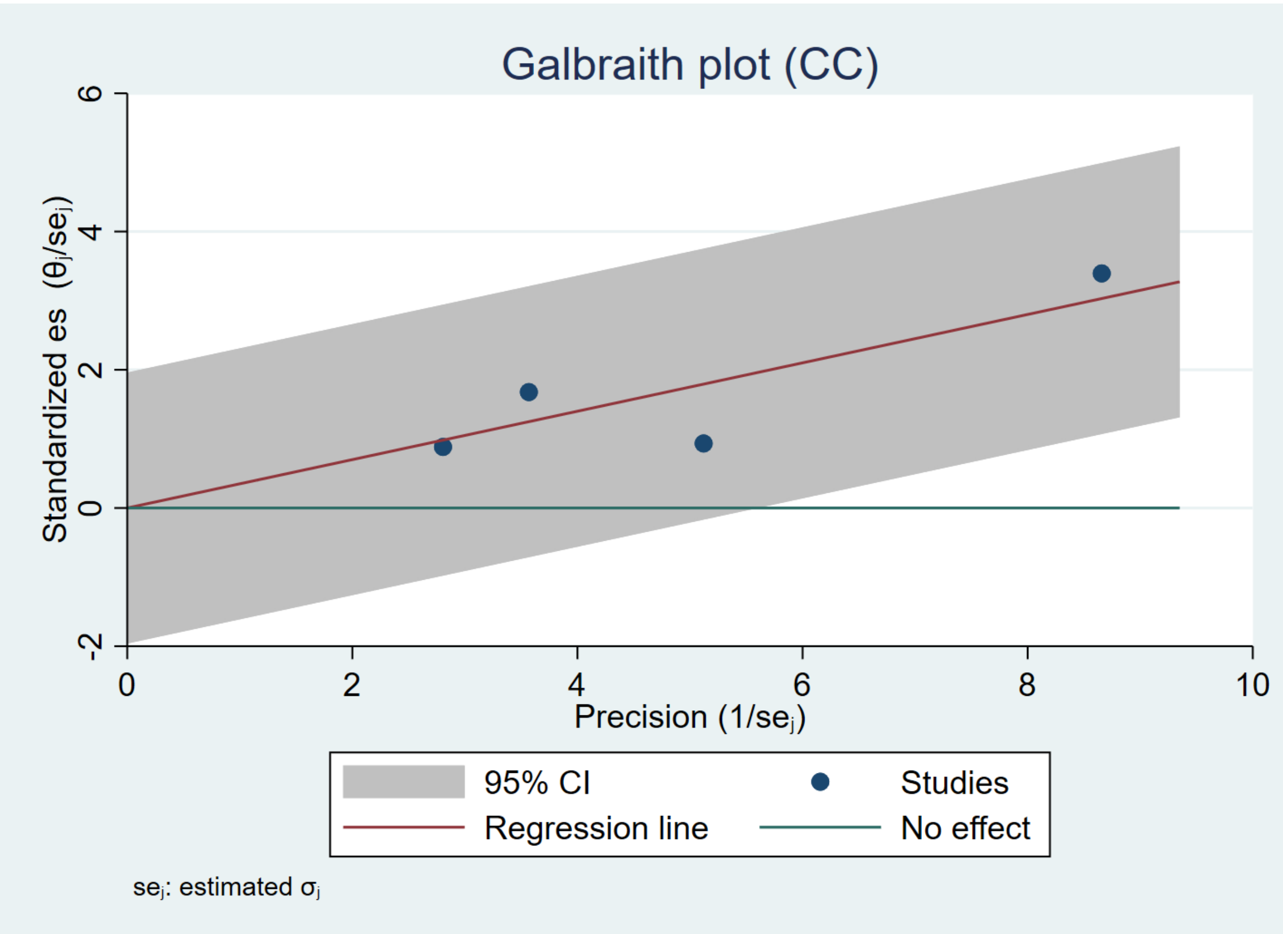


**Figure S7.** Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of endometrial cancer (EC)

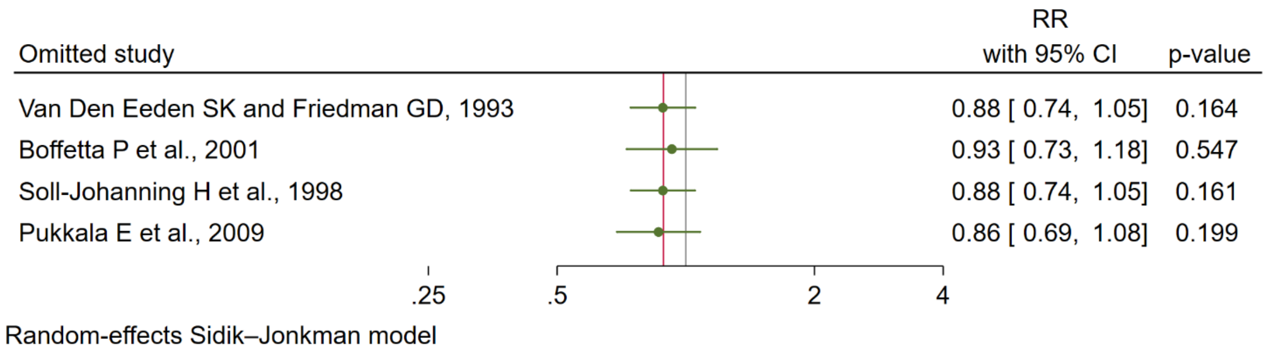



**Figure S8.** Funnel plot of the analysis on occupational diesel exhaust exposure and risk of endometrial cancer (EC)

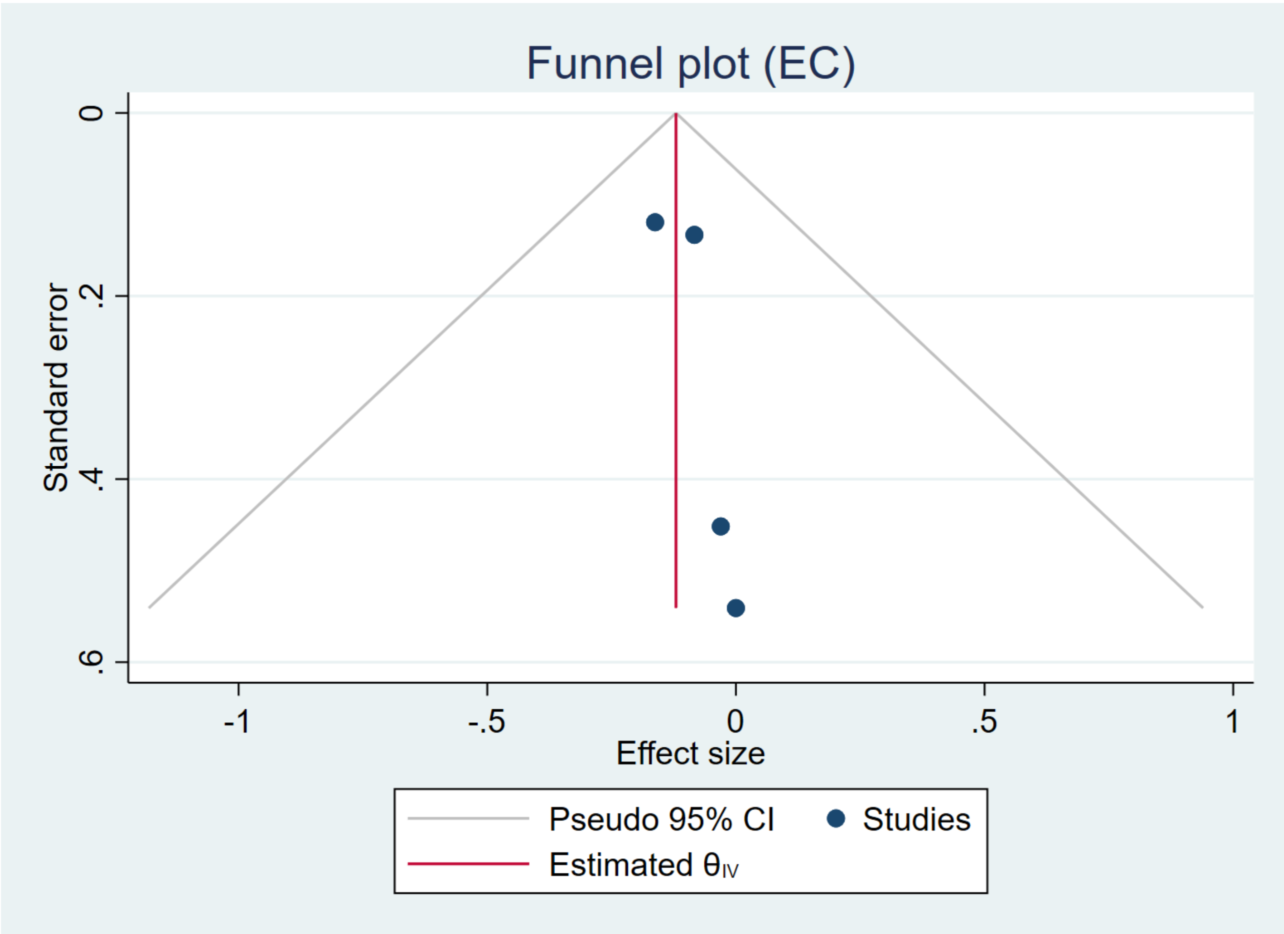


**Figure S9.** Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of endometrial cancer (EC)

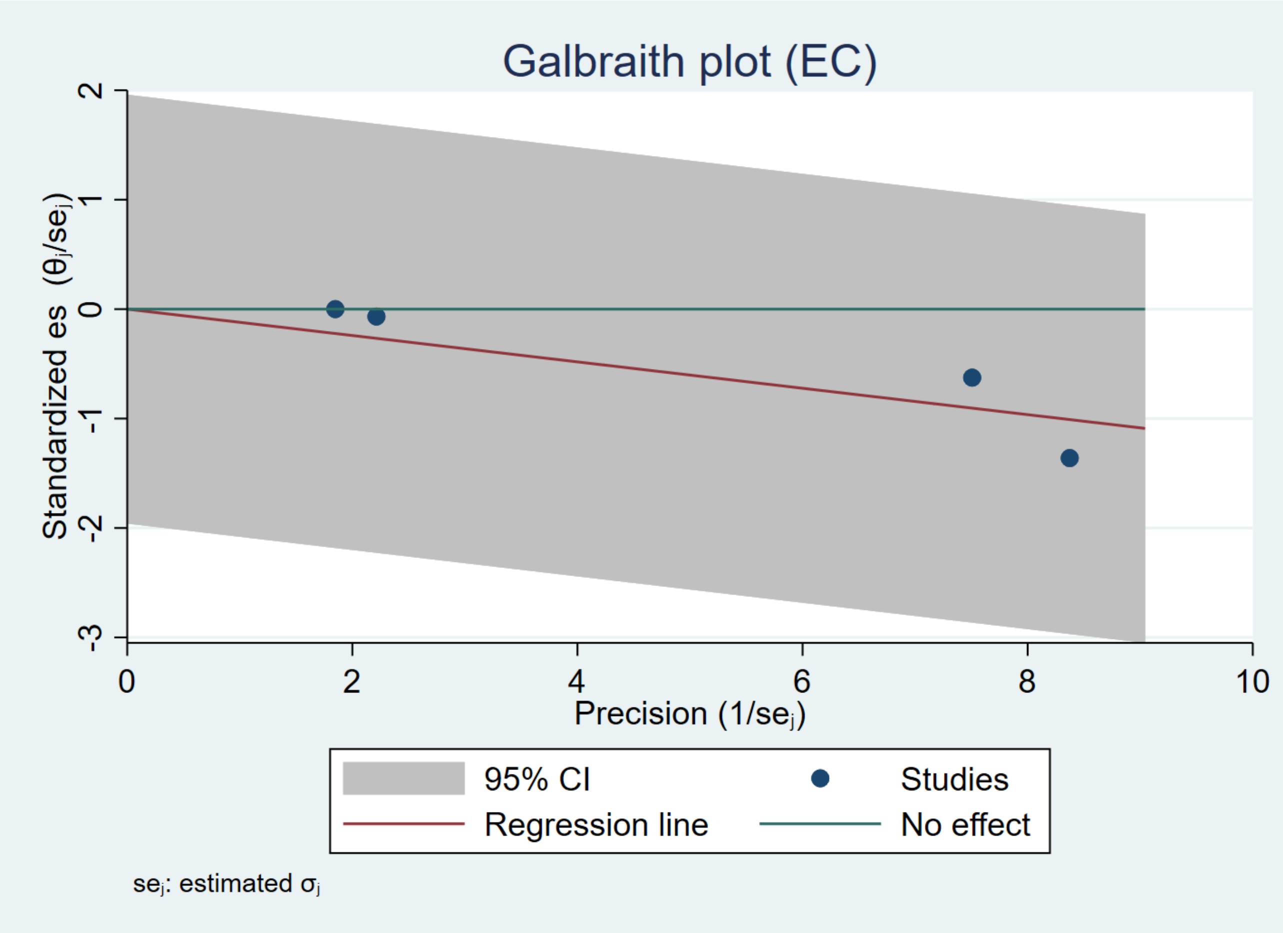



**Figure S10.** Forest plot of the leave-one-out meta-analysis of cohort studies on occupational diesel exhaust exposure and risk of ovarian cancer (OC)

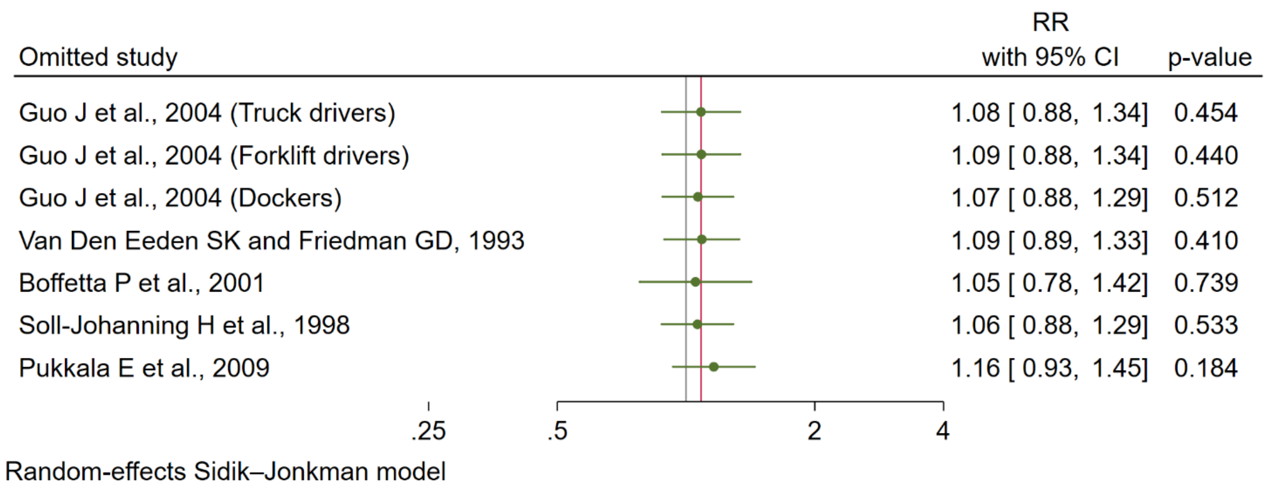


**Figure S11.** Funnel plot of the analysis on occupational diesel exhaust exposure and risk of ovarian cancer (OC)

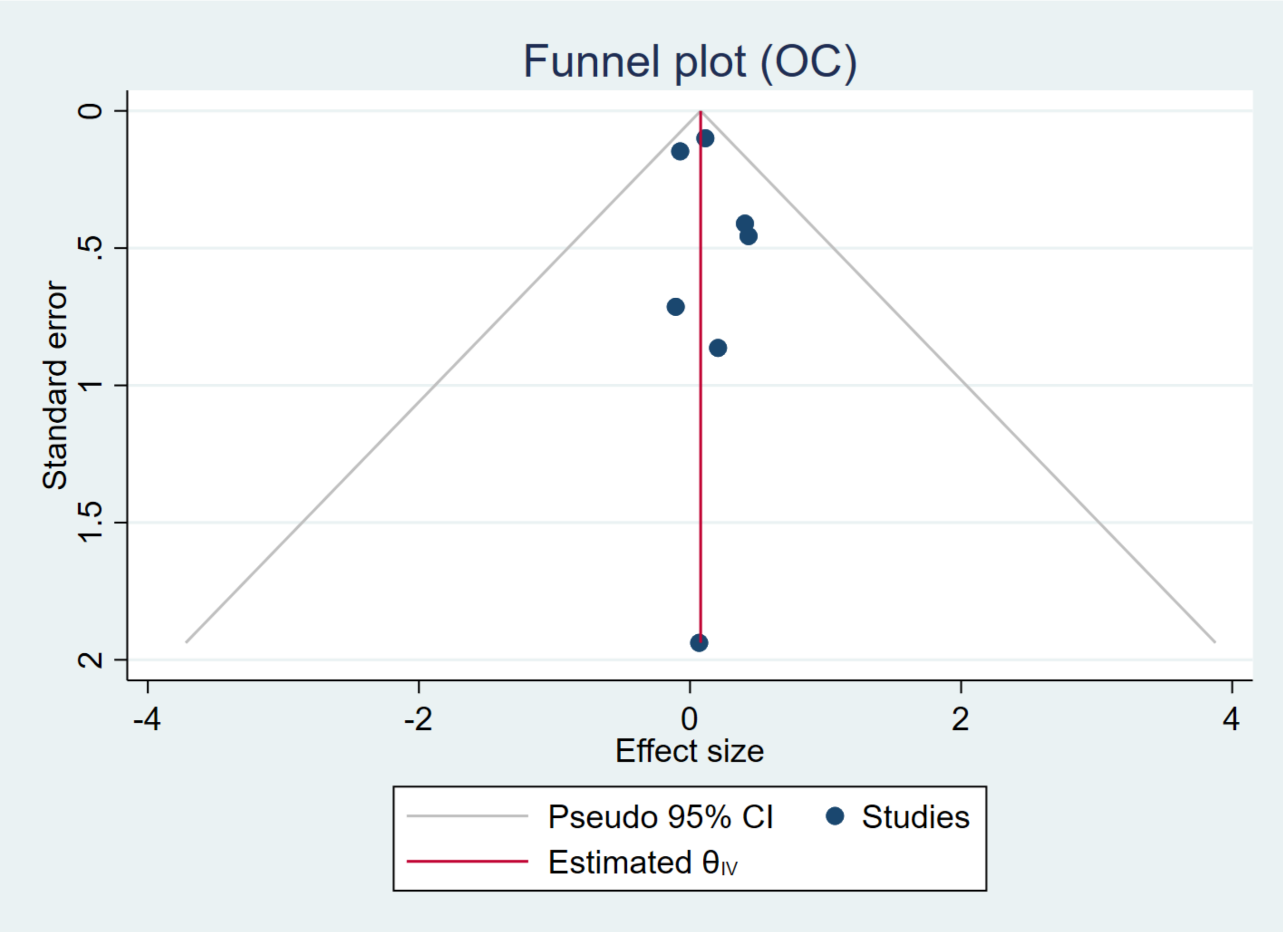
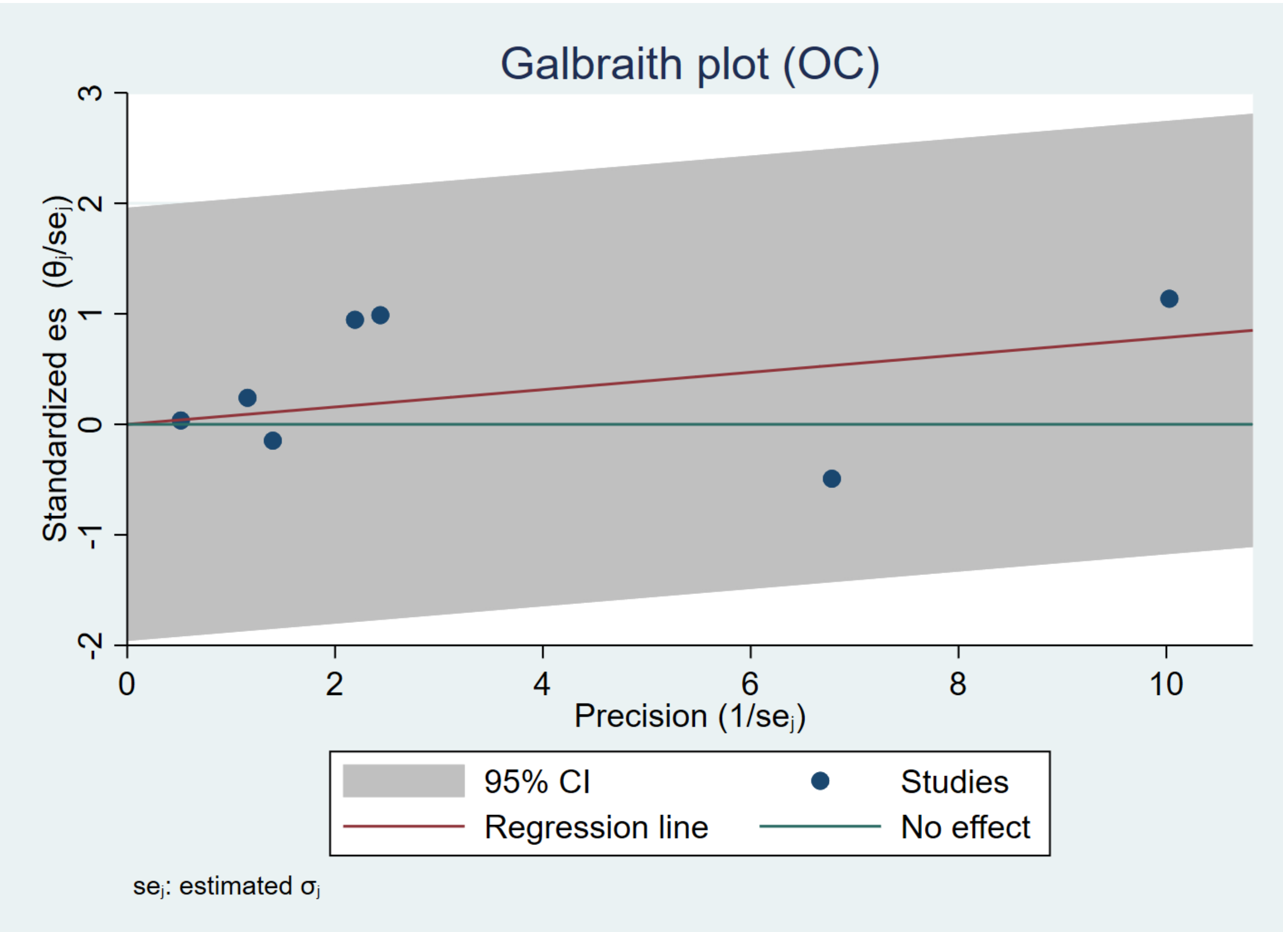



