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Systematic Review

A Systematic Review Discussing the Sustainability of Men and Women's Work in Industry 4.0: Are Technologies Gender-Neutral?

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Abstract: The introduction of new technologies at work in the context of Industry 4.0 (I4.0) has led to the emergence of risks for health, even if they are still underexplored. However, their understanding does not usually adopt a gender perspective, even though the gendered division of work has differentiated health outcomes. As sustainability is at the top of the political agenda and in consideration of the gender segregation that exists at work, it is pertinent to question how I4.0 technologies are reconfiguring workplaces and impacting women and men's health. Following a systematic review approach using the PRISMA protocol, this study explores how gender is integrated in I4.0-themed studies, exploring employment, work, and health. After the identification and screening phases were completed, a total of 16 papers were included. Literature exploring technological transformation from a gender point of view is scarce, as well as research developed in concrete work contexts. The literature in this domain tends to address employment prospects, and women are generally described as being more at risk for job loss through automation processes. Health risks in the literature found in this review were mostly neither considered nor differentiated for women and men. Future studies should consider the specificities of different work contexts through the development of case studies in different activity sectors so that the risks for women and men can become visible. This way, interventions at a work organization level are enabled to create more sustainable working conditions.

Keywords: Industry 4.0; technological transformations; gender; health and work; work sustainability; health-related risks

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1. Introduction

The concept of Industry 4.0 (I4.0) is based on the digitalization and automation of production processes, leading to the emergence of a new industrial paradigm [1]. That is, the introduction of technologies (such as artificial intelligence, augmented reality, Internet of Things, and collaborative robots) potentiates the interconnection between different actors, systems, and technological artifacts, creating intelligent systems that collect and process data more efficiently and supporting real-time operational monitoring [1–3]. In terms of sustainability, the dominant literature frequently highlights that such new human–machine cooperation has the potential to improve both efficiency and occupational health (e.g., prevention of musculoskeletal disorders by reducing the physical burden for workers through automation) [4–6]. However, some risks for employment, work, and health have also emerged in this context.

To begin with, the academic literature has been flooded with predictive studies regarding the reconfiguration of the labor market and the new forms of work organization brought about by I4.0; however, the projections that have been made vary. Some authors foresee a mass automation of work and increased unemployment rates, e.g., [7], and others predict the likeliness of an inadequate adjustment of workers to these new (or reconfigured) jobs, the lack of access to new forms of qualifications/training, an increase in temporary employment and/or virtual work, and a further polarization between workers [8,9]. The latter issues can also lead to digital exclusion and to an increase in the unequal distribution of work [10–13].

Also, the labor market is highly segregated in terms of gender [10,14], which means for men and women, these risks may be different. There is an unequal employment distribution in terms of gender (e.g., fewer women in higher hierarchical positions) and differences in the tasks that are developed by women and men (even when sharing the same profession), thus creating differentiated health outcomes [10,14–17]. Nonetheless, the I4.0 literature is mostly focused on employment impacts. On the one hand, some authors draw attention to how digital technologies might enhance gender bias as it increases flexible and non-standard work, thus possibly increasing female employment, as women tend to work in non-standard employment with lower wages [10,18]. This possibility was evidenced, for instance, using AI algorithms for recruitment purposes by Google: "when Google displays highly paid job adverts to male rather than female users, or Amazon's recruitment algorithm downgrades CVs that mention 'women', the history of gender bias becomes encoded within digital platforms" [10] (p. 6). On the other hand, the changing patterns in women's education and work can affect these impacts [19].

While the future is still yet to be unraveled [20], the various risks which have been pointed out—and that threaten the sustainability of work—should not be undermined. Those risks are more than just labor market risks, as threats for the health and well-being of workers also emerge in the context of I4.0 technology-induced changes [21]. For instance, work intensification, human–machine conflicts, increased cognitive workload, feelings of job insecurity, and even physical hazards can be found in the literature [22–25]. Still, the gender dimension remains generally underexplored in the I4.0 literature, even though these risks are, simultaneously, determinants and effects of different dimensions such as gender, age, and/or territorial employment distribution [26]. That is, while some studies have pointed out that I4.0-induced changes can hold risks for health, e.g., [23,24], the differentiated impacts on women and men remain unclear, as I4.0 research that includes the gender dimension is scarce [21,22]. The predominantly technology-centered discourses tend to focus on the development and implementation of technology, which are often distant from real work contexts, neither considering those who shape its use nor their specific health consequences [21,22,27].

The introduction of technology is not homogenous throughout different activity sectors as its usability requires a process of appropriation that is always shaped by the surrounding socio-technical structure [28]; this includes social (e.g., gender) roles and expectations. In other words, the uses of technology reflect their specific social contexts and thus may perpetuate existing forms of gender inequality into the so-called new forms of work—technologies as being "crystallizations of society" [29] (p. 4). For instance, in a factory in the cork industry, still at an initial phase of its automation process, Cunha et al. [30,31] found that female workers ended up, through their experience, having to compensate for the limitations of the technology introduced, and the separation between female and male workers' tasks was reinforced. This was an example of how technological transformation at work interacted with the context's pre-existent gender segmentation and enhanced it.