**Figure S12.** Galbraith plot of the analysis on occupational diesel exhaust exposure and risk of ovarian cancer (OC)



La Medicina del Lavoro

Original article

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# Benzene Exposure in Workers From a Waste Oil Regeneration Plant During Ordinary Activities by Air and Biological Monitoring

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**Keywords:** Urinary Benzene; S-Phenyl Mercapturic Acid; Oil Regeneration; Biological Monitoring; Biomarkers; Exposure Assessment; Circular Economy; Green Jobs

**Abstract**

**Background:** *In the regeneration of waste oil, a strategical technological process for the European Union circular economy action plan, exhausted oils are regenerated to produce high performing oil bases. Aim of this work was to assess the exposure to benzene in plant workers during ordinary activities.* **Methods:** *59 workers, potentially exposed to benzene, and 9 administrative workers from an Italian plant were monitored for the whole work shift with personal air samplers; urinary benzene (BEN-U) and S-phenyl mercapturic acid (SPMA) were measured by mass spectrometry methods in end-shift urine samples. Different job tasks were identified among workers.* **Results:** *Median (minimum-maximum) airborne exposures to benzene were <0.9 (<0.9-6.3) and <0.9 (<0.9-0.9) µg/m$^3$, BEN-U and SPMA levels were 0.094 (<0.015-3.095) µg/L and 0.15 (<0.10-9.67) µg/g crt and 0.086 (0.034-0.712) µg/L and <0.10 (<0.10-3.19) µg/g creatinine in workers and administrative workers, respectively. No differences were found among job tasks and between workers and administrative workers, while higher levels were found in smokers than in non-smokers. For all job tasks, the exposure to benzene was always below occupational limit values.* **Conclusions:** *This study has investigated for the first time the exposure to benzene of workers employed in the re-refining of exhaust oil. The results showed that normal production activities in regenerating used oils do not pose a risk of exposure to benzene in workers.*

## 1. Introduction

Lubricating oils are liquid mixtures used in several industrial sectors for the lubrication of mechanical parts, to prevent metal-to-metal contact, remove contaminants, cool machine surfaces, remove wear debris, and transfer power.

The main component of lubricating oil is represented by the base oil (53-99% in volume), which can be produced either by chemical synthesis (synthetic oils, such as polyalphaolefins) or by distillation from crude oil (mineral oils). To meet the desired characteristics for specific uses, several additives are added to the base oil (generally present from 1 to 30% by volume), such as antioxidants, anti-wear agents, detergents, and dispersants [1].

Due to mechanical stress, the possibly high operating temperatures and pressure, and the contact

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with engine parts, lubricating oils undergo additive depletion and dilution with several contaminants, including water, chlorides, antifreeze, fuel, light hydrocarbons, metals, solids, sulphur, mono-aromatic and polycyclic aromatic hydrocarbons [1, 2]. Waste oils are considered hazardous waste with dangerous properties and are managed in Europe according to the Waste Framework Directive 2008/98/EC, following the repeal of the Waste Oils Directive 74/439/EEC [3]. In particular, the directive 2008/98/EC stipulates that waste oil must be treated, prioritising regeneration or alternatively to other recycling operations (i.e. preparation of fuels, energy recovery, and hazardous waste incineration) delivering an equivalent or a better overall environmental outcome than regeneration. Besides, as recently underlined by the European Union Green Deal and Circular Economy Action Plan [4], oil regeneration has become a key technological process for Europe.

Various industrial processes may be used for waste oil regeneration (also called re-refining), including high-pressure hydrogenation, distillation, acid/clay process, and extraction with compressed propane. Distillation processes, in particular, may use different combinations of vacuum and atmospheric pressure distillation [5].

A national consortium for the management, collection, and treatment of mineral waste oils (CONOU) operates in Italy, with the main tasks of ensuring and promoting waste oil collection throughout the national territory and ensuring that the waste oils collected are sent to the most appropriate treatment and primarily to re-refining for the production of base oils. About 93% of the collectable waste oil was collected in 2017 in Italy, while the amount of regenerated oil placed on the market in 2018 was about 400,000 tonnes, 46.7% of lubricant oils. Up to 100% of the waste oil collected in Italy is regenerated to produce re-refined base oil, while only minimal amounts go to energy recovery or incineration, making Italy one of the leading countries in Europe in this field [5].

Given the strategical role in de-carbonising the economy and minimising the generation of waste and pollution [6], oil regeneration activities are acknowledged among the so-called green jobs. However, workers in the green industries may face hazards that are commonly known in classical workplaces [7]. Given the hazardous properties of waste oils, workers employed in plants dealing with its regeneration may be exposed to several chemical contaminants. Among these, benzene is of particular relevance for its toxicological properties.

Benzene is a known carcinogen to humans (group1) [8] and it is a category 1A (H350) carcinogen according to the European Commission (EU) [9]. To protect workers' health from the occupational exposure to benzene, the EU revised the former limit value of 3300 $\mu g/m^3$ (1 ppm) [10] and set a revised limit value of 660 $\mu g/m^3$ (0.2 ppm) to enter in force on 5 April 2026 [11]. As a transitional measure, the limit value of 1 ppm should continue to apply until 5 April 2024 and a transitional limit value of 0.5 ppm (1650 $\mu g/m^3$) should apply from 5 April 2024 until 5 April 2026 [11]. For the biological monitoring of benzene, the measurement of S-phenylmercapturic acid (SPMA) in end-of-shift samples is recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) [12], while the measurement of urinary benzene (BEN-U) has also been proposed as a sensitive and specific marker of exposure to benzene by the German Deutsche Forschungsgemeinschaft (DGF) and by the European Chemicals Agency (ECHA] [13, 14].

The aim of this study was to assess the exposure to benzene in workers employed in a regeneration plant in Italy during normal activities by personal exposure air sampling and biological monitoring of SPMA and BEN-U.

## 2. Methods

### 2.1. Study Population

The study was performed from June 15 to 28, 2017, in a plant for the regeneration of exhaust oil in the province of Lodi (Italy). The plant's total treatment capacity is around 200,000 tonnes per year, and it produces mainly regenerated lube bases, diesel oil, and a mixture for applications in bituminous membranes.

The study population consisted of 68 healthy adults, among which 59 were plant workers (here referred to as "workers"), and 9 were workers from the administrative staff of the same plant (administrative workers). Based on job tasks, different working units were identified, including exhaust oil receiving (REC), remote and on-site plant control (PLANT), plant maintenance supervising (MAN), exhaust and regenerated oil quality controls (LAB), and regenerated oil storage and delivery (DEL). Workers involved in the remote and on-site plant control worked in 8-h shifts throughout the 24 hours (day: 8:00 a.m.-4:00 p.m., afternoon: 4:00 p.m.-24:00 p.m.; night: 24:00 p.m.-8:00 a.m.), while the other workers and the administrative staff worked 8-h day shifts (typically 7:00 a.m.-3:00 p.m. or 8:00 a.m.-4:00 p.m.). Samplings were performed in all shifts, including 1 afternoon-, 2 night-, and 4 day-shifts. All workers wore protective equipment (overall, gloves, helmet, and safety shoes). Workwear is changed weekly or at the worker's convenience, if necessary, and a laundry service exists.

Data regarding personal characteristics, health status, active and environmental tobacco smoke, diet, lifestyle (commuting time and means of transport; car refuelling, use of solvents, dyes or paints in the spear time, and biomass burning in the previous 24 hours), and residential characteristics (rural, urban peripheral, or urban area, presence of industrial sites near residence, intensity of traffic at residence, presence of a car garage linked to house) were collected by a questionnaire administered by trained interviewers.

All the operations related to the sampling during the monitoring campaign were carried out in a clean room located in the plant's administration building.

## 2.2. Personal Exposure to Benzene

Individual personal exposure to airborne benzene (BEN-A) was monitored for the whole shift. Air was sampled using the passive sampler Radiello equipped with a 35-50 mesh charcoal cartridge (Merck, Milano, Italy). Workers wore the sampler on their upper chest, near their respiratory zone. At the end of the sampling period, the cartridge was sealed in the appropriate glass tube and stored in a clean box at room temperature until analysis. Cartridges were analysed within 30 days of collection, according to the manufacturer's instructions.

Airborne benzene was measured by gas chromatography coupled to mass spectrometry (GC-MS) [15]. Quantification limit (LOQ) was 16 μg/L. Considering the average sampling time and the uptake rate of airborne benzene, this concentration was estimated to correspond to airborne levels of 0.9 μg/m$^3$.

## 2.3. Urine Samples Collection and Analysis

Urine spot samples were collected in disposable polyurethane tubes at the end of the shift on the same day of the air sampling. A disposable syringe was used to immediately place a 7 ml aliquot in a pre-sealed glass storage vial for the determination of urinary benzene, while a 10 ml aliquot was poured in a polyethylene tube for the determination of SPMA, cotinine, and creatinine (crt). Samples were immediately stored at -20°C and delivered frozen to the laboratory at the end of the survey. All aliquots were kept at - 20°C and analysed, according to biomarkers' stability, within 60 days. Samples were coded and then handled without knowledge of their origin.

Urinary benzene (BEN-U) was determined by headspace solid-phase microextraction (HS-SPME) followed by GC-MS analysis according to according to a published method [16]. The LOQ for BEN-U was 10 ng/L. The urinary SPMA was determined by a liquid chromatography-tandem mass spectrometry (LC-MS/MS) method [17]. The LOQ was 0.01 μg/L. Urinary cotinine (COT-U), a biomarker of tobacco smoking, was measured by LC-MS/MS. The LOQ was 0.1 μg/L [18]. Subjects with COT-U below 30 μg/L were classified as 'nonsmokers', while subjects with COT-U equal to or above 30 μg/L were classified as 'smokers' [19]. Jaffe's colourimetric method determined urinary creatinine (crt) [20]. No criteria of acceptability based on urine dilution were applied.

For each analyte, calibration curves covering the expected range of concentrations were used. Two concentrations from the low and middle of the calibration curve for each analyte were used as internal quality control (QC) samples. A calibration curve was run with every set of unknown samples, so the typical analytical sequence was defined as a calibration curve followed by the unknown samples (n=20) prepared and analysed along with two duplicates (unknown samples randomly chosen) and two QC samples. Moreover, the quality control of the method to quantify BEN-U, SPMA, and COT-U is guaranteed by the successful participation twice a year to the German External Quality Assessment Scheme (G-EQUAS) for analyses in biological materials [21].

### 2.4. Statistical Analysis

Statistical analysis was performed using the SPSS 28.0 package for Windows (SPSS Statistics, IBM Italia). Descriptive analyses were used to obtain the median and ranges of ambient and biological analytes. A value corresponding to one-half of the quantification limit was assigned to measurements below analytical quantification. Additional statistical analyses were performed on decimal log-transformed to ensure normal distribution. Student's t-test or analysis of variance was applied to compare two or more groups of independent samples, Pearson's correlations were used to test the associations between variables, and the chi-square test was used to compare the percentage distribution of positive values among groups. The raw values calculated from the integration of analytical peaks were used unchanged instead of applying substitution methods (e.g., fractions of the quantification limit) to avoid substantial bias by substitution [22]. The chi-square test was used for analytes with less than 50% of the data above the LOQ.

## 3. Results

### 3.1. Study Population

Table 1 reports the main characteristics of the investigated population. Subjects were predominately males, with only 4 female workers (2 among the administrative staff and 2 among the LAB unit). Of 59 plant workers, 4 were from the REC, 6 from the DEL, 6 from the LAB, 8 from the MAN, and 35 from the PLANT unit. The mean age (46 vs. 46 years) and BMI (26.2 vs. 26.1 kg/m$^2$) were similar between administrative and plant workers. According to the questionnaire, subjects classified themselves as non-smokers (67 and 54% among administrative and plant workers, respectively), traditional cigarette smokers (33% and 32%), or e-cig smokers (12%, all plant workers). Median COT-U levels in administrative and plant workers were 0.38 and 0.35 µg/L in non-smokers, 2023 and 1554 µg/L in smokers, and 1530 µg/L in e-cig smokers, respectively. The COT-U measurements were consistent with the smoking status self-classification. In smokers, the mean number of cigarettes/day was 12 and 13, the mean number of cigarettes smoked before the shift was 1 and 2, while the mean number of cigarettes smoked during the shift was 4 and 5, in administrative and plant workers respectively.

### 3.2. Personal Exposure to Benzene

Table 2 reports the results of the personal exposure to benzene. Samples were available for 67% and 89% of administrative and plant workers, respectively. The median sampling time was 402 minutes (min 222, max 480 minutes).

Air benzene was detectable only in 17 and 44% of samples, with median (minimum-maximum) levels <0.9 (<0.9-0.9) µg/m$^3$ and <0.9 (<0.9-6.3) µg/m$^3$ in administrative and plant workers. One subject from the PLANT unit, with BEN-A > 30 µg/m$^3$, was excluded from the statistical elaboration, as this value was considered an outlier due to probable sample contamination. No significant difference was found (p-value for $\chi$-test= 0.179) between plant workers and administrative workers and comparing the different job tasks among plant workers (p-value for $\chi$-test= 0.102).

Figure 1 shows the distribution of benzene exposure in workers and administrative staff in comparison with the EU occupational limit values for benzene (3300, 1650, and 660 µg/m$^3$) and the European air quality target value as a mean calendar year limit (5 µg/m$^3$). All subjects had benzene exposure below these limits, but one subject from the REC unit had benzene exposures above 5 µg/m$^3$ (6.3 µg/m$^3$).

**Table 1.** Summary of selected characteristics in all subjects and in subjects stratified according to their job.

| | | Amministrative workers | Plant workers | Plant Units | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | REC | DEL | LAB | MAN | PLANT |
| **Number of subjects,** N | | 9 | 59 | 4 | 6 | 6 | 8 | 35 |
| **Male sex,** N (%) | | 7 (78) | 57 (97) | 4 (100) | 6 (100) | 4 (67) | 8 (100) | 35 (100) |
| **Age,** mean (min-max) year | | 46 (31-59) | 46 (27-62) | 48 (37-62) | 52 (45-62) | 49 (41-53) | 46 (33-51) | 44 (27-56) |
| **BMI,** mean (min – max) kg/m$^2$ | | 26.2 (21.4-37.0) | 26.1 (19.0-34.3) | 24.2 (19.0-27.7) | 27.9 (24.7-30.3) | 24.6 (20.8-29.4) | 25.5 (19.6-29.4) | 26.4 (21.0-34.3) |
| **Smoking habit, N (%)** | **non-smoker** | 6 (67) | 32 (54) | 2 (50) | 4 (67) | 5 (83) | 5 (62) | 16 (46) |
| | **e-cig smoker** | 0 (0) | 7 (12) | 0 (0) | 0 (0) | 0 (0) | 2 (25) | 5 (14) |
| | **cigarette smoker** | 3 (33) | 19 (32) | 2 (50) | 2 (33) | 1 (17) | 1 (13) | 13 (37) |
| | **missing** | 0 | 1 (2) | 0 | 0 | 0 | 0 | 1 (3) |
| **Cigarette/day**[a]**,** mean (min – max) N | | 12 (2-20) | 13 (3-25) | 14 (12-15) | 7 (3-10) | 8 | 20 | 15 (4-25) |
| **Cigarettes smoked before the shift,** mean (min – max) N | | 1 (1-2) | 2 (0-10) | 2 (1-2) | 2 (1-2) | 1 | 3 | 3 (0-10) |
| **Cigarettes smoked during the shift,** mean (min – max) N | | 4 (1-6) | 5 (0-10) | 6 (5-7) | 4 (2-5) | 3 | 5 | 6 (0-10) |
| **COT-U,** µg/L median (min-max); % > LOQ | **non-smoker** | 0.38 (<0.1-1.11); 83 | 0.35 (<0.1-3.05); 69 | 1.02 (0.84-1.19); 50 | 0.20 (<0.1-1.74); 50 | 0.60 (0.15-1.45); 80 | <0.1 (<0.1-1.48); 40 | 0.27 (<0.1-3.05); 69 |
| | **e-cig smoker** | - | 1530 (1108-2794); 100 | - | - | - | 2082 (1530-2634); 100 | 1442 (1108-2794); 100 |
| | **cigarette smoker** | 2023 (1789-2246); 100 | 1554 (401-4915); 100 | 2900 (1796-4020); 100 | 827 (687-968); 100 | 675 (100) | 3619 (100) | 1554 (401-4915); 100 |

*REC= exhaust oil receiving, PLANT= remote and on-site plant control, MAN= plant maintenance supervising, LAB= oil quality control, DEL= regenerated oil storage and delivery.*
*a= only for cigarette smokers*

**Table 2.** Personal exposure to airborne pollutants and concentrations of urinary biomarkers in all subjects and in subjects stratified according to their job and to their smoking habit.