In short, the unequal distribution of work, which are visible through both vertical and horizontal segregations, means that I4.0 changes present different risks for women and men's health and well-being, which impact the sustainability of their professional paths [10,17,32]. Therefore, interventions of working conditions cannot be analyzed without considering the specificities of the context. Disregarding the role of gender ends up concealing the differentiated risks to the health of women and men that emerge from work and its uneven distribution [16,17,30], precluding appropriate interventions. Considering the United Nation's call for sustainability through their Sustainable Development Goals—namely, goal numbers 3 (good health and well-being), 5 (gender equality), and 8 (decent work) [33], this is an opportune moment to integrate these aspects into the debates on I4.0 technology and the future of work.

Hence, this study follows a systematic literature review approach to explore the sustainability of I4.0 workplaces from a gender perspective. The intent is to follow up on a previous review exploring the representation of human workers in I4.0, as well as the health risks that have emerged from the introduction of technologies [22]. But, this time, the aim is to consider gender as the main variable to explore this issue. Specifically, this study will explore if technological implementation does or does not contribute towards the dilution of previous forms of gendered labor segregation, as well as what health risks exist for men and women in the context of these reconfigured workplaces.

Our main research question is: "Does the I4.0 paradigm guarantee sustainable and healthy workplaces for men and women at work?"; we followed the concept of work sustainability as proposed by Volkoff and Gaudart [34]. That is, the issues that are raised in this review concern: (i) if the working conditions described within I4.0 enable people to remain healthy; (ii) what types of difficulties that workers are confronted with to maintain their well-being at work in these contexts; (iii) what the consequences for workers stemming from the exposure to such workplace risks are; and (iv) what differences in the exposure and impacts for health are found for men and women at work. This debate is anchored in the scientific tradition of work psychology and activity ergonomics. Specifically, we aim to explore:

RQ1: What does I4.0 research reveal about the impacts on women and men's labor market and work distribution?

RQ2: What are the risks for both men and women's health when using I4.0 technology? That is, which risks are described? And are they different for women and men?

2. Materials and Methods

In order to systematically review and analyze how the existing literature perceives the relationships between gender and I4.0 technology at work, the methodological steps mentioned in Shamseer et al. [35] were followed, obeying the PRISMA 2020 protocol criteria. The PRISMA checklist used as protocol has been made available as a Supplementary Material, as mentioned in the Supplementary Materials Section.

This review drew on the cross-disciplinary database Scopus, as it covers the broadest variety of indexed journals [36]. Articles were collected between the 23rd of September 2022 and the 31st of January 2023, and the search terms are presented in Table 1.

Table 1. Keywords and filters used in the research.

Keyword		Publication Year		Language		Field
"Gender" AND "Industry 4.0"	AND	>2014	AND	"English"	AND	TITLE-ABSTRACT-KEYWORDS-AUTHORS
"Gender" AND "Factories of the future"	AND	>2014	AND	"English"	AND	TITLE-ABSTRACT-KEYWORDS-AUTHORS
"Women" AND "Industry 4.0"	AND	>2014	AND	"English"	AND	TITLE-ABSTRACT-KEYWORDS-AUTHORS

The terms were searched in the abstracts, titles, and keywords on the Scopus database using the following inclusion criteria: language (English) and publication year (published from and including 2015). Both authors reviewed the information of each article, title, abstract, and type of publication. Considering the full content of each selected paper, the data extraction was performed by focusing on the research objectives. That is, in terms of inclusion criteria, the research had to consider the gender dimension, and I4.0-specific technologies or the I4.0 concept. Studies with empirical data and with workplace applicability were also considered. The application of these criteria in the identification phase of the methodology led to the exclusion of 82 papers. Once the relevant articles were collected, filtered, and had duplicates removed, the full text of the papers were reviewed and once again filtered with a view of eliminating those that were not in English and those that were not directly related to the objectives, which resulted in a total of 16 papers.

A database was created for each article, which summarized the main information extracted from each paper; the information was discussed in several meetings that were held along the study's development with both authors. Due to the lack of information available that is focused on the research questions described, the literature review articles obtained during the search were also included in the results. No software was used to support the analysis.

Figure 1 illustrates the process used to gather the literature using the PRISMA methodology and the structure that led to the final selection of articles.

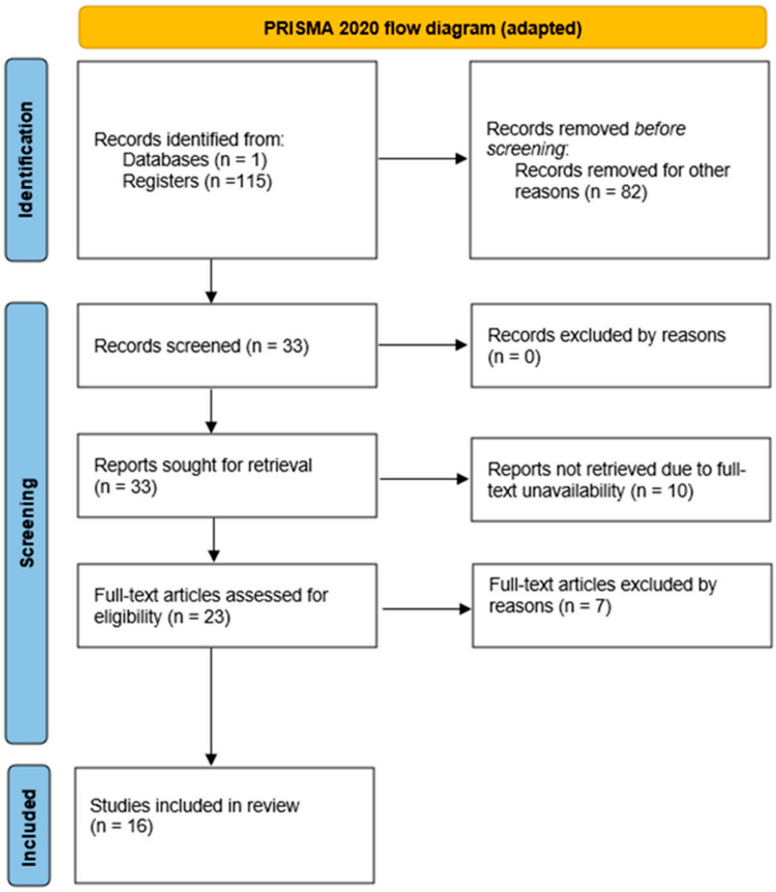

Figure 1. Flow diagram of the research selection process using the preferred reporting items for systematic review and meta-analysis protocols (PRISMA), retrieved and adapted from Page et al. [37].

In the final screening phase, eight articles were excluded due to the following reasons: full-text not available in English (2 articles); gender only being briefly mentioned and not being actively considered in the study nor in its results (4 articles); not being specific to the Industry 4.0 context (1 article); and the study's focus not being pertinent for industrial work scenarios (i.e., focus being placed on the general use of technologies by seniors retired from work) (1 article).

3. Results

This section presents the results obtained through the research methodology previously described. After the articles were thoroughly read and selected, a table with the main contributions retrieved from the included 16 papers was created to serve as a base for the analysis of results and discussion. Figure 2 illustrates how the final selection of articles that resulted from the aforementioned research strategy are distributed throughout the years.

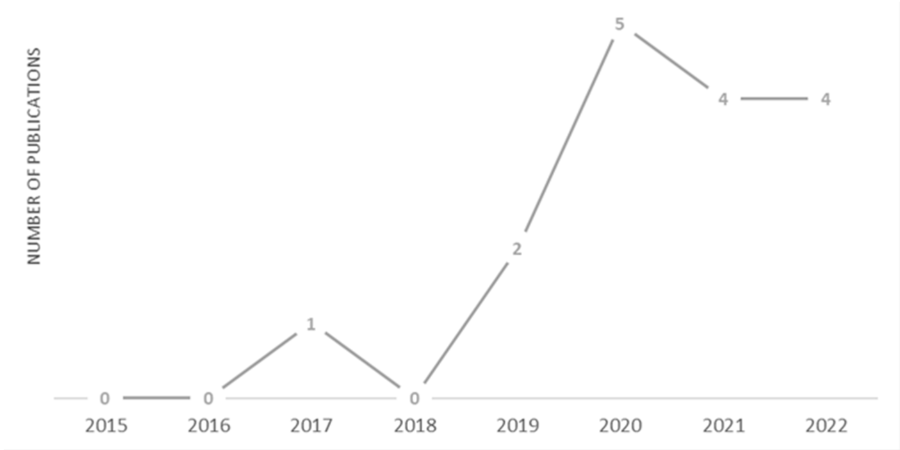

Figure 2. Distribution of the filtered publications included in the analysis per year since 2015.

While papers remain scarce, studies considering gender, work, and I4.0 technologies have increased since 2018. This is perhaps due to the generalized I4.0-focused literature that has occurred since that year, e.g., [38], possibly instigated by the emergence of the European Commission's Horizon 2020 project. This project led to a greater financing of research focused on Industry 4.0 [39] and, consequently, a greater amount of literature published until 2020.

4. Discussion

Overall, despite the initial 115 articles in the unfiltered results, there is a clear lack of empirical studies focusing on the gender dimension within the I4.0 paradigm that included both the gender dimension and work, which resulted in the inclusion of only 16 papers. In the ones that consider these dimensions, the emphasis was mostly placed on employment through projections looking into who will be more at risk of suffering job loss. Only a few articles were developed in a specific context, performed through case study methodologies, or focused on the use of specific technologies. The different studies' methodology, the corresponding research questions addressed, and the studies' contributions have been described in Table 2; the themes explored throughout the different discussion topics is explained below.

Table 2. Synthesis of the main results, with 'x' marking each paper's corresponding category/categories.

Authors and Year of Publication	Publication Type	Corresponding Research Question	Method Adopted	Focus on Employment (Considering Global Trends) and How Technological Transformations Can Increase/Decrease Employment from a Gender Perspective	Analysis According to Specific Technologies (Either Being Used at Work or for the Understanding of Employment Prospects)
Barker and Jewitt, (2022) [40]	Journal Article	RQ2	Ethnography, interviews, and observations		x
Barton (2020) [41]	Conference Paper	RQ1	Critical discourse analysis	x	