| | | Administrative workers | Plant workers | Plant Units | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | **REC** | **DEL** | **LAB** | **MAN** | **PLANT** |
| | | **Personal monitoring** | | | | | | |
| **Number of samples, N (%)** | | 6 (67) | 52 (88) | 4 (100) | 6 (100) | 6 (100) | 6 (75) | 30 (86) |
| **Benzene μg/m$^3$ median (min-max); % > LOQ** | | <0.9 (<0.9-0.9); 17 | <0.9 (<0.9-6.3); 44 | 1.3 (<0.9-6.3); 50 | <0.9 (<0.9-2.1); 33 | <0.9 (<0.9-<0.9); 0 | <0.9 (<0.9-1.7); 33 | 1.0 (<0.9-3.9); 57 |
| | | **Biological monitoring** | | | | | | |
| **Number of samples, N (%)** | | 9 (100) | 58 (98) | 4 (100) | 6 (100) | 6 (100) | 8 (100) | 34 (97) |
| **BEN-U μg/L median (min-max); % > LOQ** | **All** | 0.086 (0.034-0.712); 100 | 0.094 (<0.015-3.095); 89 | 0.569 (0.111-2.373); 100 | 0.137 (0.039-0.956); 100 | 0.043 (0.017-0.094); 100 | 0.073 (0.051-2.402); 100 | 0.101 (<0.015-3.095); 97 |
| | **Non- smokers** | 0.073 (0.034-0.209); 100 | 0.061 (<0.015-0.245); 78 | 0.122 (0.111-0.132); 100 | 0.083 (0.039-0.179); 100 | 0.041 (0.017-0.046); 100 | 0.081 (0.051-0.101); 100 | 0.059 (<0.015-0.245); 94 |
| | **e-cig smokers** | - | 0.064 (0.046-0.893); 100 | - | - | - | 0.062 (0.060-0.064); 100 | 0.065 (0.046-0.893); 100 |
| | **smokers** | 0.238 (0.108-0.712); 100 | 0.885 (0.045-3.095);100 | 1.689 (1.005-2.373); 100 | 0.824 (0.692-0.956); 100 | 0.094 (0.094-0.094); 100 | 2.402 (2.402-2.402); 100 | 0.875 (0.045-3.095); 100 |
| **SPMA μg/g crt median (min-max); % > LOQ** | **All** | 0.09 (<0.10-3.19); 56 | 0.15 (<0.10-9.67); 68 | 3.13 (<0.10-9.67); 100 | 0.19 (<0.10-1.44); 83 | <0.10 (<0.10-1.81); 17 | <0.10 (<0.10-6.32); 38 | 0.17 (<0.10-8.46); 79 |
| | **Non- smokers** | <0.1 (<0.1-0.13); 33 | <0.1 (<0.1-0.70); 46 | 0.22 (<0.1-0.37); 50 | 0.15 (<0.1-0.30); 75 | <0.1 (<0.1-<0.1);0 | <0.1 (<0.1-0.70); 20 | <0.1 (<0.1-0.33); 53 |
| | **e-cig smokers** | - | 0.14 (<0.1-0.35);86 | - | - | - | 0.10 (<0.1-0.14);50 | 0.16 (0.10-0.35);100 |
| | **smokers** | 1.37 (0.20-3.19);100 | 1.81 (0.12-9.67);100 | 7.78 (5.88-9.67);100 | 0.83 (0.21-1.44);100 | 1.81 (1.81-1.81);100 | 6.32 (6.32-6.32);100 | 0.80 (0.12-8.46);100 |

*REC= exhaust oil receiving, PLANT= remote and on-site plant control, MAN= plant maintenance supervising, LAB= oil quality control, DEL= regenerated oil storage and delivery.*

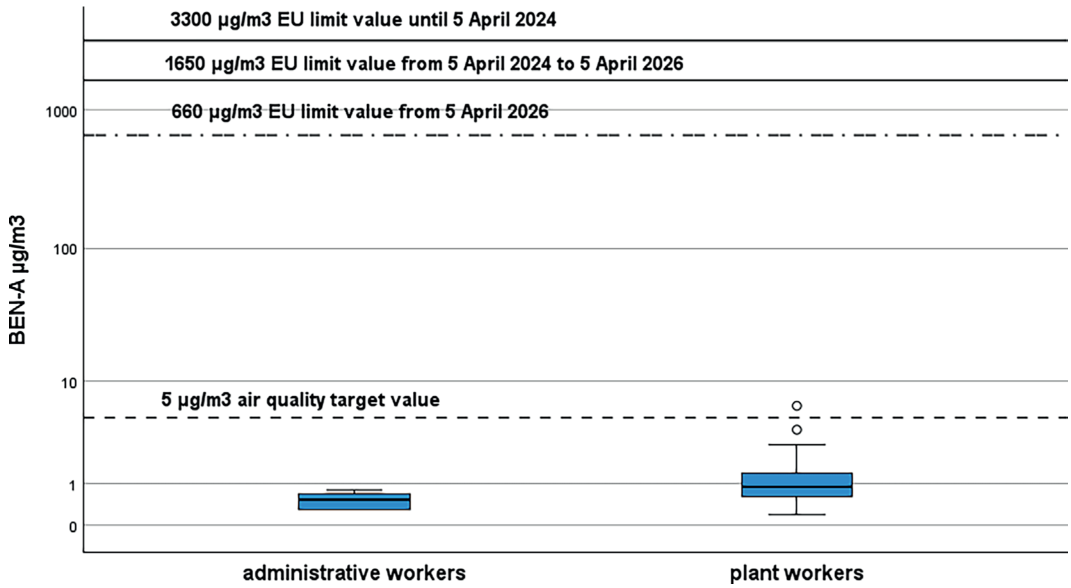


**Figure 1.** Box-plot of the exposure to airborne benzene in the investigated subjects in comparison with the air quality target value (5 µg/m$^3$), and the occupational limit values according to EU Directive 2022/431 (3300, 1650, and 660 µg/m$^3$, corresponding to 1, 0.5, and 0.2 ppm, respectively).

### 3.3. Biological Monitoring

BEN-U and SPMA levels are reported in Table 2. Urinary samples were available for 67 subjects out of 68 workers. Analytes were above the LOQ for 100 and 89% of samples in administrative and plant workers for BEN-U, and in 56 and 68% of samples in administrative and plant workers for SPMA.

Considering all subjects, BEN-U and SPMA median levels were not different between administrative and plant workers (p=0.731 and p= 0.332 for BEN-U and SPMA, respectively). BEN-U and SPMA values were mostly below the respective biological value equivalent (DFG EKA 7.5 µg/L and ECHA BLV 0.7 µg/L for BEN-U; DFG EKA 45 µg/L and ECHA BLV 2 µg/g crt for SPMA) or biological limit value (ACGIH BEI, 25 µg/g crt for SPMA) (Fig. 2 and 3). In workers, no difference was found among the different job tasks.

When considering the smoking habit, both BEN-U and SPMA levels were higher in plant workers smokers of traditional cigarettes (median 0.885 µg/L and 1.81 µg/g crt, for BEN-U and SPMA, respectively) than in non-smokers (0.061 µg/L and <0.1 µg/g crt) and e-cig smokers (0.064 µg/L and 0.14 µg/g crt) (p<0.001), while no difference between non-smokers and e-cig smokers was observed (p=0.708). In administrative workers too, both BEN-U and SPMA levels were higher in smokers of traditional cigarettes (median 0.238 µg/L and 1.37 µg/g crt, for BEN-U and SPMA, respectively) than in non-smokers (0.073 µg/L and <0.1 µg/g crt) (p=0.043 and 0.076) (Fig. 4 and 5). For both BEN-U and SPMA, values in non-smokers were always below the respective ECHA Biological Guidance Value (BGV) (0.3 µg/L for BEN-U and 0.5 µg/g crt for SPMA) [14].

Considering only non-smokers, BEN-U and SPMA levels were no different between administrative and plant workers (p=0.393 and 0.179, respectively) and among job tasks in plant workers (p=0.150 and 0.336, respectively).

### 3.4. Pearson's Correlation

In all subjects, significant correlations were found between BEN-U and SPMA (expressed as a function of creatinine) (r=0.748, p<0.001) and between both biomarkers and COT-U (r=0.648, p<0.001 for BEN-U, and r=0.697, p<0.001 for SPMA,

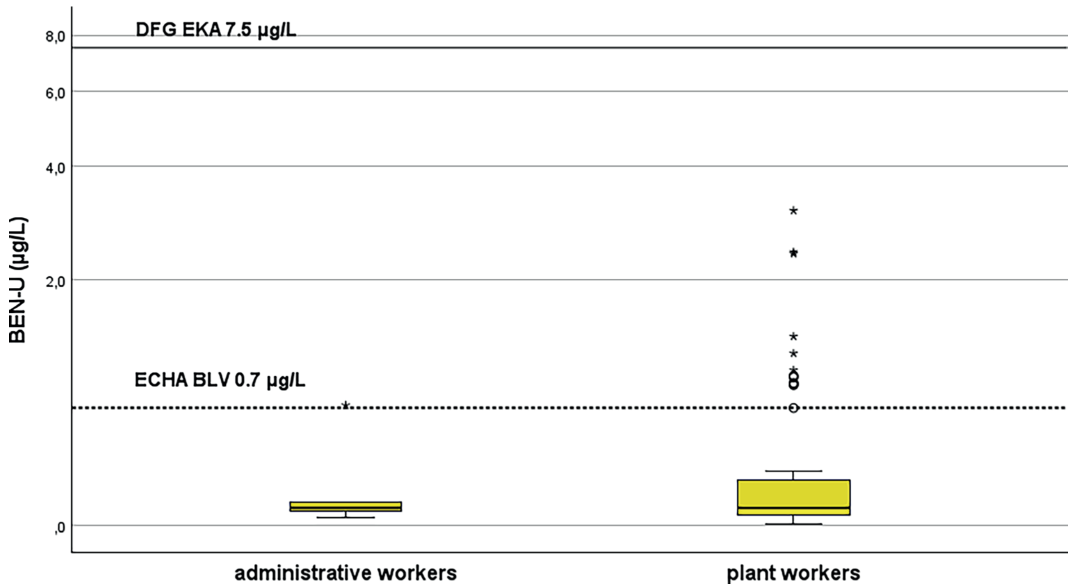


**Figure 2.** Box-plot of urinary benzene (BEN-U) in the investigated subjects in comparison with the DFG EKA value (7.5 µg/L, corresponding to an exposure to 3300 µg/m$^3$) and the ECHA Biological Limit Value (0.7 µg/L, corresponding to an occupational exposure limit of 165 µg/m$^3$ air benzene).

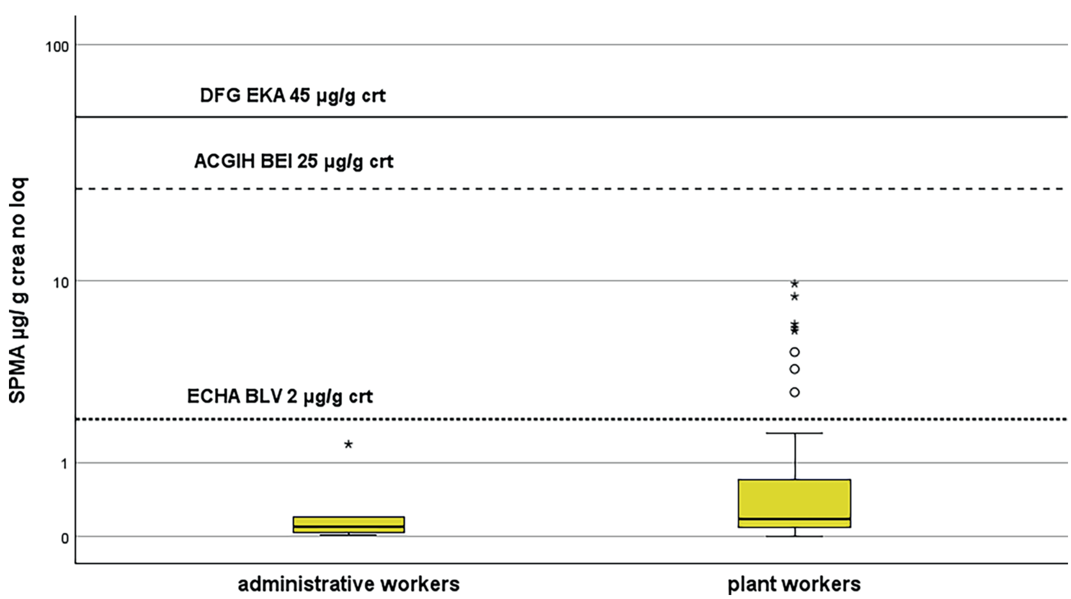


**Figure 3.** Box-plot of SPMA in the investigated subjects in comparison with the DFG EKA value (45 µg/g crt, corresponding to an exposure to 3300 µg/m$^3$), the ACGIH BEI (25 µg/g crt, corresponding to an exposure to 1650 µg/m$^3$) and the ECHA Biological Limit Value (2 µg/g crt, corresponding to an occupational exposure limit of 1650 µg/m$^3$ air benzene).

respectively). A small but significant correlation was found between BEN-A and BEN-U (r=0.283, p=0.033), and between BEN-A and SPMA (r=0.356, p=0.007).

Considering only non-smokers, the correlation between BEN-U and BEN-A (r=0.128, p=0.493) and between BEN-A and SPMA (r=0.323, p=0.082) was lower than considering all subjects.

## 4. Discussion

This study assessed the exposure to benzene of workers employed in the re-refining of exhaust oil by measuring both personal exposure and urinary biomarkers. As far as we know, this is the first time workers from this industrial setting have been investigated.

The exposure to airborne benzene was very low and less than 50% of samples had a measurable concentration. In plant workers, both the median and maximum levels found (<0.9 and 6.3 μg/m$^3$) were more than one thousand times lower than the EU occupational limit value for benzene (3300 μg/m$^3$) (Fig.1), but also far below the revised limit value (600 μg/m$^3$) to enter in force in 2026. Moreover, in all subjects but one, median benzene exposure was also lower than the European air quality target value (5 μg/m$^3$). This result was expected in some way, as worker activities most frequently occurred near closed systems, as it is normally found in refinery plants [23].

However, a higher, even if not significant, proportion of samples had detectable values in plants than in administrative workers, thus showing the possible occurrence of occupational exposure to benzene, although well controlled. Among plant workers, in particular, only workers from the REC and the PLANT unit had quantifiable levels of benzene in at least 50% of samples (Table 2). This could be reconducted to the job tasks of these workers, as REC workers deal directly with the exhaust oil, while PLANT workers may deal with exhaust oil during some specific and short-duration operations, such as the substitution of dirty filters or oil sampling. The exposure to airborne benzene can be considered negligible for LAB workers, for which no samples above the limit of detection were found.

Previous studies on personal exposure to benzene in this setting are not available. However, this peculiar occupational setting can be considered in some way similar to that of the petroleum refinery industry. In this regard, the results of this study are much lower than those reported for workers at four refinery plants in the U.S. (mean value 0.21 ppm or 0.67 mg/m$^3$) [23], at a Swedish plant (mean values 3.6-74.5 μg/m$^3$, depending on the job task) [24], at Italian plants (median 18.5-25 μg/m$^3$) [25, 26], and at offshore oil and gas installations in Norway (geometric mean 12.7 μg/m$^3$) [27]. Some of these studies also reported a percentage of detectable samples below 50% [23, 24].

Biological monitoring of exposure was performed using two biomarkers, SPMA and BEN-U. Both biomarkers are recognised as sensitive and specific biomarkers of benzene exposure and have been used in both occupational and environmental settings [25, 28]. SPMA is recommended by ACGIH, with 25 μg/g crt as BEI equivalent to the threshold limit value (TLV) as the time-weighted average (TWA) during an 8 h work shift of 0.5 ppm benzene [12]. A value of 45 μg/g crt has been proposed by DFG as a biological value equivalent (EKA) for exposure to 3300 μg/m$^3$ (1 ppm) benzene [13], while a value of 2 μg/g crt has been suggested by ECHA as a biological limit value (BLV) corresponding to an occupational exposure limit of 0.05 ppm (160 μg/m$^3$) air benzene [14]. For BEN-U, DFG has proposed a value of 7.5 μg/L as a biological value equivalent (EKA) for an exposure to 3300 μg/m$^3$ (1 ppm) benzene, ECHA has suggested 0.7 μg/L as a BLV corresponding to an occupational exposure limit of 0.05 ppm air benzene, while ACGIH does not lists BEN-U among the recommended biomarkers of exposure for benzene [12, 13, 14].

Median levels in samples from the investigated subjects were 10- to 100-fold lower than the respective limit values, and levels in plant workers were not different from those of the administrative workers, underlying a low and controlled exposure to benzene, in agreement with the airborne measurements. Moreover, for non-smokers, both plant and administrative workers, values were always below the ECHA Biological Guidance Value for non-smokers [14].

Like personal exposure, biological monitoring has never been performed in this industrial setting. Previous studies in petrochemical plants reported

BEN-U median values in the range 0.15-0.31 μg/L (non-smoker workers) [25, 26], similar to our results, and for SPMA in the range 0.10-8.65 μg/g crt [25, 26, 29, 30].

The low but significant associations found between biomarkers and airborne benzene underline the reliability of both biomarkers, even at the low exposure levels reported here. The relatively low correlation coefficients (0.356<r<0.283) are justified, considering that multiple confounders may affect the relationship between air and urinary analytes, especially considering their low levels. We note that the correlation coefficient between BEN-U and BEN-A was similar to what was recently reported for the general population [31].

Moreover, the low biomarker levels and their significant correlations with air levels show that the possible occurrence of dermal exposure to benzene due to contact with dirty materials or to the contamination of workwear has been well controlled. It should be underlined that dermal exposure for these workers was expected to be low as workers may deal directly with exhaust oil or dirty materials only for some specific operations and appropriate personal protective devices (protective overall, gloves, helmet, and safety shoes) were used. This result underlines the benefit deriving from the application of biological monitoring in occupational settings, where differen sources of exposure can occur.

The biochemical verification of the smoking habit through the measurement of COT-U enabled us to quantify the exposure to cigarette smoke. In non-smokers, median and maximum COT-U levels were consistent with no active exposure or with a passive exposure [19]. In cigarette smokers, median (2023 and 1554 μg/L in administrative and plant workers, respectively) and maximum levels (up to 4915 μg/L in plant workers) were indicative of a mean strong or even very strong addiction to nicotine. The same strong addiction was evident in e-cig users, as their median COT-U levels were similar to that of cigarette smokers.

Cigarette smoking had a great impact on biomarker levels, with higher levels of both BEN-U and SPMA in smokers than in non-smokers. For BEN-U, median levels in smokers were almost 10-fold higher than in non-smokers, while for SPMA, median levels in smokers were almost 20-fold higher than in non-smokers (Figures 4 and 5). Moreover, biomarker levels were more frequently detected in smokers than

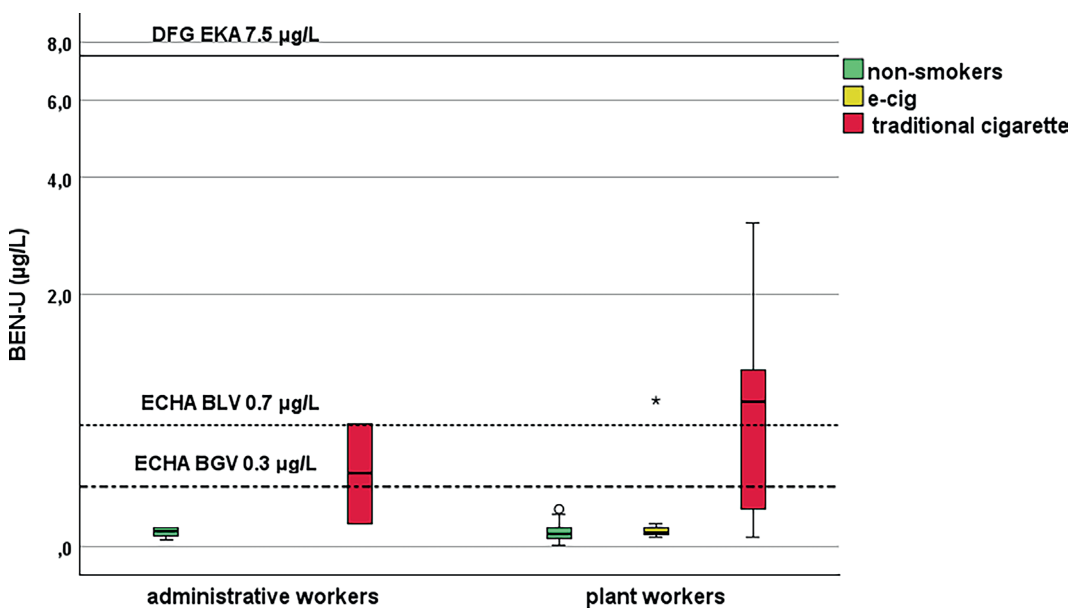


**Figure 4.** Box-plot of urinary benzene in the investigated subjects stratified according to their smoking habit and in comparison with the DFG EKA value (7.5 μg/L, corresponding to an exposure to 3300 μg/m$^3$), the ECHA Biological Limit Value (0.7 μg/L, corresponding to an occupational exposure limit of 165 μg/m$^3$ air benzene), and the ECHA Biological Guidance Value for non-smokers (0.3 μg/L).

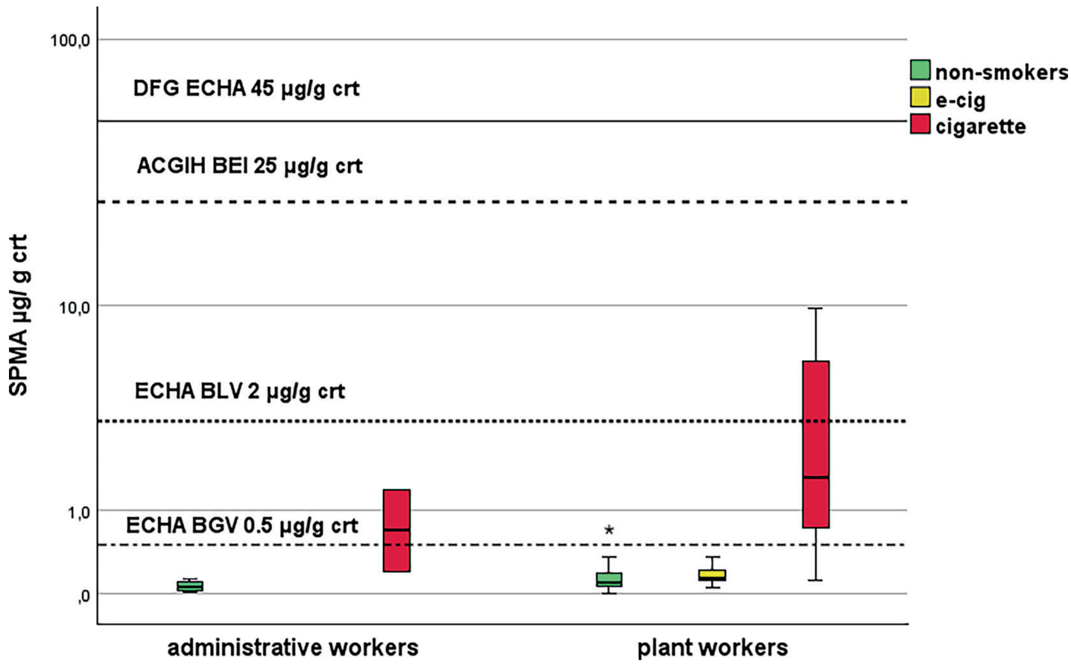


**Figure 5.** Box-plot of SPMA in the investigated subjects stratified according to their smoking habit and in comparison with the DFG EKA value (45 µg/g crt, corresponding to an exposure to 3300 µg/m$^3$), the ACGIH BEI (25 µg/g crt, corresponding to an exposure to 1650 µg/m$^3$), the ECHA Biological Limit Value (2 µg/g crt, corresponding to an occupational exposure limit of 1650 µg/m$^3$ air benzene), and the ECHA Biological Guidance Value for non-smokers (0.5 µg/g crt).

in non-smokers. These results underline the great influence of cigarette smoking on the internal dose of benzene. The presence of a relatively small group of e-cig smokers among workers allowed us to estimate the impact of e-cig use on benzene exposure. Results showed that levels of BEN-U and SPMA in e-cig users were not different than in non-smokers, so a collateral result of this work is the lack of contribution of e-cig vaping to benzene exposure. This is quite expected, as liquids in e-cigs are vaporised at a temperature lower than that reached by burning tobacco in traditional cigarettes, thus leading to a lower emission of combustion by-products than traditional cigarettes, at least for certain toxics [32, 33]. However, given the great variety of e-liquids possibly used by consumers, the variety of e-cig devices and their uses in terms of battery power settings, and the low numbers of e-cig users in this study, this result should be considered cautiously.

The main strength of this work is the comprehensive evaluation of benzene exposure in workers from this peculiar industrial setting by using a combined approach of personal air monitoring and biological monitoring. For the latter, two up-to-date benzene biomarkers were used, leading to reliable results. On the other side, the main limitation of this study is the relatively small number of subjects investigated. However, the number of workers included in the study coincided with the number of workers employed in the plant, and this allowed us to investigate all the different job tasks performed by workers. It should be mentioned that the low number of subjects is a limitation very common in occupational studies that could be tackled only by performing repetitive studies over time.

## 5. Conclusion

In conclusion, this study investigated for the first time the exposure to benzene of workers employed in the re-refining of exhaust oil. The results showed that the exposure to benzene was well controlled and always below the occupational limit values, while the contribution of cigarette smoking to benzene exposure was higher than that of occupational exposure.

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**INSTITUTIONAL REVIEW BOARD STATEMENT:** Ethical review and approval were waived for this study due to the conduction of the research in the frame of the risk assessment activity, according to the Italian legislation D.Lgs. 81/08, for the protection of workers' health, under the supervision of the plant occupational health service. The study has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

**INFORMED CONSENT STATEMENT:** Written informed consent was obtained from all subjects involved in the study.

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# Comparing Exposure to Psychosocial Risks: Face-to-Face Work vs. Telework

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**Keywords:** Psychosocial Risks; Non-Manual Workers; Telework; Face-to-Face Work; Gender; Spain

## ABSTRACT

**Background:** *In recent years, substantial changes have occurred in the work organization and arrangements. One of the main ones has been the popularization of teleworking among non-manual workers. This paper aims to assess the exposure of psychosocial risks among non-manual Spanish wage-earners, depending on the working modality (mainly telework, combining teleworking with onsite work, or onsite work).* **Methods:** *Based on an online survey conducted between April and May 2021, a cross-sectional study was carried out among n=11,519 members of a trade union where Psychosocial Risks (PSR) were measured through COPSOQ Questionnaire Scales. All analyses were performed stratifying by sex.* **Results:** *Women who combine telework and face-to-face work (aPR: 1.21; 95%CI 1.07-1.37) and men who mainly telework (aPR: 1.26; 95%CI 1.11-1.43) and that combine (aPR: 1.27; 95%CI 1.11-1.45) are more exposed to quantitative demands than men and women who do not telework. On the other hand, women who telework, either entirely (aPR: 0.89; 95%CI 0.82-0.97) or combining (aPR: 0.89; 95%CI 0.81-0.98), are less exposed to emotional demands than women who do not telework, and the same occurs among men who mainly telework (aPR: 0.84; 95%CI 0.76-0.92). Telework and horizontal or vertical social support are not associated, except for supervisor support among males, nor with work-life conflict.* **Conclusions:** *Except for quantitative demands, employees who combine telework and face-to-face work are less exposed to psychosocial risks than those who mainly telework or work face-to-face only. More studies with a gender and class perspective are needed in this area.*

## 1. Introduction

The COVID-19 pandemic has profoundly impacted work and non-work roles, fundamentally altering the traditional work environment. With the necessity to adapt to remote work, many workers have had to blur the boundaries between their professional and personal lives, transforming their homes into dual-purpose spaces serving residences and offices [1]. Consequently, a pressing need arises to redefine these boundaries and confront the ensuing challenges to achieve a harmonious work-life balance.

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According to estimates by the Publications Office of the European Union [2], approximately half of Europeans worked remotely, at least partially, in response to the COVID-19 crisis, representing a significant increase from the pre-pandemic figure of 12%. By 2022, however, this proportion has receded to 30% (including hybrid modality).

Digitalization has undoubtedly facilitated greater autonomy and connectivity within the workplace. Still, it may also trigger the "need to work faster and to face tighter deadlines" [3, 4] and potentially increase the risk of presenteeism.

While the trend towards flexible work arrangements has been ongoing for several years, it has accelerated due to the pandemic. New flexible work designs [5] have been implemented. Work flexibility encompasses variations in location (flexplace), work schedule (flextime) [6], and tasks. Research suggests that flextime and flexplace are positively associated with job satisfaction [7, 8], which, in turn, is related to autonomous motivation. Conversely, these flexible arrangements may lead to presenteeism due to chronic illness [9] or infectious illness [10], as workers can fulfil their responsibilities without commuting and without concern for spreading infections to colleagues. Moreover, flextime allows for later starts and earlier finishes, facilitating work even when individuals are partially unwell [11].

The sudden transition to remote work has presented challenges in attaining a work-life balance, mainly due to the diverse experiences resulting from variations in work modalities among household members. These challenges exist alongside more traditional structural factors such as gender and social class [12, 13]. Ultimately, work-life balance reflects the collective outcome of individuals' effectiveness and satisfaction in their professional and personal roles [14].

Research findings regarding vulnerability and health impairment are inconclusive, as both positive and negative effects on workers' health have been observed [15, 16]. This may stem from the risk of work encroaching on non-work time, as work can be conducted from any location without time constraints, thereby facilitating the intrusion of work into non-work hours [17] and hindering a proper split between work and personal time and potentially, which can lead to poor psychological detachment [18]. The possibility of choosing working hours has a minimizing effect on the perception of the mental demands that the job entails [19]. This, combined with the fact that employees often feel "privileged" to have the opportunity to work from home, can lead them to work while ill to maintain this work modality [20]. Consequently, decreases in absenteeism cannot be solely interpreted as indicative of positive health status among teleworkers [21].

Given the existing gaps in the literature, it becomes necessary to obtain evidence of the impact of working from home on the workers' well-being, to understand the current situation better, and to design suitable and efficient strategies to improve their lives and working conditions. Hence, this study aims to evaluate the exposure to psychosocial risks among non-manual wage-earning workers in Spain, explicitly emphasizing working modalities (mainly telework, combining teleworking with onsite work, or onsite work), considering potential sex inequalities [22].

## 2. Methods

### 2.1 Design, Study Population, and Sample

Based on an online survey, a cross-sectional study was carried out among the *Comisiones Obreras* (CCOO) members, the largest trade union in Spain. For this study, we selected non-manual workers over 16 years old who reside in Spain and have been working in a salaried job for at least 1 hour during the week preceding the survey. The sample consists of n=11,519 workers. All study procedures were approved by the Ethics Committee of the Autonomous University of Barcelona (reference CEEAH/3445). Participants signed a written informed consent.

### 2.2 Data Collection

Data was obtained between April and May 2021 from an online self-administered questionnaire. The trade union emailed participants, whose participation was confidential and voluntary.

### 2.3 Variables

*2.3.1 Dependent Variables – Psychosocial Risk Factors (PSR)*

PSR was measured through scales of the COPSOQ Questionnaire (Copenhagen Psychosocial Questionnaire) for Spain [23]. In this study, we used eleven scales grouped into four domains: quantitative demands, work pace, and emotional demands (Psychological Demands at Work); influence and possibilities for development (Work Organization and Job Contents); social support from colleagues and social support from supervisors (Interpersonal Relations and Leadership); job insecurity, labour market insecurity, insecurity over working conditions and work-life conflict (Work Individual Interface). See Table 1S (supplementary material) for more details on the scales.

*2.3.2 Explanatory Variables*

The primary explanatory variable was working modality (teleworking, combining teleworking with onsite work, onsite work), and the stratification variable was sex (men, women). Adjustment variables were age (16-34; 35-49; 50 years old or more), occupational group (based on the National Classification of Occupations-CNO11), contract (permanent, temporary, and without contract), and living arrangements (cohabitation with children 0-12 years old; cohabitation with elderly people 70-80 years old; cohabitation with people >80 years old; cohabitation with sick or disabled people).

### 2.4 Analysis

Firstly, a descriptive analysis was performed by sex. Secondly, multivariate analyses were performed using robust Poisson regression models to calculate prevalence ratios (PR), with their 95% confidence intervals (95%CI), to estimate the exposure to psychosocial risk factors according to the working modality, stratifying by sex and adjusting by the rest of the explanatory variables. All the analyses were performed using STATA version 15.

## 3. Results

Almost half of women (47.8%) are between 35 and 49 years old (Table 1), representing a limited percentage of women under 34 (9.2%). The vast majority (78.9%) work with a permanent contract. The highest percentages are found for women who telework (90.2%), followed by those who combine work modalities (84.2%). The most prevalent occupations among women are "scientists, academics and similar professionals" (48.5%) and "accountants, administrative workers and other office employees" (36.3%). Moreover, around 30% of women live with children under 12 years old, with higher percentages among those who telework (33.2%). Around 4% of women live with people between 70 and 80. With people over 80, these percentages are slightly higher among women who telework (4.3%) in the first case and women who combine work modalities (5.6%) in the latter. Finally, 17% of women live with sick or disabled people, with slight differences according to the working modality.

Most men (52.4%) are more than 50 years old, with a minority (6.6%) under 34 years old (Table 2). Most (88.6%) work with a permanent contract, from whom 93.7% telework and 89.9% combine work modalities. The most prevalent occupations among men are "scientists, academics and similar professionals" (57.2%) and "technicians and professional support staff" (23.2%). As for women, around 30% of workers live with children under 12 years old, with higher percentages among men who telework (31.8%). Around 3% of the men live with people between 70 and 80 years old, and with people over 80, these percentages are slightly higher among men who do not telework. Finally, 13.9% of men live with sick or disabled people, with slight differences according to the working modality.

Tables 3 and 4 show the prevalence of exposure to each psychosocial risk and the adjusted prevalence ratios (aPR) by sex and working modality.

Women combining telework and face-to-face work (Table 3) are more exposed to quantitative demands than women who do not telework (aPR: 1.21; 95%CI 1.07-1.37). On the other hand, women who telework, either entirely (aPR: 0.89; 95%CI

**Table 1.** Sample description. Women.

| | Women | | | |
|---|---|---|---|---|
| | **Mainly telework n (%)** | **Combine n (%)** | **No telework n (%)** | **Total n (%)** |
| **Age** | | | | |
| 16-34 | 92 (8.6) | 57 (6.1) | 424 (10) | 573 (9.2) |
| 35-49 | 571 (53.2) | 440 (47) | 1972 (46.6) | 2983 (47.8) |
| ≥50 | 411 (38.3) | 440 (47) | 1832 (43.3) | 2683 (43) |
| **Type of contract** | | | | |
| Permanent | 978 (90.2) | 790 (84.2) | 3188 (74.9) | 4956 (79) |
| Temporary | 106 (9.8) | 148 (15.8) | 1065 (25) | 1319 (21) |
| Without contract | 0 | 0 | 1 (0.02) | 1 (0.02) |
| **Occupational group** | | | | |
| Directors and managers | 4 (0.4) | 4 (0.4) | 25 (0.6) | 33 (0.5) |
| Scientific and intellectual professionals | 397 (36.6) | 412 (43.9) | 2237 (52.6) | 3050 (48.5) |
| Technicians and mid-level professionals | 204 (18.8) | 156 (16.6) | 560 (13.2) | 920 (14.7) |
| Accountants, administrative workers and other office employees | 479 (44.2) | 366 (39) | 1432 (33.7) | 2277 (36.3) |
| **Living with children under 12 years old** | | | | |
| Yes | 319 (33.2) | 246 (30) | 1160 (31.3) | 1725 (31.4) |
| No | 642 (66.8) | 573 (70) | 2549 (68.7) | 3764 (68.6) |
| **Living with people 70-80 years old** | | | | |
| Yes | 41 (4.3) | 32 (3.9) | 152 (4.1) | 225 (4.1) |
| No | 920 (95.7) | 787 (96.1) | 3557 (95.9) | 5264 (95.9) |
| **Living with people over 80 years old** | | | | |
| Yes | 30 (3.1) | 46 (5.6) | 171 (4.6) | 247 (4.5) |
| No | 931 (96.9) | 773 (94.4) | 3538 (95.4) | 5242 (95.5) |
| **Living with sick or disabled people** | | | | |
| Yes | 165 (17.2) | 140 (17.2) | 628 (17) | 933 (17.1) |
| No | 796 (82.8) | 673 (82.8) | 3061 (83) | 4530 (82.9) |

0.82-0.97) or combining (aPR: 0.89; 95%CI 0.81-0.98), are less exposed to emotional demands than those who do not telework. Moreover, women who mainly telework are more exposed to low influence over their work (aPR: 1.24; 95%CI 1.08-1.41) and to low development possibilities (aPR: 1.20; 95%CI 1.08-1.34) than women who do not telework. Finally, women who mainly telework (aPR: 1.4; 95%CI 1.25-1.56) are more exposed to job loss insecurity, while women who combine telework and face-to-face work (aPR: 0.83; 95%CI 0.72-0.96) are less exposed than those who do not telework. Women who mainly telework (aPR: 1.22; 95%CI 1.13 to 1.33) are more exposed to labour-marked insecurity, and women who combine (aPR: 0.94; 95%CI 0.89-0.99) are less exposed to working conditions insecurity than those who do not telework.

Concerning men (Table 4), those who telework entirely (aPR: 1.26; 95%CI 1.11-1.43) or combined

**Table 2.** Sample description. Men.

| | Men | | | |
|---|---|---|---|---|
| | **Mainly telework n (%)** | **Combined n (%)** | **No telework n (%)** | **Total n (%)** |
| **Age** | | | | |
| 16-34 | 79 (8.5) | 41 (5) | 218 (6.5) | 338 (6.6) |
| 35-49 | 410 (44.3) | 306 (37.6) | 1374 (40.9) | 2091 (41) |
| ≥50 | 437 (47.2) | 466 (57.3) | 1769 (52.6) | 2672 (52.4) |
| **Type of contract** | | | | |
| Permanent | 871 (93.7) | 736 (89.9) | 2939 (87) | 4546 (88.7) |
| Temporary | 58 (6.2) | 83 (10.1) | 438 (13) | 579 (11.3) |
| Without contract | 1 (0.1) | 0 | 0 | 1 (0.02) |
| **Occupational group** | | | | |
| Directors and managers | 7 (0.8) | 8 (1) | 36 (1.1) | 51 (1) |
| Scientists, academics and similar professionals | 553 (59.5) | 491 (60) | 1893 (56.1) | 2937 (57.3) |
| Technicians; professional support staff | 215 (23.1) | 180 (22) | 795 (23.5) | 1190 (23.2) |
| Accountants, administrative workers & other employees | 155 (16.7) | 140 (17.1) | 653 (19.3) | 948 (18.5) |
| **Living with children under 12 years old** | | | | |
| Yes | 257 (31.8) | 208 (28.9) | 829 (28) | 1294 (28.8) |
| No | 552 (68.2) | 512 (71.1) | 2130 (72) | 3194 (71.2) |
| **Living with people 70-80 years old** | | | | |
| Yes | 23 (2.8) | 15 (2.1) | 107 (3.6) | 145 (3.2) |
| No | 786 (97.2) | 705 (97.9) | 2852 (96.4) | 4343 (96.8) |
| **Living with people over 80 years old** | | | | |
| Yes | 18 (2.2) | 25 (3.5) | 115 (3.9) | 158 (3.5) |
| No | 791 (97.8) | 695 (96.5) | 2844 (96.1) | 4330 (96.5) |
| **Living with sick or disabled people** | | | | |
| Yes | 109 (13.5) | 94 (13.1) | 419 (14.2) | 622 (13.9) |
| No | 699 (86.5) | 625 (86.9) | 2532 (85.8) | 3856 (86.1) |

with face-to-face (aPR: 1.27; 95%CI 1.11-1.45) are more exposed to quantitative demands than men who do not telework.

On the other hand, men who mainly telework (aPR: 0.84; 95%CI 0.76-0.92) are less exposed to emotional demands than men who do not telework. Finally, men who mainly telework are more exposed to job loss insecurity (aPR: 1.21; 95%CI 1.07-1.37) and to labour marked insecurity (aPR: 1.13; 95%CI 1.03-1.24) than those who do not telework, while men who combine are less exposed to job loss insecurity (aPR: 0.85; 95%CI 0.73-0.99).

Nevertheless, statistically significant differences are not found in the exposure to work pace, work-life conflict, and social support according to the working modality, neither among men nor women.