Table 2. *Cont.*

Authors and Year of Publication	Publication Type	Corresponding Research Question	Method Adopted	Focus on Employment (Considering Global Trends) and How Technological Transformations Can Increase/Decrease Employment from a Gender Perspective	Analysis According to Specific Technologies (Either Being Used at Work or for the Understanding of Employment Prospects)
Cassioli et al. (2020) [42]	Conference Paper	RQ1	Reflective concept review	x	x
Diniz et al. (2021) [43]	Conference Paper	RQ1	Survey study	x	x
Haiss, et al. (2021) [44]	Journal Article	RQ1	Computerized probabilities using available employment frameworks and national secondary data	x	x
Johansson et al. (2017) [45]	Journal Article	RQ1	Reflective review	x	
Kurt (2019) [46]	Journal Article	RQ1	Literature review	x	
Lamberti et al. (2022) [47]	Conference Paper	RQ2	Case study application		x
Lambrechts et al. (2020) [48]	Book Chapter	RQ1	Literature review	x	
Mehta et al. (2021) [49]	Journal Article	RQ1	Employment and occupation mapping using national secondary data	x	
Nadeem et al. (2021) [50]	Conference Paper	RQ1	Systematic literature review	x	x
Nedomová et al. (2019) [51]	Conference Paper	RQ1	Employment and qualification mapping using national secondary data	x	
Paviglianiti and Pasero (2020) [52]	Conference Paper	RQ2	Case study application		x
Ramos, et al. (2022) [53]	Journal Article	RQ1	Employment and occupation mapping using national secondary data	x	
Soukupová et al. (2020) [54]	Journal Article	RQ1	Survey study	x	
Turk, et al. (2022) [55]	Journal Article	RQ2	Case study application		x

The following discussion topics will be divided by these two major results. The idea of sustainability from a gender point of view must be considered from different levels of analysis: (i) the impact of technology on employment (e.g., macro analysis; gendered labor distribution; algorithms and the idea of perpetuating previous social roles; wages and worker polarization), which is addressed in Section 4.1; (ii) how concrete activity is reshaped through technology, i.e., what is actually performed within the contexts of each work activity and the gender differences (e.g., task distribution between men and women within the same professions), which will be addressed in Section 4.2; (iii) and which risks and health impacts for workers' professional paths arise from the differentiated use of technology and that of task distribution, which is addressed throughout both Sections 4.1 and 4.2.

4.1. A Gendered Labor Market View

During this review, the literature that was found tended to assume a macro perspective that was based on statistical data or general employment frameworks, and they were distant from the fields in which the technology was concretely implemented; however, the methodologies and data used to achieve this end, as well as the determinants evaluated, did have variations. In this following section, these issues will be further analyzed, as well as the results obtained that challenge the idea of I4.0 as a new form of work organization and integrated sustainable values. While they all also describe very distinct realities, it is still relevant to understand how such analyses were carried out and what expected global impacts they foresaw.

Some authors adopted global frameworks to interpret national employment data. For instance, Ramos et al. [53] developed a 'multinominal logit model' using national statistical data to understand how labor and sociodemographic characteristics could determine occupational automation risk in Mexico. The authors used data from 2013 to 2018, meaning that part of this data was at least partially collected in a very initial stage of the I4.0 concept and prior to the intensification of I4.0 technology-related literature, which arose circa six years ago [56]. On the one hand, they did mention that Mexico's informal sector and the generally low wages reduce the overall risk for automation due to the costs of investing in technology; on the other hand, they found that for low-skilled jobs with 'demotivated workers' [53] (p. 8)—as in workers looking for an alternative job in order to improve their working conditions (such as working hours, work benefits, work environment, or social security)—this risk was higher.

Mehta et al. [49] also used secondary national data (in this case, from the Indian National classification of occupations and from the Periodic Labour Force Survey, collected from 2018 to 2019) to predict employment prospects. Nevertheless, while Ramos et al. [53] used gender as one of many mere sociodemographic factors, Mehta et al. [49] specifically focused on how I4.0′s predicted impacts could be different for men and women. Their idea was to explore women's employment in the context of new I4.0 technologies that were being introduced into India by focusing on the labor distribution according to sector (e.g., service, agriculture), territory (rural and urban), skill level (unskilled, low-skilled, medium-skilled and high-skilled), and type of tasks (e.g., physical routine tasks) [49].

The findings of both of these studies in terms of the job loss for men and women were distinct and were also according to country-level specificities and the type of data considered. Mehta et al. [49] found differentiated risks that could lead to an increased polarization between jobs in terms of skill levels and gender. That is, taking into account the large proportion of women in low-skill and unskilled jobs working in the manufacturing and service sector, by developing the so-called 'routine' tasks, the risk of automation seemed to be much higher for the case of women [49]. Ramos et al. [53], however, did not find a negative relationship between the likeliness of automation and having a lower educational level, as commonly found in the literature, e.g., [57], nor did they find that women were more exposed to this risk. In both of these examples, assumptions were based on general projections about which occupations could be more or less automated, which was determined according to parameters such as sector, type of company, or educational level. Sustainability in I4.0 contexts is thus only considered from a job availability point of view.

Following this perspective, the study presented in Haiss et al. [44] also focused on the socio-economic effects of the introduction of I4.0 technologies (specifically, robots, algorithms, and digital technologies) in Austria using available data regarding employment distribution. But, for their study, Frey and Osbourne's [7] framework was used to derive computerized probabilities of occupations being automated, and the work focused on the technological capabilities [44]. The authors predicted an increase in job polarization and that a large percentage ("about 40%"), of the Austrian workers were expected to undergo significant changes regarding the structure of their tasks, required skills, and working environment [44]. In this scenario, they also concluded that women were the ones most affected by technological changes due to their sectoral distribution (mostly education or public administration) [44], which were in occupations that were described as higher risk.