**Table 3.** Prevalence and prevalence ratio of the exposure to psychosocial risks according to the working modality. Women.

| | Women | | |
|---|---|---|---|
| | **Exposure (%)** | **aPR (95%CI)*** | **p-value** |
| **High quantitative demands** | | | |
| No telework | 33.2% | ref | - |
| Mainly telework | 36.8% | 1.06 (0.94 to 1.20) | 0.319 |
| Combine | 40.1% | 1.21 (1.07 to 1.37) | 0.002 |
| **High work pace** | | | |
| No telework | 51.1% | ref | - |
| Mainly telework | 55.2% | 1.05 (0.95 to 1.16) | 0.347 |
| Combine | 46.3% | 0.90 (0.80 to 1.01) | 0.063 |
| **High emotional demands** | | | |
| No telework | 79.3% | ref | - |
| Mainly telework | 69.1% | 0.89 (0.82 to 0.97) | 0,009 |
| Combine | 70.7% | 0.89 (0.81 to 0.98) | 0,013 |
| **High work-life conflict** | | | |
| No telework | 59.8% | ref | - |
| Mainly telework | 61.1% | 1.02 (0.93 to 1.12) | 0.654 |
| Combine | 57.6% | 0.98 (0.89 to 1.09) | 0.738 |
| **Low influence** | | | |
| No telework | 23.3% | ref | - |
| Mainly telework | 32.3% | 1.24 (1.08 to 1.41) | 0.002 |
| Combine | 22.2% | 0.90 (0.77 to 1.07) | 0.229 |
| **Low development possibilities** | | | |
| No telework | 35.3% | ref | - |
| Mainly telework | 49.1% | 1.20 (1.08 to 1.34) | 0.001 |
| Combine | 34.4% | 0.94 (0.82 to 1.07) | 0.321 |
| **Low social support from colleagues** | | | |
| No telework | 42.4% | ref | - |
| Mainly telework | 43.7% | 1.01 (0.90 to 1.13) | 0.886 |
| Combine | 41.9% | 1.00 (0.89 to 1.12) | 0.991 |
| **Low social support from supervisor** | | | |
| No telework | 53.1% | ref | - |
| Mainly telework | 50.6% | 0.92 (0.83 to 1.02) | 0.098 |
| Combine | 48% | 0.92 (0.82 to 1.02) | 0.128 |
| **High job loss insecurity** | | | |
| No telework | 35% | ref | - |
| Mainly telework | 45.8% | 1.4 (1.25 to 1.56) | <0.001 |
| Combine | 27.3% | 0.83 (0.72 to 0.96) | 0.011 |

| | Women | | |
|---|---|---|---|
| | Exposure (%) | aPR (95%CI)* | p-value |
| **High labour market insecurity** | | | |
| No telework | 64.4% | ref | - |
| Mainly telework | 78.0% | 1.22 (1.13 to 1.33) | <0.001 |
| Combine | 65.1% | 1.05 (0.95 to 1.15) | 0.364 |
| **High working conditions insecurity** | | | |
| No telework | 42% | ref | - |
| Mainly telework | 48.8% | 1.03 (0.98 to 1.08) | 0.237 |
| Combine | 35.5% | 0.94 (0.89 to 0.99) | 0.032 |

**Adjusted by age, type of contract, occupational group, and living arrangements (cohabitation with children 0–12 years old; with elderly people 70–80 years old; with people >80 years old; with sick or disabled people).*

**Table 4.** Prevalence and prevalence ratio of the exposure to psychosocial risks according to the working modality. Men.

| | Men | | |
|---|---|---|---|
| | Exposure (%) | aPR (95%CI)* | p-value |
| **High quantitative demands** | | | |
| No telework | 32.1% | ref | - |
| Mainly telework | 39.8% | 1.26 (1.11 to 1.43) | <0.001 |
| Combine | 40.3% | 1.27 (1.11 to 1.45) | <0.001 |
| **High work pace** | | | |
| No telework | 40.7% | ref | - |
| Mainly telework | 41.2% | 0.97 (0.86 to 1.10) | 0.663 |
| Combine | 38.1% | 0.93 (0.82 to 1.07) | 0.313 |
| **High emotional demands** | | | |
| No telework | 76.4% | ref | - |
| Mainly telework | 65.4% | 0.84 (0.76 to 0.92) | <0.001 |
| Combine | 70.8% | 0.91 (0.83 to 1.01) | 0.064 |
| **High work-life conflict** | | | |
| No telework | 54.3% | ref | - |
| Mainly telework | 54.4% | 0.98 (0.88 to 1.09) | 0.734 |
| Combine | 56.2% | 1.04 (0.93 to 1.16) | 0.522 |
| **Low influence** | | | |
| No telework | 22.4% | ref | - |
| Mainly telework | 21.5% | 1.00 (0.84 to 1.18) | 0.988 |
| Combine | 19.3% | 0.94 (0.78 to 1.13) | 0.515 |
| **Low development possibilities** | | | |
| No telework | 37.9% | ref | - |
| Mainly telework | 41.8% | 1.11 (0.98 to 1.26) | 0.1 |
| Combine | 36.2% | 0.98 (0.86 to 1.12) | 0.782 |

*Table 4 continues*

**Table 4.** Prevalence and prevalence ratio of the exposure to psychosocial risks according to the working modality. Men. *(continued)*

| | Men | | |
|---|---|---|---|
| | **Exposure (%)** | **aPR (95%CI)*** | **p-value** |
| **Low social support from colleagues** | | | |
| No telework | 39.0% | ref | - |
| Mainly telework | 36.5% | 0.95 (0.83 to 1.08) | 0.419 |
| Combine | 35.3% | 0.90 (0.78 to 1.03) | 0.128 |
| **Low social support from supervisor** | | | |
| No telework | 51.5% | ref | - |
| Mainly telework | 46.7% | 0.89 (0.80 to 1.00) | 0.055 |
| Combine | 48% | 0.94 (0.84 to 1.06) | 0.308 |
| **High job loss insecurity** | | | |
| No telework | 35% | ref | - |
| Mainly telework | 42.1% | 1.21 (1.07 to 1.37) | 0.002 |
| Combine | 30.1% | 0.85 (0.73 to 0.99) | 0.031 |
| **High labour market insecurity** | | | |
| No telework | 67.2% | ref | - |
| Mainly telework | 75.4% | 1.13 (1.03 to 1.24) | 0.01 |
| Combine | 67.7% | 1.03 (0.93 to 1.14) | 0.593 |
| **High working conditions insecurity** | | | |
| No telework | 43% | ref | - |
| Mainly telework | 42.3% | 0.98 (0.93 to 1.04) | 0.487 |
| Combine | 38.1% | 0.96 (0.91 to 1.02) | 0.225 |

**Adjusted by age, type of contract, occupational group, and living arrangements (cohabitation with children 0-12 years old; with elderly people 70-80 years old; with people >80 years old; with sick or disabled people).*

## 4. Discussion

This study has allowed us to assess the distribution of psychosocial risk exposures among non-manual Spanish wage-earners, according to the working modality and stratified by sex one year following the onset of the COVID-19 pandemic.

Examining the relationship between demands and work pace, we find that men who mainly telework and both men and women who combine telework and face-to-face work show higher quantitative demands than those who do not telework. Most studies around this topic, also considering other countries, find that the workload has increased for a substantially more significant proportion of women than men, mainly attributed to increased domestic responsibilities [24]. Telework appears to increase workload, extended and irregular working hours, and perpetual availability requirements, all of which represent prominent risk factors, particularly relevant within the context of the COVID-19 pandemic [25, 26], a phenomenon that had already been observed before the pandemic [27, 28].

Regarding work-life conflict, it is notable that while the percentages are slightly higher for women compared to men, there are no differences based on the working modality. Conflicting results from other literature suggest that working from home may positively impact well-being by enhancing the ability to balance family lif [29]. The reduction in work-family challenges stems from employees' perception of having control over their work location, timing, and processes. Kossek et al. [30] found that employees with a greater perception of job control exhibited significantly lower turnover intentions, family-work conflict, and depression. Telework may necessitate the integration of childcare and household responsibilities due to the challenges in delineating boundaries between work and personal life [31]. Over the past two decades, telework has undergone significant changes owing to technological advancements and its expansion to numerous occupations, necessitating careful consideration when interpreting these findings. Children's presence often prompts a redistribution of household chores within couples, emphasizing gender disparities and exacerbating work-to-family issues [32]. Women, who typically have a higher involvement in childcare, face a greater need to strike a balance [33], as evidenced by studies reporting increased work-to-family conflict, stress, and anguish among women [34, 35]. Recent research has also indicated an increase in domestic work among mothers working from home, particularly in routine childcare, compared to mothers who do not telework [36]. However, a more equitable allocation of cleaning and routine childcare is observed when comparing fathers commuting to employer facilities with those working from home. In Spain, women have experienced a lesser impact from lockdown situations, likely due to their heavier care workload. This contributes to women's significantly lower incidence of permanent and full-time contracts, ultimately leading to partial or total withdrawal from the labor market [37]. Nevertheless, studies have demonstrated that implementing planned, agreed, and prepared remote working measures under the "new normal" conditions has reduced work-family conflict [38].

While the observed differences are not statistically significant for social support, there is a pattern in which those who telework have better support, especially men. Our findings show that both women and men report lower levels of social support from supervisors when not teleworking. Additionally, when it comes to social support from colleagues, men experience lower levels when not teleworking, whereas women report diminished support when primarily teleworking. Literature frequently highlights negative emotions such as social isolation and loneliness among teleworkers, affirming the significant social aspect of emotions [39]. Moreover, research underscores that computer-mediated communication, as opposed to face-to-face interaction, can detrimentally impact the emotional well-being of workers [40].

In terms of limitations, it is a cross-sectional study, which doesn't allow for the assurance of either the directionality of the relationships or their causality. Specific associations between working modalities and psychosocial risks explored herein may hint at reversed relationships. For example, when considering influence, although the versatility to integrate diverse working modalities may likely lead to heightened influence, an alternative viewpoint suggests that individuals with greater influence possess a heightened ability to alternate between in-person work and teleworking. Analogous reasoning can be extended to assessments of possibilities for developmental or job insecurity. As a result, our investigation principally focuses on associations that conform to a cause-and-effect logical sequence: the modality of work (cause) and exposure to psychosocial risks (effect). It is also important to acknowledge that the participants in this study were affiliated with the CCOO trade union. While the sample size is substantial, and this trade union encompasses all sectors of economic activity, we must refrain from asserting the sample's representativeness for the entire Spanish working population.

On the other hand, the analysis of exposure to PSR, according to the work modality, was conducted by adjusting for occupational groups to obtain conclusions that, as much as possible, could be explained independently of the occupation. The categorization used for this variable was based on the Spanish national occupational classification (CNO-11) at the 1-digit level, which is broad and, in some cases, might "hide" unequal distributions in some occupations that could explain part of the results. For example, the finding of higher emotional demands in women who work at their employer's premises may be confounded by a higher frequency of non-manual women with occupations in the healthcare sector, where telework is not possible, and where there are usually higher emotional demands. However, beyond the already mentioned large sample size, it is worth noting that, to the best of our knowledge, our study is the first to analyse the exposure to psychosocial risks according to the working modality for the non-manual Spanish population and also consider potential differences based on a fundamental axis of inequality in the labor market, such as sex.

## 5. Conclusions

This study examines the exposure to psychosocial risks based on working modality, notably incorporating the combination of telework and face-to-face work into its analysis to understand better the effect of the different types of telework widely spread since the COVID-19 pandemic. A key finding of this study reveals that employees, irrespective of sex, who combine telework and face-to-face work are generally less exposed to psychosocial risks than those who mainly telework or those who work onsite, except for quantitative demands. Specifically, telework is associated with a lower exposure to emotional needs, but, on the other hand, it is associated with higher work demands (especially when combined with onsite work). Furthermore, the exposure to psychosocial risks varies by sex across different working modalities. Women primarily engaged in telework exhibit elevated levels of job insecurity across all dimensions, alongside challenges related to work pace, influence, and development possibilities. Similarly, men primarily engaged in telework also show a higher prevalence of job insecurity.

These findings can be valuable from an occupational medicine standpoint, considering that these remote working arrangements present a challenge for preventive services and occupational physicians, who traditionally operate within physical workplaces. The results highlight the importance of assessing the exposure to psychosocial risk factors among teleworkers to mitigate them, especially those concerning quantitative demands, thereby preventing potential adverse health effects.

**Supplementary Material:** Table S1

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**Author Contribution Statement:** AGD and ANG conceived and designed the study; CLS, SSN and ANG collected the data; PFR conducted the statistical analysis; AGD and LEM drafted the manuscript; ANG supervised all phases of research activity planning. All authors reviewed and interpreted the results and approved the final version of the manuscript.

**Declaration of the use of AI:** We declare that we have not used AI for any of the stages of the article.

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# Comparing Exposure to Psychosocial Risks: Face-to-Face Work vs. Telework

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**Table S1.** Supplementary material. Definitions and origins of the exposition to PSR.
**Description of the 11 different exposure dimensions of psychosocial risks under the COPSOQ method.**

| | |
|---|---|
| **QUANTITATIVE DEMANDS** | |
| *Definition* | **Origin** |
| *Psychological demands derived from the amount of work. They are high when we have more work than we can do in the allocated time.* | They have to do mainly with lack of personnel, incorrect time measurement or poor planning, although they can also be related to the salary structure (for example, when the variable part of a low salary is high and forces to increase the pace) or with the inadequacy of tools, materials or work processes (forcing to do more tasks to make up for deficiencies). High quantitative demands can lead to a lengthening of the working day. |
| **WORK PACE** | |
| *Definition* | **Origin** |
| *Psychological demand related to work intensity.* | Given the close relationship with quantitative exigence, the origin can be the same. |
| **EMOTIONAL DEMANDS** | |
| *Definition* | **Origin** |
| *These are the demands not to get involved in the emotional situation (or to manage the transfer of feelings) that derive from the interpersonal relationships involved in the work, especially in occupations of care for people in which the aim is to induce changes in them (for example: to follow a medical treatment, to acquire a skill...), and which may involve the transfer of feelings and emotions.* | In care occupations, exposure to emotional demands has to do with the nature of the tasks and cannot be eliminated (we cannot "eliminate" patients, students, etc.), so they require specific skills and sufficient time to be able to manage them effectively. In addition to the origin derived from their nature, they also have a lot to do with quantitative demands, the exposure time (hours, number of patients, etc.) can be reduced, since excessive workdays imply a greater exposure and produce a greater emotional fatigue that will require longer rest times. |
| **WORK-LIFE CONFLICT** | |
| *Definition* | **Origin** |
| *These are the synchronous, simultaneous demands of the work environment and the domestic-family environment.* | In the labor sphere, it has to do with quantitative requirements, the organization, duration, lengthening or modification of the working day and with the level of autonomy over it; for example, with working hours or days that are incompatible with care work or social life. |

| | |
|---|---|
| **INFLUENCE** | |
| *Definition* | **Origin** |
| *It is the margin of autonomy in the day-to-day work in general, and also particularly in relation to the tasks to be performed (the what) and in the way it is carried out (the how).* | It has to do with the participation that each worker has in decisions on fundamental aspects of his or her daily work, that is, with the work methods used and whether or not these are participatory and whether or not they allow or limit autonomy. It can be highly correlated with development possibilities. |
| **POSSIBILITIES OF DEVELOPMENT** | |
| *Definition* | Origin |
| *It is the level of opportunities offered by the work performance to put into practice the knowledge, skills and experience of the workers and to acquire new ones.* | It is highly related to the levels of complexity and variety of tasks, with standardized and repetitive work being the paradigm of harmful exposure. It is related to work and production methods and the design of work content (more routine, standardized or monotonous at one extreme, more complex and creative at the other) and to influence. |
| **SOCIAL SUPPORT FROM COLLEAGUES** | |
| *Definition* | **Origin** |
| *It is receiving the help needed and when it is needed from colleagues to perform the job well.* | Lack of peer support may have to do with personnel management practices that hinder cooperation and the formation of true work teams, encouraging individual competitiveness (for example, with variable salaries based on individual objectives), or assigning tasks, changes in schedules, center, etc., in an arbitrary or non-transparent manner. |
| **SOCIAL SUPPORT FROM SUPERVISOR** | |
| *Definition* | **Origin** |
| *It is receiving the help needed and when needed from superiors to perform the job well.* | The lack of support from superiors has to do with the lack of principles and specific personnel management procedures that promote the role of the superior as an element of support for the work of the team, department, section or area he/she manages. It is also related to the lack of clear guidelines regarding the fulfillment of this role and the lack of training and time to do so. |
| **JOB LOSS INSECURITY** | |
| *Definition* | **Origin** |
| *It is the concern to lose the job given the internal and external factors surrounding the worker situation.* | It has to do mainly with the organization situation and the worker performance.<br>It can be experienced differently depending on the time of life or family responsibilities of each worker. |
| **LABOR MARKET INSECURITY** | |
| *Definition* | **Origin** |
| *It is the concern for the future in relation to the occupation.* | It has to do with job stability and employability in the labor market of residence.<br>It can be experienced differently depending on the time of life or family responsibilities of each worker. |

| WORK CONDITIONS INSECURITY | |
|---|---|
| *Definition* | **Origin** |
| *It is the concern for the future in relation to unwanted changes in fundamental working conditions.* | It relates to threats of worsening of particularly valuable working conditions. These can originate both in the current situation (for example, if the assignment of working hours, tasks and bonuses or salary supplements is arbitrary) and in the possibility of changes (for example, the announcement of a corporate restructuring, outsourcing of a position or service, a lay-off, etc.); more so if there are worse working conditions in the context outside the company (same sector, territory...). Like the previous one, it can be experienced differently depending on the vital moment or the family responsibilities of each worker. |

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# Job Retention by People With Disabilities: A Qualitative Study of the Perspectives of People With Multiple Sclerosis

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**Keywords:** Multiple Sclerosis; Job Retention; Disability

**Abstract**

**Background:** *Multiple sclerosis (MS), because of its early age at onset, greatly impacts the working lives of those affected by it in ways linked to different factors, both professional and personal. It has been observed that only a small percentage (20-40%) of workers with MS retain their jobs after the diagnosis. When identifying factors determining job retention or loss in this setting, it is essential to consider the direct perspectives of people with MS (PwMS).* **Methods:** *A qualitative study, based on the conduction of two focus groups, was conducted to explore the personal experiences of PwMS who work.* **Results:** *The results show that there are numerous factors, both positive and negative, that can influence these people's ability to retain their jobs. The climate established in the workplace and the relationship between workers with MS and their colleagues were fundamentally important aspects, as was knowledge of the disease at the level of public opinion.* **Conclusions:** *Managing work is a complex undertaking for people with a disabling condition like MS. There needs to be greater awareness of the employment rights of PwMS. Improving these knowledge-based aspects could undoubtedly improve the quality of the working lives of PwM.*

## 1. Introduction

Multiple sclerosis (MS) is a chronic inflammatory and degenerative disease of the central nervous system [1]. An estimated 127,000 people in Italy have MS and 2.8 million live with the disease worldwide, including a million in Europe [2].

Because of its early age at onset, MS greatly impacts the working lives of those affected by it, in ways linked to different factors, both professional and personal [3, 4]. According to the literature, 90% of people with multiple sclerosis (PwMS) worked before their diagnosis, and around 60% were working at the time of it; however, only a small percentage

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(20-40%) continued working after being diagnosed with MS [5]. Recent European studies showed employment rates ranging from 31% to 65%, which depended on many factors: sociodemographic, clinical, therapeutic and related to working conditions [6-9]. Indeed, in a recent Italian study, work difficulties were found to be related to invisible symptoms such as fatigue and mood disorders and not just to the presence of comorbidities and disability levels [10]. These findings suggest that PwMS find it difficult to work or remain in work. However, they also highlight areas ripe for potential interventions and developments.

This study was conducted as part of a broader project, funded by the Italian National Institute for Insurance against Accidents at Work, named "*PRISMA: Prevenzione rischi, Reti collaborative, Inclusione lavorativa nella Sclerosi MultiplA dalla conoscenza della realtà lavorativa delle persone con SM in Italia alla messa a punto di modelli e programmi innovativi per l'inclusione lavorativa*" (PRISMA: risk prevention, collaborative networks, work inclusion in multiple sclerosis: from knowledge of the working reality of people with MS in Italy to the development of innovative models and programmes for work inclusion). It was conducted to improve the workplace inclusion of PwMS in compliance with their fundamental rights and with the principles of accessibility and health and safety at work. The findings reported herein refer to a qualitative study undertaken to explore, based on the experiences of PwMS, the main factors associated with job retention/loss in this population. Particular attention was paid to relevant topics such as MS-related symptoms, the work environment, the attitudes of others in the workplace, financial considerations, as well as good practices to promote reasonable accommodations.

## 2. Methods

### 2.1 Study Design and Settings

The study involved creating two focus groups (FGs) which, because of the pandemic, had to meet using web conferencing technology [11]. The FG sessions lasted around two hours, and each saw the participation of five/six PwMS (the group included residents of both northern and central-southern Italy), as well as a moderator and two observers. The participants were identified through the local sections of the Italian MS Association (AISM) based on the following selection criteria: male or female; being of working age (18-65 years); either being in work or out of work for no more than 3 years. The identified subjects were contacted via email and invited by the researchers to participate in the FG activity after signing the relevant privacy information and informed consent documents.

### 2.2 Data Analysis

Both FG sessions were recorded with the participants' consent, and in each one, the moderator, who had an outline of the topics of interest, guided the discussion. On the other hand, the interview's analysis was guided by a (constructivist) grounded theory [12].

At the end of each FG session, two researchers (AV and EP) independently codified the raw transcripts. Basically, after a joint discussion of the interpretations, they developed a coding framework [13] and used the constant comparative technique (open coding) to identify emerging themes [14].

## 3. Results

In total, 17 PwMS were contacted (12 women and 5 men). Of these, only 10 (all women) agreed to participate in the study. The participants (a healthcare worker, two office workers, a researcher, a freelancer, a hotel employee, two teachers, a social worker and a call centre operator) ranged in age from 30 to 65 years, and all but one were actually in work at the time of the survey. Most participants had a disease duration of less than 10 years; in just one case, the diagnosis dated back more than 30 years. The PwMS taking part in the study reported different degrees of disability: two PwMS used walking aids (sticks), another had difficulty climbing stairs/steps, one used a wheelchair, and all struggled with fatigue.

**Table 1.** Topics that emerged during the FG sessions within the different areas of discussion

| Areas of discussion | Topics |
|---|---|
| Diagnosis disclosure | The role of colleagues and superiors/employers |
| Work benefits, especially during the pandemic | Contract types<br>Working remotely<br>Reasonable accommodations |
| Institutional figures of reference | The occupational physician |
| Aspects influencing job retention | The role of colleagues<br>Support for managing family life/work<br>Getting to and from work |

### 3.1 Diagnosis Disclosure

Only one main topic emerged in this area of discussion, namely the role of colleagues and of the individual's superior or employer.

Various interventions by the participants underlined just how crucial it is to get on well with colleagues. Good working relations can help build a climate of trust in which PwMS find they can disclose their condition and talk about their difficulties.

*…My colleagues were very sympathetic and supportive… they don't discriminate against me or judge me in any way.*

The findings differed regarding the role of superiors/employers, given that these figures seemed to play no part in the participants' decisions to disclose their diagnosis. Only one participant mentioned her superior, but more to underline that person's particularly empathetic nature rather than any aspects linked to their role. In this case, the superior even took the trouble to identify the "best" hospital where the participant might seek a diagnosis.

*…I really couldn't understand what was wrong with me, and it was my boss who made the necessary enquiries and got me admitted to an excellent hospital where I finally got the correct diagnosis.*

In short, being met with empathy and understanding from colleagues and direct superiors is fundamentally important when a person with MS has to disclose their diagnosis. Having an understanding and sensitive colleagues or a boss with the same attributes, capable of putting the person with MS at their ease and reassuring them that their condition will not be used as an excuse to slow down/block their professional growth or career, emerged as an important aspect during the discussions.

*…when I got my diagnosis, I didn't mention it at work as I was afraid that I might end up being excluded from work projects or applications for funding… when we got a new supervisor, who is an understanding and helpful person, I did speak out about my illness; it didn't change a thing at work, no allowances are made for me, which is fine by me!*

Other participants in the public and private sectors had no problems informing their colleagues of their diagnosis. In some cases, colleagues were the first to be told; in others, it was the superior/employer.

Finally, it was found to be fundamental to have good relationships with colleagues in order to accept or enjoy certain benefits without feeling uncomfortable or fearful of being judged by others.

*…colleagues made me feel bad about the remote working, they weren't happy about it…*

All the FG participants stated that they never used their illness as a way of "getting out of things" at work but only mentioned it to get help when necessary (e.g., in the case of the healthcare worker, who needed to avoid excessively physically demanding tasks or patients).

*…my colleagues help me out; they deal with the most challenging neurological and orthopaedic patients because I can no longer treat them. It's too much of a struggle for me…*

### 3.2 Work Benefits

Three main topics emerged in this discussion area: the types of work contracts assigned to PwMS, their access to remote working, and reasonable accommodations. All the participants except the freelancer had standard work contracts and could, therefore, be absent due to illness for a period of six months without significant consequences.

*…I am allowed up to six months of sick leave per year by contract and I use it when I need to.*

The discussion on work benefits also revealed that the possibility of working remotely, granted to some participants during the pandemic, sometimes created difficulties, either because the women felt that their colleagues were not happy about it, or because they would prefer to have been assigned other duties so that they could continue to come into work.

*…they got me to stay at home because I am immunosuppressed, but I would have preferred to change roles and work on refresher courses or something else…*

Generally speaking, for all the participants, the expression "reasonable accommodations" had negative connotations, which made us realise that none of them really understood its true meaning.

In fact, they themselves admitted that they weren't familiar with the term, or associated it with the idea of having to "make do" or "compromise", and therefore with the idea of having to give up or forfeit something.

*…it's a compromise, a negative thing, because you have to give up one thing in order to get another… [it's something] designed more to benefit the company than the person… [it's] about having to give up a part of yourself... or having to adapt to what the company wants from you.*

When explicitly asked, "What comes to mind if I talk of reasonable accommodations?" the participants gave answers relating to settings that have nothing to do with work. Again, this suggests that none of the participants knew what "reasonable accommodations" meant.

*…Having to wait a year for a new car to arrive to have one with superior specifications…*

Only one person knew the true meaning of reasonable accommodations and the laws governing this field.

### 3.3 Relations with Institutional Figures of Reference

The only topic to emerge in this discussion area concerned occupational doctors and their role towards workers affected by MS. While recognising the importance of the occupational doctor, the participants generally felt that these professionals were "not experts" in the field of MS, as they had not managed to suggest suitable tasks/duties based on the severity of the condition.

*…I got no suggestions on how my role at work might be adapted…*

Furthermore, the participants tended to be rather "suspicious" of the occupational physician in the company's employ and could potentially place obstacles in the way of their professional advancement.

*…after all, the doctor is paid by the company and, therefore, has the company's interests at heart, not ours*

This professional figure was found to be absent in public sector workplaces; only in one particular case, at the specific request of the participant, was a meeting with an occupational physician organised. On the other hand, as reported by the participants, an occupational physician was more likely to be present in private workplaces.

*…you don't find them in schools, I don't know of any. …but in the private sector, you do, and they can be a mixed blessing!*

Finally, an unmet need came to light, namely the need for the presence, within the company, of a specially trained person capable of modifying the tasks/duties of PwMS in the event of any worsening of their condition.

*…our coordinator is very understanding and supportive, and she talks over my situation with the bosses, but she is not trained… my area manager understands because he is in a similar position, but he is not trained …*

### 3.4 Aspects Influencing Job Retention

In this area, the discussion centred on three main aspects, seen as factors influencing job retention, namely the role of colleagues, the presence of support for managing work-life demands, and the "burden" of getting to and from work.

Once again, a plus point was being on good terms with colleagues, since they are in a position to encourage PwMS, and can understand the situations and problems they have to deal with. In some cases, colleagues could be a source of "gratification" for PwMS, when they recognise and acknowledge the strength and courage they show in addressing and overcoming their difficulties.

*…I thought that my colleagues might discriminate against me, but instead they admired me for how bravely I face my daily difficulties. …I felt quite moved*

*when the principal, during a meeting, said that diversity is a source of enrichment.*

Juggling work and family life can be challenging, especially for women with MS. One of the participants, who still lives with her elderly parents, described the situation as "heavy".

*…my mother has been looking after me for more than 20 years, but it's heavy, it stresses me out…*

In many cases, the women needed external support to manage the home (once a week, or as needed), or their husbands contributed. One of the participants, who lives alone and uses a wheelchair, said she needed round-the-clock support.

*…I live alone and am in a wheelchair, and so I need help. I have found a carer who lives in with me …*

In one case, AISM was asked to provide support in managing the period immediately after the birth of the participant's first two daughters.

*…with my first two pregnancies, AISM helped me manage the post-partum period…*

Getting to and from work was found to be a burden either because public transport is not geared for those with walking difficulties or, in the case of those using their own cars, because it is onerous and time-consuming, taking away time that could otherwise be spent on self-care.

*…for me it's a real problem getting to work. I struggle with one leg and can't use public transport, so I take the car, but parking is really expensive…; physiotherapy is really important, but you have to have time for it. If you work, and it takes you ages just to get to work, then there isn't much time left over for physiotherapy…*

The participant, who uses a wheelchair, said that she has to pay someone to take her from home to school (due to inefficient local council social services) and someone else to help her get around once she is at work.

*…I live 5 minutes away from my place of work, which is a quarter of an hour in a wheelchair, but I have to pay someone to take me to school because I get no help from council social services, they never got back to me.*

## 4. Discussion

The PwMS taking part in the two FGs, talking about "*disclosing the diagnosis*", revealed that it helped to have empathetic and sensitive colleagues, putting them at ease. Such colleagues can create a relaxed working environment and climate of trust in which PwMS can raise the subject of their condition and discuss their difficulties. An easy environment can also help them avoid feeling uncomfortable or criticised whenever a benefit (such as remote working) is offered. Very often, however, participants, especially in the private sector, felt "inhibited" about informing their superior or employer of their diagnosis; conversely, public sector workers often informed their superior/employer of their illness before their colleagues. These results align with the literature, in which a fear of being discriminated against is reported as the main reason for not communicating the diagnosis [15]. Finally, all the FG participants agreed that the reason they disclosed their diagnosis was never to obtain concessions or benefits but only so that they might get any help they needed. This shows that PwMS just want "normality", i.e., to have a job and be treated like their colleagues, without any special favours.

The discussion of "*work benefits*" showed that PwMS, both in the public and private sectors, have standard work contracts that do not cater to disease-related needs. However, these contracts allow up to six months of sick leave, meaning PwMS can be off work without creating any particular problems. Remote working was found to be a helpful measure, but also difficult to manage. During the pandemic, some of the PwMS taking part in this study, depending on the nature of their work, were allowed to work from home; for some of them, however, this was not a positive experience since they felt that their colleagues were not happy about the decision, especially when it affected their workloads. In one case, remote working was a negative experience because it made the participant in question feel excluded from the workplace, so much so that she offered to undergo specific training to be able to switch to another role. This led us to question whether the participants knew the meaning of the expression "reasonable accommodations". Their various answers, negative or unrelated to the working environment, suggested that the term is not very well known. Therefore, there seems to be a need for an awareness-raising campaign about MS, aimed both at employers and at PwMS who work.

Society today generally demands that people participate more actively in their own self-determination, but in the case of PwMS, this is complicated by the fact that they are often unaware of the range of opportunities, such as reasonable accommodations, that are open to them.

Previous studies report that PwMS have a particular need for reasonable accommodations, which are essential to allow them to continue doing their jobs even as the disease progresses [16, 9].

During the discussion on "*Institutional figures of reference*", it became clear that the role of occupational physician is poorly recognised. Indeed, these doctors are not always present, and even when they are present, they often fail to appropriately review the work roles of PwMS. This could possibly be due to a lack of specific training. In private workplaces, where occupational physician are more likely to be present, workers with MS have some misgivings about them since they are employed by the company and could, therefore, potentially interfere with their careers. In accordance with the literature, our results suggest that occupational doctors need to be provided with targeted and ongoing training to ensure that they are better able to respond to the needs and wishes of PwMS [9].

Finally, in the discussions on "*aspects influencing job retention*", good relations with colleagues, help from family members, carers/home helps, and patient associations (e.g., AISM), and a short distance to work all emerged as elements making it easier to continue working. On the other hand, a lack of efficient local social services and a medium-long commute (deemed burdensome due to walking difficulties, a lack of adequate public services, or the expense involved) were found to be obstacles. Here, our results again reflect the evidence of elements that emerged during our FG discussions [16].

One major limit of our study is the absence of men among the PwMS taking part in the SG sessions, given that it would certainly have been interesting to have the perspectives of working men with MS. It is also to be noted that most of the patients who withdrew their consent to take part did so at the last minute, mostly due to feelings of anxiety or mood disorders. This latter aspect shows how emotional factors often interfere with the social and relational dimensions of these individuals' lives.

## 5. Conclusion

These results show that managing work is a complex undertaking for people with a disabling condition like MS. They also show that there are numerous factors, both positive and negative, that can influence these people's ability to retain their jobs. The main influencing factor is the role that can be played by colleagues with whom they have a good relationship; colleagues who are able and willing to provide support at difficult times facilitate the ability to remain at work. Another aspect found to be crucially important in this setting is the need for greater knowledge of MS both at the level of public opinion (colleagues and superiors/employers) and among occupational doctors. Similarly, there needs to be greater awareness of the employment rights of PwMS. Improving these knowledge-based aspects could undoubtedly improve the quality of the working lives of PwMS.

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**Declaration of Interest:** Authors declare that they do not have conflicts of interest.

**Author Contribution Statement:** MP, EP and AV designed the study and developed the protocol. MP, EP, and AV participated in the data acquisition. MP, EP, AV, TM, EG, and BP participated in the data interpretation and provided comments on the paper. MP, TM, EG, EP, AV, BP, PD and PB participated in the critical revision of the manuscript for important intellectual content. All the authors agreed to be accountable for all aspects of the work and all read and approved the final version to be published.

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# Occupational Physicians' Management of Workers with Multiple Sclerosis in Italy: Results from a Survey

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**Keywords:** Multiple Sclerosis; Occupational Physicians; Occupational Health Practice

**Abstract**

**Background:** *This study, conducted on a sample of Italian occupational physicians (OPs), aimed to gather data regarding professional activity and their needs in managing workers with multiple sclerosis (MS).* **Methods:** *A convenience sample of OPs recruited by e-mail invitation to the list of Italian Society of Occupational Medicine members was considered. A total of 220 OPs participated between July and October 2022. An ad hoc questionnaire was developed based on previous survey experiences. It investigated, among others, the characteristics of OP respondents, the evaluation of fitness for work issues, and the OP training and updating needs on MS and work.* **Results:** *Ninety-one percent of OPs had to assess the fitness for work of workers with MS during their activity. Sixty-four percent experienced particular difficulties in issuing a fitness for work judgment. Regarding the level of knowledge on MS, 54% judged it sufficient. The "Assessment of fitness for work for the specific task" and the "Role of the OPs in identifying reasonable accommodations" were the most interesting training topics regarding MS management in work contexts chosen by the respondents.* **Conclusions:** *The interest in the work inclusion and job retention of people with disability, particularly the aspects linked to the Identification and implementation of reasonable accommodations, will require integration with the occupational safety and health protection system and will undoubtedly impact the OP's activities.*

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## 1. Introduction

Multiple sclerosis (MS) is an inflammatory demyelinating chronic disease of the central nervous system. It is one the most frequent causes of neurological disability in young adulthood, generally diagnosed between the ages of 20 and 40; it affects females more than men in a ratio equal to 2:1. The majority (approximately 85%) of the patients affected by MS are diagnosed with relapsing-remitting form (RRMS) that is characterized by episodes of significant worsening of symptoms (relapses), followed by complete or partial recovery, and then periods of remission. RRMS is more common among women and young adults (average age 30) [1-3]. Around 15% of patients are diagnosed with primary progressive form (PPMS), in which disability continuously progresses and relapses may or may not be present. PPMS is usually diagnosed in older patients than RRMS (average age 40) and with no differences based on gender [2, 4]. In many cases, individuals with RRMS develop after years of a secondary-progressive MS form (SPMS).

In 2023, 2.9 million people lived with MS worldwide [5], 1,200,000 in Europe [6]. MS prevalence has increased in every world region since 2013. Indeed, in 2020, the prevalence worldwide was 43.95 per 100,000 population (a 50% increase compared with 2013). In Europe, the prevalence was 142.81 per 100,000 population, with a rise of 32% compared to 2013. Although MS is found in all parts of the world, its prevalence varies greatly, being highest in the Americas (111 people with MS per 100,000) and Europe (137 people with MS per 100,000) and lowest in Africa and Western Pacific region (5 people with MS per 100,000) according to most recent statistics [5]. The pooled incidence rate across 75 reporting countries is 2.1 per 100,000 persons/year, and the mean age of diagnosis is 32 years. Females are twice as likely to live with MS as males [5].

In Italy, Italian Multiple Sclerosis Society (AISM) estimates the existence of approximately 137,000 people with MS in 2023, with an incidence of over 3,600 new cases each year (6 per 100,000 people, 12 in Sardinia region) and a prevalence of 221 per 100,000 people [6].

In 2015, the Italian Multiple Sclerosis Registry (RISM) was created to build an organized multicenter structure to collect data on all MS patients followed in the various Italian MS centers for better defining the disease epidemiology, improving quality of care, and promoting research projects [7]; in September 2023 there were over 85,000 cases in the register, corresponding to about 60% of the MS population estimated in Italy according to the 2023 MS barometer [8].

MS represents a significant psychological, physical, financial, and social burden for patients; in fact, the most common symptoms of the disease are related to depression and cognitive dysfunction, problems with walking, deadness, difficulties in balance and coordination, dysarthria, bladder and bowel disturbance, visual impairment, reduced heat tolerance, pain, and fatigue [4, 9].

Battaglia et al. [10] showed that patients with MS are affected by several burdensome and disabling symptoms, above all the overwhelming presence of fatigue. Moreover, they showed a great impact of the disease on daily and work activities, referring in particular to life plans, difficulties in travelling, attention and presence at work, salary, and early exit from the job market or retirement.

In 2019, the overall cost of the disease in Italy was €4.8 billion. The National Healthcare System sustained most of the costs (80%), most notably direct healthcare costs, while patients paid almost all non-healthcare expenses [10].

A study on seven European cost-of-illness analyses showed that the societal economic burden varies between MS types; in particular, costs for SPMS were higher than those for RRMS [11, 12]. For example, it was estimated that in Europe, the total economic costs of MS amount to 14.6 million €/year, with the highest costs per subject (26,974 €/year) among the main brain disorders [13]. This significant economic burden is mainly related to the young age of MS onset (symptoms first appear between ages 20 and 50) and to its unemployment rates [13, 14]. In this regard, the consequence of MS is a decrease in employability due to a reduced ability to perform occupational functions and tasks. People with Multiple Sclerosis (PwMS) are at an increased risk of unemployment during the disease. In recent years, progress has been made in improving the time until patients have to leave the workforce permanently [15]. Loss of employment is still one of the most troubling consequences of MS and contributes to the economic burden of the disease on the societal and personal level. In this context, several studies examined the impact of MS on employment status: unemployment rates among PwMS can reach 80% [16].

Within the "PRISMA project – Risk Prevention, Collaborative Networks, Work Inclusion in Multiple Sclerosis: From Knowledge of the Working Reality of People with MS in Italy to the Development of Innovative Models and Programs for Work Inclusion", funded by Italian Workers' Compensation Authority (INAIL) aimed at identifying tools and strategies to contribute to overcoming the difficulties in the protection of occupational health and safety of workers with MS (WwMS), exciting results have arisen.

Regarding the occupational outcomes of PwMS, Vitturi et al. [17] show that even for patients who remain employed, more than a quarter show some deterioration in employment status, and 56% observe a work performance loss in the short term after the diagnosis. Furthermore, once unemployed, it is difficult for WwMS to return to the workforce. Workers are exposed to different typologies of barriers during their jobs. These barriers refer to job characteristics, work environment (e.g., access to the workplace, presence of steps, etc.), social relationships at work (e.g., interaction with supervisors, employer's attitude, etc.), adverse work events and lack of information [18, 19]. It comes to light that a multidisciplinary approach can help manage the interaction between the impairments caused by MS, the physical environment, and the job demands [19]. A literature review also shows that in the last years, even though still prevalent in WwMS, unemployment and early retirement have slightly decreased [20].

Therefore, it is easy to understand the pivotal role of the occupational physician (OP) [21] – a key figure in the company prevention system according to Italian occupational health and safety (OSH) regulations – in defining fitness for work judgment and identifying specific prevention and protection measures, including reasonable accommodations. This intervention will contribute to job retention for WwMS, favoring anti-discriminatory processes and real work inclusion as much as possible, using a shared and integrated approach among the different professionals of the company prevention system. In this context, among the specific objectives of the PRISMA project, a survey of Italian OPs was conducted through a self-administered questionnaire to gather data regarding the professional activity and their needs in the management of WwMS. In particular, the survey aimed to explore some issues related to the fitness for work in the presence of WwMS, the training needs on "MS and work", and the OP's perception of including the disabled worker.

## 2. Methods

### 2.1. Participants

A convenience sampling approach was used, contacting OPs recruited by e-mail invitation to the list of members of the Italian Society of Occupational Medicine (SIML). A total of 220 OPs living and working in Italy participated in this study between July and October 2022.

Under current privacy legislation (Legislative Decree 196/2003), all the participants were informed in written form about the survey's aims and told that the data obtained would be used only for research purposes, collected and processed anonymously and aggregately. After this disclosure, the participants were asked to answer a questionnaire voluntarily.

Ethical review and approval were waived for this study due to the anonymity of the data collected, the observational design, and the absence of patient clinical data.

### 2.2. Questionnaire

To pursue the study's aims, a structured ad hoc questionnaire was developed. The items and questions included in the questionnaire were prepared and contextualized based on tools already administered in previous survey experiences and on the analysis of scientific literature [21, 22].