However, quantitative studies such as the one conducted by Frey and Osbourne [7] do not consider the subjectivity found in work action, i.e., the non-routine tasks that are found even in the jobs that are labelled as routine [58], as well as how variability is managed by experience or corporified knowledge. Additionally, the study by Haiss et al. [44] appears to assume that several factors are universal and applicable to all jobs, even though they affect how likely a job is to be automated. Such factors include information about how technology is actually used; the professional experiences of those who use it; the social dimensions of its use; or what parts (if any) of the work process have previously been automated. A similar critique can be made about the study by Diniz et al. [43] who explored the openness of workers to "to accept, welcome and adapt to this new environment" (p. 2); this view still assumes that it is the workers' responsibility to have to continuously adapt to the technological changes forced upon them, as if no previous experience was there to shape the technology that will be used. These techno-centric views of I4.0 continuously reinforce the idea of workers as subordinates to technology while not properly examining the problems that technology will presumably resolve [27]. Thus, the risks that these introductions pose for workers' health or their safety are ignored. The workers in the actual work systems undergoing changes seem to be continuously portrayed as neutral humans and as 'adjustment variables', with emphasis largely being placed on the potentialities of technology (as seen in [22]). Health was not considered.

When the reference to the gender dimension is missing, it is generalized. For example, Diniz et al. [43] mention that men seem to be more comfortable with the concept of big data analytics when compared with women and that younger generations were more knowledgeable of concepts such as augmented reality, simulation, and systems integration. However, the motives or specificities of the work contexts of the respondents were not surveyed and, once again, nor was the level of technological advancement in the contexts of the different respondents. The focus merely seemed to be on the knowledge regarding the different technologies and not the different factors from which this knowledge stems from (e.g., social and territorial context, education area, interest, or even the current evolution of technological introduction at their workplaces) [59–62].

However, one explanation for the asymmetrical knowledge found for women and men regarding I4.0 technologies found in Diniz et al.'s [43] study may be the continuously low female presence in science, technology, engineering, and mathematics disciplines (also known as STEM disciplines) compared with men [19]. This persists, even despite the increase in the demand of certain technical skills from these areas [46]. Such an issue has been pointed out as a gender equality obstacle, as STEM occupations are expected to be the most common and best-paying future jobs [57]. Kurt [46] evaluated the probable effects of the 4th Industrial Revolution on employment. The author found that due to the expansion of artificial intelligence and the capacity to digitize service sector tasks (in which women occupy a larger ground), it is probable that the female labor force will suffer a greater job loss [46]. Similarly, Nedomová et al. [51] found that in the Czech Republic, Hungary, Poland,

and the Slovak Republic, while IT-qualified people are important for the development of the countries' digital economies, the number of female ICT professionals is permanently decreasing. For these reasons, it is also no surprise that Soukupová et al. [54] observed that gender as well as age served as significant factors for discrimination through the use of a questionnaire that calculated the profile of employees that perceived the changes triggered by I4.0 as most threatening. As underemployment and lower levels of IT literacy tend to be more frequent among women, and as they are also less probable to pursue technical disciplines [54], the perception of women as a more vulnerable group in the labor market when compared with men is perpetuated. That is, women continue to lose ground in STEM areas, even if these are in high demand and are expected to continue to increase in the future [54].

The low presence of women in STEM disciplines is not, however, the only factor that contributes to the continuous gender bias in technology. As mentioned by Nadeem et al. [50], as AI algorithms are trained according to datasets shaped by their creators' values, pre-existing social bias 'slips' into the AI systems, thus augmenting gender stereotypes and discrimination. This view is not unique to AI systems, nor is it unique to the I4.0 technologies [45,63]. As we have seen in previous technological developments, even beyond those specific for work, technological artifacts were often primarily targeted, designed, and tested on male bodies [42]. Following up on one of the examples described in Cassioli et al. [42], the crash test dummies having been primarily tested on male bodies and have led to more women being engaged in accidents that ended up deadly. Therefore, if the introduction of technologies at work perceives workers as neutral or assumes them to be typically male, women may be more likely to be exposed to health hazards. This traces back to a long history of perceiving technologies as masculine, intertwined with associations of these to typically masculine environments—perceptions that are still perpetuated in the modern concepts of technology. Specifically, Cassioli et al. [42] mention: "Ambient Intelligence (AmI) and IoT, like old technologies, are masculine domains and the smart environments that result from these are masculine concepts. Gender studies show that differences in use of ICT—and thus of AmI and the IoT—are shaped by socio-culturally prescribed or constructed roles of masculinity and femininity. (. . .) Gender difference will persist in uses of ICT" (p. 327).

Barton [41] argues that the whole concept of I4.0 is based on the idea of reproducing social and cultural power through technology while reinstating domination forces. For this author, the whole of the I4.0 narrative does not acknowledge and value women's labor, which undermines women's participation in the future [41], reinforced by the longstanding notion of a 'masculinization of technology' that is noticeable in the socially shared dialogue about technology [45]. For the latter authors, the literature still fails to address the relationship between new technology and working conditions, qualifications, identity, and gender; the literature also fails to address the future of the workers' collective and integrity issues in human–machine interactions [45]. As Barton [41] mentions, the 4th Industrial Revolution is biased towards women and Global South citizens, and the author claims that risks for economic and social sustainability are larger for Global South countries. While work-specific risks remain concealed, it is harder to reinforce such arguments. But, it is known that even the Global North is not that equal itself in terms of gender [10].