A pilot test was conducted on a small sample of subjects (n=10) to determine each item's length, content, clarity, and comprehensibility. The questionnaire was adapted according to suggestions and observations gathered during the pilot test phase.

The questionnaire consisted of close-ended questions organized into the following sections:

I. the OP demographic and professional characteristics: gender, age, region of residence, specialization in Occupational Medicine or other disciplines, medical activity in other fields besides Occupational Medicine, number of workers examined as OP, number and types of companies seen as OP and risks present;
II. the evaluation of fitness for work of WwMS: potential experience in WwMS management, type of company and risks, frequency, and areas of difficulty in managing the fitness assessment linked to occupational risk or aspects of the disease, need and usefulness of specialist medical certifications, need and usefulness of discussion with other healthcare professionals;
III. the OP training and updating needs on issues related to disability and work and in particular MS and work: disability and work with a focus on MS and work – specific training insights, degree of usefulness of the topics, particular areas of interest in participating in training events on the subjects, the effectiveness of different teaching methodologies;
IV. knowledge and consultation of "Fitness for Work and Multiple Sclerosis. Guide for Occupational Physicians" published in 2013 by AISM in collaboration with SIML [23]: reasons for the consultation and the degree of interest in the different sections of the Guide.

Different 1-5 scales were used, where 1=minimum level and 5=maximum level, to investigate the utility, complexity, or interest level in some issues. The questionnaire was administered via the web on the Survey Monkey platform via an e-mail invitation to the list of SIML members.

### 2.3. Statistical Analysis

Statistical analysis was performed with SPSS software version 25. Descriptive analysis was performed: percentages and frequencies were calculated on the total sample and, at a greater level of detail, contingency tables were employed to display the frequency distribution of the variables in the subsets generated by sociodemographic variables and highlight any peculiarities. Five-point scales were re-coded in three classes: "not at all" was aggregated with "slightly" and "very" was aggregated with "extremely".

## 3. Results

### 3.1. Sociodemographic and Professional Information

The convenience sample consisted of 220 OP respondents (equal to approximately 16% of the active members of SIML). Most respondents were male (52,7%), aged 45-64 years (55.9%), lived in the North-West of Italy (35.9%), and specialized in Occupational Medicine (80.7%). Over half of the sample (52.3%) began their activity as OPs between 1991 and 2007, and 31.8% subsequently; 52.4% worked as self-employed, and 36.4% worked in other fields besides Occupational Medicine. Most of the sample (43.2%) worked in less than ten companies, 50.0% examined more than 1,500 workers overall, and 36.4% of OPs worked for large companies (more than 250 employees). The most frequent risk factors present in the visited companies were manual handling of loads (11.8%) and video display units (11.4%). Sociodemographic information is reported in Table 1.

### 3.2. The Assessment of Fitness for Work in Workers with Multiple Sclerosis

Most of the participants (90.9%) had to assess the fitness for work of WwMS during their OPs activity, mainly 1-4 times overall (47.7%). Mostly, WwMS for

**Table 1.** Description of the sample: sociodemographic and professional information.

| | N | % |
|---|---|---|
| **Gender** | | |
| Male | 116 | 52.7 |
| Female | 104 | 47.3 |
| **Class of age** | | |
| <35 yr | 15 | 6.8 |
| 35-44 yr | 35 | 15.9 |
| 45-54 yr | 61 | 27.7 |
| 55-64 yr | 62 | 28.2 |
| ≥65 yr | 47 | 21.4 |
| **Geographical area of residence** | | |
| North-West Italy | 79 | 35.9 |
| North-East Italy | 62 | 28.2 |
| Middle Italy | 42 | 19.1 |
| South and Islands | 37 | 16.8 |
| **Legal requirements to perform OP profession**[1] | | |
| Specialty in Occupational Medicine | 192 | 80.7 |
| Specialty in Hygiene and Preventive Medicine | 14 | 5.9 |
| Authorization pursuant to article 55 of Decree Law no. 277/1991 | 12 | 5.0 |
| Teaching Occupational Medicine or Preventive Medicine for Workers and Psychotechnique or Industrial Toxicology or Industrial Hygiene or Physiology and Occupational Hygiene | 10 | 4.2 |
| Specialty in Legal Medicine | 8 | 3.4 |
| University master for specialists in Hygiene and Preventive Medicine or Legal Medicine | 2 | 0.8 |
| **Total number of workers examined as OP in a year** | | |
| ≤100 | 14 | 6.4 |
| 101-500 | 25 | 11.4 |
| 501-1000 | 35 | 15.9 |
| 1001-1500 | 36 | 16.4 |
| >1500 | 110 | 50.0 |
| **How many employees do the companies in which you have most assignments as OP have?** | | |
| <10 employees (micro) | 38 | 17.3 |
| 11-49 employees (small) | 57 | 25.9 |
| 50-249 employees (medium) | 45 | 20.5 |
| ≥250 employees (large) | 80 | 36.4 |
| **What is(are) the risk(s) in the companies where you carry out activities as OP?**[1] | | |
| Manual handling of loads | 209 | 11.8 |
| Visual display units | 202 | 11.4 |
| Chemical substances | 183 | 10.4 |
| Biomechanical overload of the upper limbs | 178 | 10.1 |
| Night work | 174 | 9.8 |

*Table 1 continues*

**Table 1.** Description of the sample: sociodemographic and professional information. *(continued)*

| | N | % |
|---|---|---|
| Biological agents | 172 | 9.7 |
| Noise | 148 | 8.4 |
| Vibrations | 115 | 6.5 |
| Carcinogenic substances | 110 | 6.2 |
| Artificial optical radiation | 108 | 6.1 |
| Electromagnetic fields | 99 | 5.6 |
| Other | 69 | 3.9 |

[1]*Multiple choice question, percentages of responses.*

whose fitness for work was assessed by the OPs interviewed belong to the health and social care sector (22.6% of the answers provided), followed by other services activity (12.4%), public administration (7.6%) and manufacturing activities (6.9%). About the occupational risks to which WwMS were exposed, video display units were mainly represented (21.5%), followed by manual handling of loads (19.7%).

Most respondents (64.0%) experienced (sometimes, often, and always) specific difficulties in issuing a fitness for work judgment. Among the aspects that are mainly attributable to the problems encountered in assessing fitness for work, the working posture appears to be the leading cause (18.9% of the answers provided), followed by job rotation (15.9%) and, with almost the same percentages (about 14%), working hours, type of risk and working environment. The main findings related to the management of WwMS by Italian OPs are reported in Table 2.

Regarding MS-related aspects that can make the assessment of fitness for work challenging, the "Evolution of clinical picture over time" was the topic which reached highest percentage of subjects that considered it very and extremely complex (36.0%), followed by the "Identification of specific organizational measures, prescriptions and job limitations" topic (34.9%) and the "Presence of relapses and remissions" (33.1%) (Figure 1).

For the assessment of fitness for work, 40.0% of respondents declared the medical documentation submitted by WwMS to be exhaustive, while 56.6% considered necessary to acquire the medical certifications or reports issued by the WwMS's specialist clinical center of reference; only 3.4% of respondents

**Table 2.** The management of WwMS.

| | N | % |
|---|---|---|
| **Health risks to which WwMS whose fitness for work you assessed were exposed to**[1] | | |
| Visual display units | 138 | 21.5 |
| Manual handling of loads | 126 | 19.7 |
| Biological agents | 99 | 15.4 |
| Night work | 78 | 12.2 |
| Biomechanical overload of the upper limbs | 71 | 11.1 |
| Chemical substances | 51 | 8.0 |
| Noise | 25 | 3.9 |
| Vibrations | 15 | 2.3 |
| Other | 38 | 5.9 |
| **How often has the fitness for work judgment presented difficulties in the WwMS assessment?** | | |
| Never | 18 | 9.1 |
| Rarely | 53 | 26.9 |
| Sometimes | 101 | 51.3 |
| Often | 22 | 11.2 |
| Always | 3 | 1.5 |
| **The difficulties you experienced in issuing a fitness for work judgment were mainly due to…**[1] | | |
| Working posture | 77 | 18.9 |
| Job rotation | 65 | 15.9 |
| Working hours | 59 | 14.5 |
| Typology of risk factors | 58 | 14.2 |
| Work environments overall | 57 | 14.0 |
| Magnitude of occupational risk factors | 38 | 9.3 |
| Equipment and working machinery | 34 | 8.3 |
| Other | 20 | 4.9 |

[1]*Multiple choice question, percentages of responses.*

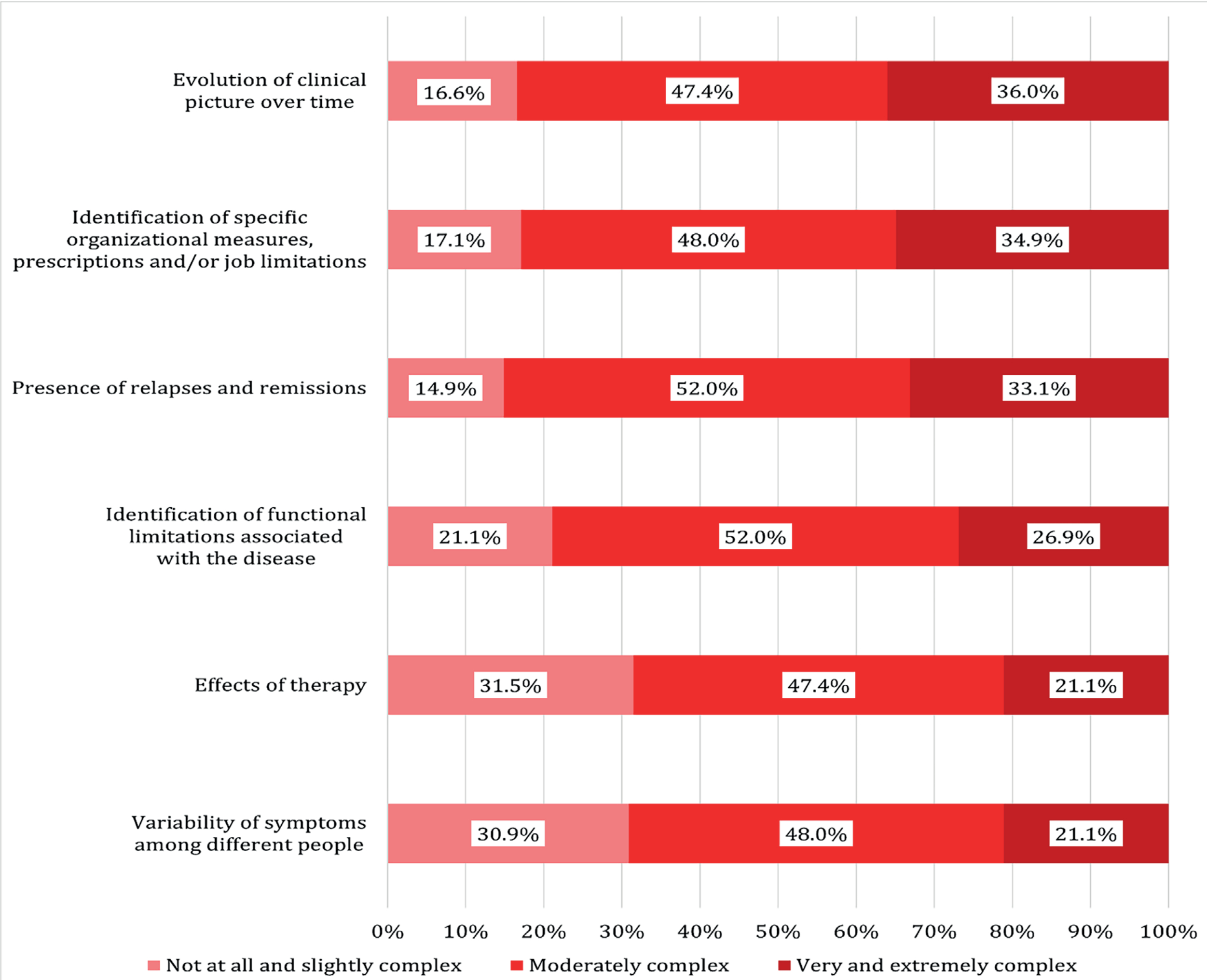


**Figure 1.** Degree of perceived complexity of different aspects for the assessment of fitness for work of WwMS. The scale ranged from not at all complex to extremely complex.

considered necessary to have the WwMS undergo a specialist examination by a neurologist chosen by the employer.

Most respondents (85.1%) considered the availability of neurological certification during the fitness assessment for WwMS work to be very and completely useful. At the same time, 45.0% of the respondents had to ask the neurologist for advice during this process.

In broader terms, the OPs interviewed, called to respond regarding the usefulness of the interaction with different professionals during the fitness for work assessment of WwMS, considered the collaboration with the neurologist (84.6%) and physiatrist (52.6%) as very and extremely useful, in a scale from not at all useful to extremely useful, again aggregating the two extremes of both sides (Figure 2).

### 3.3. Training and Updating Needs

Investigating specifically the level of knowledge of MS, 53.6% of the sample interviewed judged it sufficient, 28.4% good and excellent, and 18.0% poor and mediocre. A high percentage (76.5%) of respondents is interested (very and completely) in

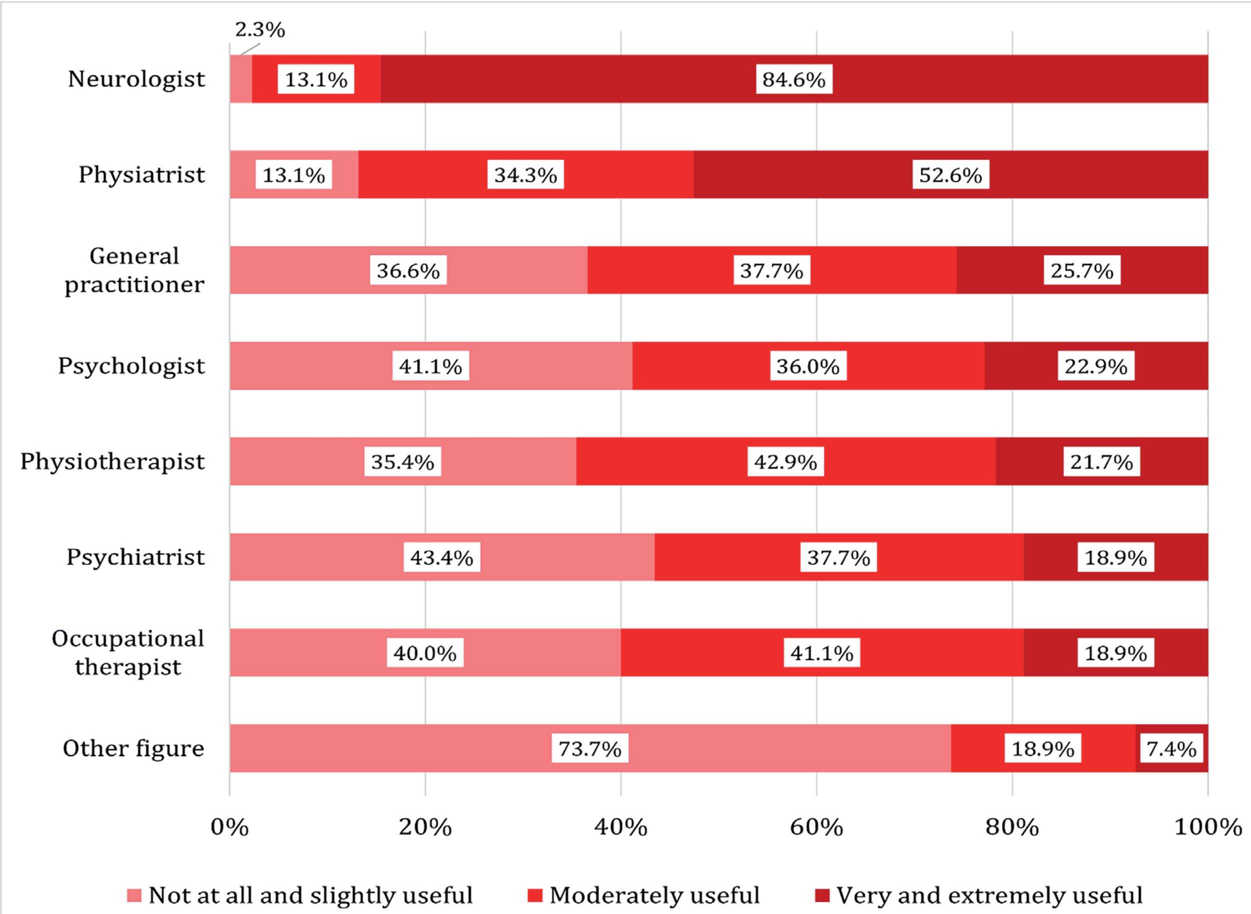


**Figure 2.** Degree of usefulness of the interaction with the different professionals for assessment of fitness for work of WwMS. The scale ranged from not at all useful to extremely useful.

participating in a Continuing Medical Education (CME) course on topics related to MS management in work contexts.

When interested in the CME course, OPs were asked to indicate their interest in different training topics regarding MS management in work contexts. The "Assessment of fitness for work for the specific task", the "Role of the OPs in identifying reasonable accommodations", "Reasonable accommodation: solutions for people with MS severe pathologies and frailty conditions" and "Health surveillance, the most common disorders, and functional limitations" were the most interesting topics of training regarding the MS management in work contexts with percentages of respondents that considered them very and extremely interesting higher than 80% (Figure 3).

### 3.4. Knowledge, Consultation, and Degree of Interest for the Guide "Fitness for Work and Multiple Sclerosis. Guide for Occupational Physicians"

Based on the results of this section of the questionnaire, more than half of the sample (53.1%) was aware of the guide created in 2013 by the collaboration of AISM and SIML, mainly through the SIML itself (56.5%), followed by word of mouth (13.0%). Among OPs that know it, 82.6% consulted it, mainly for managing WwMS (59.2%); the second reason was the need for updating (28.9%).

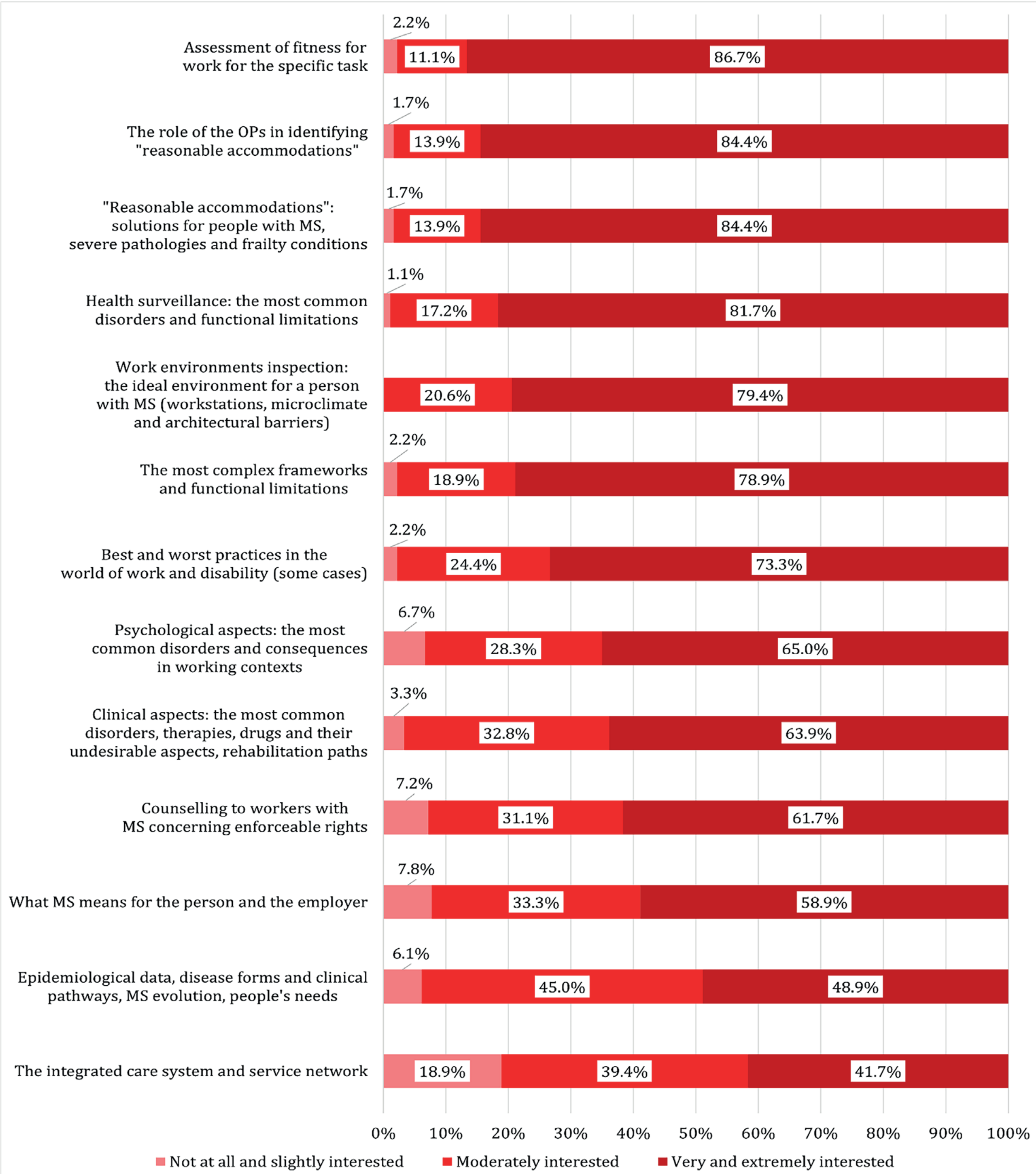


**Figure 3.** Degree of interest in topics for training in dealing with MS and work contexts. The scale ranged from not at all interested to extremely interested.