If the use of tools (including technological tools) at work is shaped by cultural, organizational, and social values [64], such risks for the sustainability of work should be considered for each context according to its specificities (e.g., employment and working conditions, workforce characteristics, resources). Beyond just the creation of such technologies, human work is situated in a given context (in its material, social, and historical components). As mentioned by Nye (2006), technologies are social constructs with political and social repercussions.

What most of the employment-centered studies described throughout this systematic review have in common is the fact that they rely on uncertainty, speculation, and/or general historic patterns, even though it has been argued for decades how, in real work contexts, the division of bodily techniques developed for work is never only connected to the gendered division of labor [65]. Ansari et al. [59] add that the primary reason for flawed predictions is grounded in the market, industry sector, or the technological specificity of the assumptions, which affect how theories are formulated and, accordingly, explained and interpretated. While gender does tend to be disregarded in the current wave of technological developments, the threat of technological introduction for human learning as well as the decline in tacit knowledge regarding work processes and systems is not a new discussion [59].

In terms of findings, skills and labor distribution (mostly by sector and occupation) tend to be the factors used for understanding the impact of I4.0 on women and men's work in the future, and women are frequently flagged as at higher risk for automation. However, the results did have some variations. For instance, some studies mention the service sector as more highly prone to automation, e.g., [49], and others find the opposite, e.g., [46]; alternatively, lower wages were flagged as an obstacle to automation, but women with lower wages were still at higher risk of being automated, e.g., [44]. This is also a consequence in part to the limited data regarding the long-term and large-scale implementations of I4.0 technology, which is also a consequence of the novelty of these technologies and of the fact that they are still under development, e.g., [66]. Acknowledging this universal absence of a shared consensus about the impact of Industry 4.0 on the labor landscape, Lambrechts et al. [48] emphasize that the digital divide (e.g., gender and age asymmetries) needs to be mitigated to put forward inclusive modernization as well as production and economic growth opportunities. Thus, interventions towards the upskilling of workers were signaled through the expansion of higher education opportunities.

Additionally, there seems to be a general conceptualization of skills that is distant to what workers actually develop to be able to work. For instance, even within the so-called 'low-skilled' workforce, these workers have been found to develop informal competencies at work through experience, which contribute to their management of unpredictability, change, and complexity [58]. A similar finding was described in Barker and Jewitt [40] among waste management workers: "picking [as in sorting and handling waste] effectively (fast and accurate) is a coordinated, reactive, and skillful activity" (p. 121). So, the labelling of such jobs as monotonous and easily automatable is reductive as it also ignores the context's specificities in shaping the actual use of technologies as well as the place that previous work experience and gender have for shaping the technical act that is reconstructed in these contexts, e.g., [67]. Not including other aspects of the work activity or not actively involving the workers in the design and implementation processes can generate a discrepancy between the skills and demands, thus creating a succession of negative consequences for both the workers and the system in general [66].

4.2. The Labor Market Is Biased, but I4.0 Literature Mostly Assumes That Technology Is Gender-Free . . . What Are the Impacts of This Assumption?

Studies such as the one conducted by Kurt [46] focus overall on the positive potentialities for occupational health, emphasizing a future with smooth human–machine cooperation and envisioning a future where working times are reduced to potentiate human health. However, these prospects have limitations (see [22]) as the assumptions are general and assume coherence and homogeneity in the technology itself despite the heterogeneity that exists in the contexts that they will be adapted to. So, considering that "we can only speak of responsibility if we believe that we have agency over these technologies in the first place" [41] (p. 305), the following paragraphs reflect on how this has been performed in studies that (i) consider the gender dimension in their results, (ii) focus on the design and development of technological artifacts, and/or (iii) describe a workplace-specific analysis of their use.

As the studies that obeyed the inclusion criteria and corresponded to the second research question were limited, the discussion will firstly focus on two studies that described the development of technologies centered on enhancing health at work. As aforementioned in the introduction, one of the main premises of I4.0 is to make work contexts more customizable and interconnected through technology, with the focus being increasing productivity [68–72]. In this light, the study developed by Turk et al. [55] focused on creating an ergonomically suitable workstation for each worker, which could increase the productivity and efficiency of a manual assembly process. The authors focused on enhancing physical health by including components that can be individually adapted, such as worktable height, lighting, assembly nest orientation, and even the grab container settings, according to the person's reach. The main limitation of this study was that it was apparently not applied in a real work context as the actual context was not specified. The authors mention that participants were untrained with the random assembly processes distributed to them for the inclusion of various types of movements [55]. The inclusion of some systems that could reduce the workers' operational leeway also seem to be endorsed, such as the pick-by-light technology [55] (pp. 8, 10).

On a similar note, Lamberti et al. [47] developed a smart cushion for the monitoring of the sitting posture symmetry, which aimed to improve workers' health by preventing the lower back pain caused by continued asymmetrical sitting. It consists of a cushion equipped with force sensors and interfaced with software to check the symmetry of the force exerted on the two sides of the seat, thus notifying the user when an appreciable asymmetry is detected [47].

While both studies have clearly described an effort of potentiating workers' health through technology, the gender dimension was once more almost treated as a mere sociodemographic characteristic to be crossed with the ergonomic data collected [e.g., "The information about the user collected prior to the real-time acquisition allows filtering the results according to the user categories, to perform age, height, width, and gender informed statistical data analysis" [47] (p. 36)]. While biological and social factors are both relevant for thinking about ergonomically appropriate workplaces [16], the gender dimension was not further explored, and the findings are not presented as being differentiated for men and women. This leaves room to question what the different usages of such an artifact by women and men are (or could be) and what contextual and work-specific factors might condition its use.

Taking on a socio-constructivist perspective, gender is a part of a constant ongoing process of understanding and constructing behavior and expectations in a particular circumstance, which is crossed by pre-existent social constructions [73] and, at work, by the pre-existing role distribution as well [74]; precisely for this reason, studies such as the one developed by Barker and Jewitt [40] are so important. This study focused on touch and the concepts of dirt and danger, which were explored through ethnography, and provided several historical contributions on how touch was reconfigured by new human–machine relationships [40]. Its aim was to contradict the lack of research on how emerging sociotechnical factors are changing the nature of work that is considered to be dirty and dangerous. Gender was contemplated in their analysis, considering the already gendered nature of the work contexts being looked at—two typically masculine contexts, in this case—as they developed their study at a glass manufacturer and waste management factory [40]. As dirty and dangerous touch tasks are gendered, are assigned to lower social statuses, or are deliberately avoided, the findings described showed how dangerous touch persisted in modern industrial settings, still as essential for identity formation, as well as the gendering of such tasks and workplaces [40]. Specifically, this type of ethnographic study developed in situ allowed for the understanding of the health impacts that emerged from the introduction of I4.0 technology while still maintaining the manual work process.

Through the historical marginalization of women in accessing such jobs, men became responsible for staying in occupations in which they were expected to be strong while also being placed in more dangerous and dirty work environments. For instance, one of the informal requirements in the glass manufacturing setting was that of being resistant to heat: "Tolerating heat was not only a necessity to being a "productive" worker, it was central to the sociality of working in the hot-end, and a key aspect of identity formation within this male dominated space" [40] (p. 122). The consequences for health varied in both contexts. Even though understanding these impacts was not the central focus of this article's analysis, the study made it possible to see how, on the one hand, the introduction of technology was a health potentiator (e.g., reduced exposure to heat in glass manufacturing settings through the use of cobots; or the waste management picking robot put in place due to safety regulations at the waste management factory); on the other hand, it also obliged workers to reconstruct how work was distributed and further increased the division of work between females and males (e.g., male workers were assigned to work with the robot and in the more uncomfortable parts of the line—i.e., where the smells were more intense—based on the premise that women are more competent in sorting multiple materials on the mainline) [40]. Therefore, within this context, the notion of techniques as gendered and socially constructed [67] was reinforced.

Lastly, a study developing 4.0 technology that considered gender and health was found during this review that, exceptionally, does not mention work in its analysis but whose findings could be relevant and applicable at work. Paviglianiti and Pasero [52] proposed a wearable smart device for health monitoring that complies with the reduction of gender bias. The wearable device takes the form of a smartwatch, which monitors heart activity and main vital parameters of the individual (blood oxygen saturation, skin temperature, and fatigue level) [52]. The authors consider that the gender equilibrium in machine learning is a vital point towards the prevention of distorted predictions made by algorithms, which disadvantage women [52]. However, in spite of this first attempt of using a de-biasing technique to guarantee that both female and male users have an adequate reading of their results, the data used in the neural network were still affected by bias [52]. For this reason, they will continue to work on the improvement of these bias-reducing techniques by also applying fairness solutions to post-processing data. As the objective is the health monitoring (outside of work) of just the main vital parameters, the impacts from the use of such a device at work remain unknown. If applied to people already in work situations, although it could help mitigate certain health impacts, therefore contributing towards more sustainable workplaces, it might further be biased by the distribution of work [i.e., women and men in different professions and/or in different tasks/activities in the same professions [16,17,74].

4.3. Study Limitations

As limitations of this study, we would like to point out (i) the use of just one research database and (ii) the lack of studies performed in situ, involving different workers, considering health and gender throughout different activity sectors, and following a participatory and worker-centered approach, e.g., [75]. These issues further limited the insights on how the I4.0 workplace changes can differently impact men and women's professional paths and, ultimately, their exposure to health risks. In spite of the intent to limit articles to those that considered gender in their findings as an inclusion criterion, this narrowed down the amount of research which was found. While the inclusion of reviews in this review was an attempt to overcome the limitation of available data, it could also originate bias.

5. Conclusions

It is pertinent to mention once more how the results discussed throughout this review were limited by the scarce amount of literature including the gender dimension in their findings, thus still perpetuating the idea of a human worker that is gender-neutral [22]. Overall, the work context seems to have little expression in the available literature on I4.0, even when the previous forms of gendered labor segregation are found to be reinforced; thus, it is hard to understand how different categories, such as gender or age, interact with health at work in concrete contexts that are undergoing technological changes, and it is difficult to explain the existent vulnerabilities. In the studies that have been carried out, gender and health at work are rarely considered; although, the risk for a possible increase in gender segregation has been identified and (in separate studies) the risks for workers' health that also emerge with technological introductions. Working conditions are either generalized (e.g., monotonous work flagged as higher risk of being replaced by automation) or placed onto an individual level that considers who will or will not have the necessary skills to work or be placed in these systems.