The guide was mostly consulted to improve knowledge on the impact of functional limitations on work-related fitness (50,7%), followed by ergonomic aspects related to MS (19.1%) and clinical aspects of MS (16.9%).

Among sections of the guide, the one regarding fitness for work for the specific job in WwMS obtained the highest percentages of respondents that considered it very and extremely interesting (89.4%), followed by legal-regulatory and medical-legal context (69.8%) and the rehabilitation and ergonomic consultancy section (69.7%).

## 4. Discussion

In recent years, there has been an increasing need for an approach to health and safety protection that includes the struggle against discriminating workers with disabilities. This is also in consideration of the Italian transposition of the Council Directive 2000/78/EC of 27 November 2000, "establishing a general framework for equal treatment in employment and occupation", regulated by Legislative Decree 216/2003 and effectively finalized with changes made by Law 99/2013 but also with ratification in Italy, through Law 18/2009, of the United Nations Convention on the Rights of Persons with Disabilities (CRPD) [24]. Indeed, the Council Directive 2000/78/EC stated, *"…to guarantee compliance with the principle of equal treatment about persons with disabilities, reasonable accommodation shall be provided. This means that employers shall take appropriate measures, where needed in a particular case, to enable a person with a disability to have access to, participate in, advance in employment, or undergo training, unless such measures would impose a disproportionate burden on the employer"*.

Subsequently, the CRPD introduced the definition of reasonable accommodation as *"means necessary and appropriate modifications and adjustments not imposing a disproportionate or undue burden, where needed in a particular case, to ensure to persons with disabilities the enjoyment or exercise on an equal basis with others of all human rights and fundamental freedoms"*. Furthermore, since 2004 the European Agency for Safety and Health at Work (Eu-Osha) declared that *"…a workplace that is accessible and safe for people with disabilities is also safer and more accessible for all employees, clients and visitors"* [25]. Therefore, considering the current regulatory framework, it is evident that Italian legislation over time established that public and private employers are required to adopt reasonable accommodations to ensure workers with disabilities are fully equal with other workers with work-related disabilities.

Taking into account what is established by the Italian legislation on the protection of health and safety at work (Legislative Decree 81/2008), the OP plays a key role in this context since he is, to all intents and purposes, a "global consultant" on the matter [26]. Indeed, in this regard, it should never be forgotten that the OP is involved in the risk assessment and based on it, as well as participating in the identification of prevention and protection tools, he is specifically called to define the health surveillance protocol and therefore to express the fitness for work judgement to the specific task of the worker [24].

Concerning the risk assessment, Legislative Decree 81/2008 establishes that it must discuss all the risks present at work, including those concerning *"groups of workers exposed to particular risks"* such as *"those categories of workers for whom, compared to the average worker, the risks relating to the same danger are comparatively greater due to subjective causes depending on the workers themselves"*, as already specified in a circular of the Ministry of Work of 1995, including workers with disability. This has also been recently reinforced by the explicit invitation to "Assess and address risks with a particular focus on groups most affected by the pandemic, such as persons with disabilities", reported in the EU strategic framework on Health and Safety at Work 2021-2027 [24]. Furthermore, rules already in force, e.g. Legislative Decree n. 75 of the 25 May 2017 and subsequent amendments and, above all, those referred to the regulatory reorganization on disability issues ongoing in Italy and undertaken with Law n. 227 of 22 December 2021, have already introduced some areas of interest also for OP, such as his involvement in the work placement processes of people with disabilities in all public administration.

Undoubtedly, the aspects relating to the protection of reasonable accommodation, already foreseen and strengthened in the forthcoming reorganization of the legislation, will be an area in which the OP will have to provide his contribution, especially regarding some issues such as the job integration/reintegration and return to work of workers with disability. Therefore, the OP's role in protecting workers with disability emerges clearly. This role requires accurate knowledge and examination of the risks present in the job task and those strictly referred to the work environment that should be correlated to any functional limitations that, in turn, are associated with disabling pathologies. The OP will also be crucial in collaborating to prepare plans for managing emergencies and their optimization based on needs required by the different types of disabilities present [24].

Our survey results show that the management of WwMS is a relatively remote occurrence since more than 90% of OP respondents experimented with it (approximately 48% at least once). These percentages are much higher than those in the previous study [21]. This is probably due to a more significant presence of subjects with MS in the world of work compared to the past and also due to the evolution of therapies that have contributed to promoting job placement and retention. Exposure to occupational risks of WwMS examined by OPs interviewed is in line with the main occupational risks seen in the Italian working population: visual display units and manual handling of loads, both with ergonomic implications.

The assessment of fitness for work of WwMS - generally a complex and challenging activity for the OP - is even more critical in the management of WwMS as it emerges from our study data, where only 10% of the responders have never encountered difficulties in the fitness for work assessment. In this regard, the aspects of the work identified as the basis of the challenges faced by OPs are also in line with the literature. They are mainly attributable to the working posture, job rotation, working hours, and the type of risk present [18-21, 27-31].

Concerning the clinical aspects of MS, those perceived by OPs as most complex for fitness for work assessment are the "Evolution of clinical picture over time" and the "Presence of relapses and remissions". From this arises the declared usefulness of the interaction with some professionals, first the neurologist, followed by the physiatrist, and of neurological certifications (reports) acquirement (very and completely useful for over 85% of OPs). However, it is necessary to take into account, beyond the management of the specific case, that the peculiarity of MS, with the diverse symptomatology that can affect patients in different functional domains, requires an approach that cannot ignore multidisciplinarity and interdisciplinarity, as in general for all complex diseases [32]. It is appropriate to undertake initiatives to implement the multi-interdisciplinary approach to encourage interactions with other professionals (e.g. the physiotherapist, the occupational therapist, the psychologist) to assess fitness for work and identify and implement any reasonable accommodations.

The study shows that over 85% of OPs needed to consult specialist medical reports to optimize their fitness for work, which in almost all cases were presented directly by the workers or requested, through the workers themselves, to the reference clinical specialist centres. A specific availability would seem to emerge within specialist clinical centres for MS in the area, which could be essential for the OP due to particular needs linked to the so-called "difficult or complex fitness for work", which require contact with second-level centres, as also highlighted in previous studies, to better protecting WwMS [22].

As previously reported, taking into account our data, it is not surprising that the training needs, through CME courses, of the OPs interviewed - given a declared sufficient knowledge of the disease – mainly focus on the issues of "assessment of fitness for work for the specific task" and "the role of the OP in identifying reasonable accommodations". Based on the survey results and other points of interest emerging from the study, a CME course was designed and implemented as part of the PRISMA project. It consisted of a synchronous webinar that subsequently merged into an asynchronous webinar in which approximately 900 OPs participated, demonstrating their interest in the topic. Among the tools to support the professional activity of OPs, the availability of guidelines has always been well appreciated by the participants, as has also emerged from the scientific literature about specific SIML initiatives. This is because, in the exercise of any medical discipline, the availability of guidelines is always considered beneficial [33-35]. For this reason, the elaboration of the guide by AISM-SIML in 2013 offered a helpful tool – although not very well known (only 53% of the OPs interviewed admitted to knowing it) whose consultation took place – in particular for the topic "fitness for work" and to explore the impact of functional limitations on fitness for work.

## 5. Conclusion

The interest in the work inclusion and job retention of people with disabilities, implemented by the specific regulatory evolution currently ongoing, in particular the aspects linked to the identification and implementation of reasonable accommodations, will require integration with the OSH protection system and will undoubtedly impact the OP's activities.

As emerged from this survey, there is a clear need for updating on MS matters, primarily referring to the profiling of the fitness for work of the WwMS for job retention. These results, together with further inputs from the PRISMA project [17-20], strengthen the opportunity for the availability of guidelines or, in any case, operational protocols on the subject, which are of significant usefulness for the OP. It is therefore believed that SIML's recent initiative to set up a working group on MS and work with a multi- and interdisciplinary approach favors the preparation of guidelines - starting from the update of the 2013 document - with the aim to supporting the work of the OP in his complex role of "global consultant".

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**Author Contribution Statement:** Conceptualization of the study: BP; Supervision: BP; Validation: BP, PD, SI; Questionnaire development: BP, SI, PD, GD, AM, AR, ND, PB; Data curation & Formal analysis: BMR, GB; Methodology: BP, BMR, GB, SI, PD; Writing – original draft: BP, PD, SI, BMR, GB; Writing – review & editing: BP, PD, BMR, GB, SI, GD, AM, AR, MAB, MP, EP, TM, MI. All authors reviewed and approved the final manuscript.

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Case report

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# Managing Allergic Nickel Dermatitis in Occupational Settings: A Case Report

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**Summary**

*Contact dermatitis is a common cutaneous inflammatory condition triggered by exposure to irritant substances or allergens. Nickel is the most prevalent allergen, a metal widely used in accessories, furniture, office materials, and the food industry, with multiple exposure pathways, making it difficult to assess which exposure is causing allergic dermatitis. Here, we report a case of an administrative worker with chronic hand eczema, limited to the radial metacarpophalangeal region of the left hand, caused by occupational exposure to nickel, confirmed by nickel deposition test on the hand and a positive test with a metallic stapler used at her workplace.*

## 1. Introduction

Allergic contact dermatitis (ACD) is a common inflammatory skin condition triggered by exposure to specific allergenic substances. It is also the most common cause of occupational dermatitis [1, 2]. Nickel stands out as one of the most prevalent allergens, both in occupational and non-occupational settings [3, 4].

The widespread use of this metal in a vast array of consumer products, ranging from jewelry, clothing, electronic devices, food, medical devices, and industrial components, significantly increases the risk of exposure, sensitization, and development of these dermatoses, making the interpretation and identification of the underlying cause of the allergic reaction challenging at the time of patient observation [1, 4]. Thus, repeated and prolonged exposure to nickel can elicit an immune hypersensitivity response in susceptible individuals, resulting in a variety of clinical manifestations ranging from mild itching to severe and debilitating eczematous skin lesions, underscoring the importance of being vigilant in these situations, striving to minimize their consequences as much as possible [1, 3].

In this case report, we present a 31-year-old administrative worker diagnosed with allergic nickel contact dermatitis confirmed by a nickel deposition test on the hand. We describe the limitations and workplace changes needed to ensure a safe and healthy working environment for that employee.

## 2. Case report

A 31-year-old female administrative worker, who has been working for 10 years, presented at

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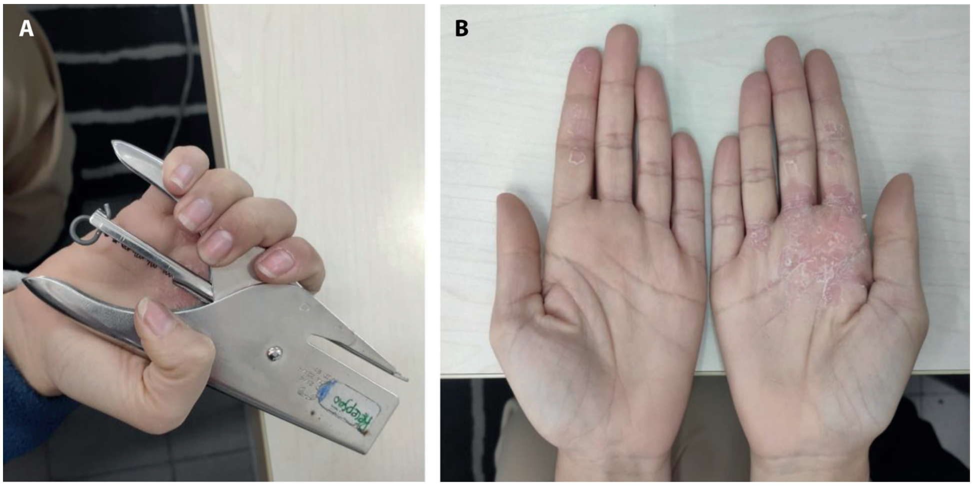


**Figure 1.** (**a**) Stapler manipulation; (**b**) Pronounced eczematous lesion in the left radial metacarpophalangeal region, coinciding with stapler use.

the dermatology clinic with contact dermatitis, in January 2024. Symptoms began in 2014, when patient started her current and only job, as an administrative worker, and have been exacerbating since 2017. The eczema started on the left palm and spread to both hands since the onset of exacerbations in 2017, but always with more pronounced symptoms on the left palm. On physical examination we identified chronic vesicular eczema on the palms of both hands, more pronounced in the radial metacarpophalangeal region of the left hand. The patient reports no history of allergic reactions to jewels. The patient also denies a history of atopy, and is unaware of triggering factors, but reports improvement of eczema during vacations and absence from work. Patch testing was performed, including the Standard series from the Portuguese Group for Contact Dermatitis Studies, applied using a 2-day occlusion and IQ Ultra Chambers (Chemotechnique Diagnostics$^{TM}$) on the dorsal region according to European Society of Contact Dermatitis recommendations [5]. The results were read on days (D) 2, D4, and D7, revealing positivity for nickel sulfate (+++).

A workplace visit was conducted, and a dimethylglyoxime (DMG) test for nickel presence was performed on occupationally used products. The DMG test confirmed positivity in the stapler, which coincides geographically with the delineation of the lesion in the metacarpophalangeal region of the left hand in Figure 1. Since starting her job as an administrative worker, she has frequently used a stapler, about 8-10 times per hour.

Nickel presence was tested in the worker's hand lesions using previously published methodologies, as described by Julander et al and Wennervaldt et al [6, 7], at the beginning of the workday and after a 4-hour shift, showing positivity at the end of the shift [6-9] in Figure 2. In this regard, a recommendation was made for her workplace to avoid contact with the metal stapler and switch to a stapler with a plastic coating. Additionally, the patient was advised to avoid contact with jewelry containing nickel, a precaution she was already following.

Actively avoiding the known sources of nickel exposure in her occupation resulted in a notable improvement of her hand eczema, verified at the follow-up appointment after 4 weeks. On physical examination, no eczema was observed. An occupational disease notification was made to the Portuguese Department of Protection against Occupational Risks, and regular follow-up by her occupational physician was requested after 8 weeks.

## 3. Discussion

Nickel is the most common cause of allergic contact dermatitis, predominantly affecting females. It is largely due to early contact with jewelry and

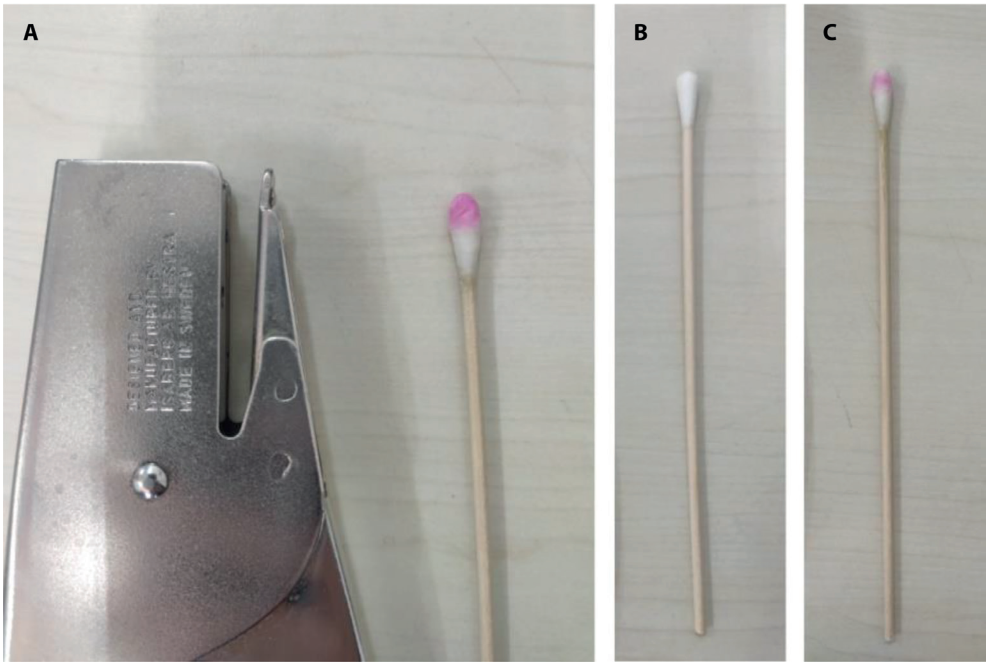


**Figure 2.** (**a**) Positive DMG test of stapler.; (**b**) Negative DMG test of hand lesions before work activity; (**c**) Positive DMG test of hand lesions after a 4-hour shift of stapler manipulation.

clothing incorporating this metal into their composition or other skin contacts with nickel-containing objects. However, occupational exposure should not be overlooked, as it is common in the construction, service, and healthcare sectors [3, 10, 11]. Indeed, allergic contact dermatitis to nickel is one of the most common occupational dermatoses, affecting workers from various fields due to continuous exposure to this allergenic agent in the workplace environment, as it is a metal frequently found in industrial and occupational use products [2, 4, 11].

In the working environment, repetitive exposure to nickel agents can lead to its deposition on the skin, potentially resulting in chronic eczema and allergic contact dermatitis [3, 12]. According to some published studies, the prevalence of occupational dermatitis due to nickel can reach up to 12% of the total number of occupational contact dermatitis [13]. Other studies have found significant associations between nickel allergy and occupational exposure, namely metal/mechanical work among women and agriculture and health care services among men [11]. In this study, we present the case of a worker diagnosed with nickel contact dermatitis, whose symptoms manifested and worsened in the occupational context.

Hand DMG testing has proven to be an efficient method for detecting nickel exposure, making it an option in suspected cases of contact dermatitis, particularly in the occupational setting [7-10]. The applied methodology should be as follows: before a regular workday, the patient's hands are thoroughly cleaned with water and soap, wiped with 1% nitric acid, and washed with deionized water. The patient is instructed to avoid hand washing during work hours. After a work shift, the patient's hands are tested with the DMG test using a swab soaked with the DMG solution and applied to the patient's hands. Finally, the hands are washed thoroughly after the examination [6, 7]. However, hand DMG testing has proven to be an efficient method; we must emphasize the importance of detailed clinical history and patch tests as an initial element in the diagnostic course of these contact dermatitis [1]. A positive DGM test indicates accumulation of >0.13 µg nickel/cm2, and probably relevant occupational nickel exposure, however a negative test does not definitively exclude occupational exposure [4, 6, 10].

This case illustrates not only the clinical relevance of allergic contact dermatitis to nickel but also underscores the importance of providing careful information to workers about potential sources of nickel exposure, as well as prevention strategies to minimize the impact of this condition on their quality of life.

Therefore, the importance of workplace visits is emphasized for the early identification of triggering factors and implementation of preventive measures. Furthermore, this article emphasizes the ongoing need for research and development of diagnostic and therapeutic approaches to improve clinical outcomes and minimize the repercussions related to nickel exposure on the quality of life of the most susceptible workers.

## 4. Conclusion

In our case, hand DMG testing has proven to be an efficient method for detecting nickel exposure in occupational nickel contact dermatitis.

This clinical case aims to increase awareness of the occupational risks associated with nickel exposure and underscore the importance of carefully evaluating work history in patients with allergic contact dermatitis. A detailed exposure history is essential for an accurate diagnosis and successful management.

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