Now—with the aim of recovering the debate about the sustainability of employment and work in the context of I4.0—gender has an influence on the exposure to risk factors (as they are differentiated for men and women). Understanding the origin and consequences of these risks is what will determine the sustainability of the working conditions. However, several questions remain open and ought to be further explored. Namely, these questions are how the I4.0 technological changes are actually impacting health at work in different sectors, workplaces, and countries; if previous work experience is considered at the time of these implementations; and what the differentiated impacts are for women and men at work, considering their real working conditions in such contexts.

There are several possibilities for action that are suggested by the articles reviewed, which are either recommendations at an organization level or at a policy level. Firstly, due to the change in skill requirements [48,49], the need for education-focused policies to reduce gender bias through upskilling of the workforce and through digital literacy policies were emphasized. Mehta et al. [49] underpin that improving skill development while considering the existing market demands (e.g., digital literacy) will support the expansion of women's job opportunities. However, the place and role of workers should not be reduced to training, especially when the existence of previous work experience is ignored [27]. Women and men's real working conditions affect how these impacts can take place, and the work requirements will also be affected by these factors in turn [48]. So, even though there are companies adjusting their policies towards a more equal gender distribution, cultural and social factors can also shape the equality of the participation of men and women at work, and these factors should be considered [48]. However, as pointed out by Barisi [76], the existing psychosocial risks that workers are exposed to are prompted by company-based policies, which often lead to issues such as work intensification or methods of individualized personnel management, which can fragilize social relationships at work. Therefore, as this author also adds, the interventions should be thought of at a work organization level (e.g., management policies aimed at the causes of the risks) and not just in terms of its consequences [76].

Nadeem et al. [50], in spite of mainly focusing on AI, highlight the importance of workplace diversity in managerial roles and the importance of ensuring that the human is kept at the center of technological design, planning, and introduction [50]. Design should thus be regarded as a mutual learning process between users and designers [64], which is beyond just gathering workers' opinions about the transformations or the technologies, aiming towards a design process that merges both the designers' knowledge with the workers' (in this case, the users') knowledge of their own work [75]. If both female and male workers, the work activity, and the worker collective are considered—further than merely considering individual or workstation perspectives—strategies for preserving performance, safety, and health can be developed [27]. When visibility is given to the gender dimension, intervention proposals can move beyond a specific workstation to be implemented at a work organization level (e.g., adapting work schedules), which can help to reshape the impacts of work on health [15].

At the moment of writing this article, there are some studies currently being developed as alternatives to the dominant studies found in I4.0 literature. One example is a study developed by our team in the automotive industry in Portugal; specifically, it focuses on a manufacturer in an advanced stage of technological development. This study focuses on understanding the health risks present and creating indicators for safeguarding workers' well-being at work. Another study is also being developed in different sectors of a garment factory at an initial stage of automation. In one of these studies, our team found how, in a typically feminine garment factory, automation contributed towards the dilution of gender boundaries at work: the introduction of a semi-automatic machine allowed for men to enter to an activity sector that was until then apparently reserved for women, as these were no longer perceived as 'seamstresses'; however, it also led to the devaluation of the work developed with the help of these machines. There is a shared representation within the company that these machines need less human intervention, that they do not require previous work experience, that they are almost 'risk-free', and that learning is almost immediate. As such, the time available for the appropriation of technological artifacts became limited, the variability of work with these machines was not taken into consideration, and the actual efforts made and described by workers became invisible [69].

Bearing in mind the limitations found in the literature on the relationship between work and health in the context of Industry 4.0 (I4.0), there is a clear need to address the changes instigated by the introduction of new technologies (i) on work organization, (ii) on work activities, and (iii) on the impacts for the health of women and men at work. The uniqueness of the work contexts should be taken into account in order to promote more sustainable working conditions. Such gaps can only be tackled through the development of case studies in different activity sectors that follow a bottom-up, work-placed, and longitudinal approach [60,77,78].

In short, the model of work organization proposed for the development of I4.0 can only be sustainable if the focus is placed on those who will use and interact with the different technologies and on the working conditions where these introductions take place. Precisely for this reason, Industry 5.0 has recently emerged to tackle this issue: a human-centric concept that draws upon the technological changes proposed for the development of I4.0 with the aim of extending it and improving previously identified issues (e.g., large-scale job automation through technology; limits of techno-centric approaches) [79]. According to the European Commission [79], Industry 5.0 provides the opportunity to construct more human-centric and sustainable workplaces. Specifically, its aim is to "ensure that the [technological] tools do not undermine, explicitly or implicitly, the dignity of the worker" (p. 18), regardless of their gender or age. However, as I4.0 remains dominant, results such as those found in this review can contribute towards the progression of Industry 5.0 by providing visibility to the gaps that still exist in the I4.0 literature and by providing recommendations for developing future studies.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/su15075615/s1: The original contributions presented in the study have been included in the article. The study was not registered due to the scope of the review, considering PROSPERO does not accept scoping reviews, literature reviews, or mapping reviews. The PRISMA protocol was followed, and the PRISMA checklist used as protocol is available as a Supplementary Material. The flow diagram can be found in the Section 2 of this paper.

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