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Social life cycle assessment of garments production using the psychosocial risk factors impact pathway

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ABSTRACT

This study presents the application of a Social Life Cycle Assessment (SLCA) methodology to two Italian case studies, allowing to estimate the possible impacts of the production of two garments "A" and "B". The hours of exposure to health risks have been accounted for the workers since they are the stakeholder group most immediately impacted. They have been analysed through the Psychosocial Risk Factors (PRF) impact pathway, a type II Social Life Cycle Assessment that allows the quantification of hours of exposure per each phase of the product or service life cycle. Using questionnaire, technical data have been gathered and all productive phases quantified and qualified in terms of duration (hours) and working conditions (ergonomics, exposures, postures, etc.). A literature review has been conducted to find relationships between these working conditions with health problems through odds ratios, a statistical measure of association between variables commonly used in retrospective studies. The functional unit chosen is one garment, and the system boundary is from cradle to firm gate; however, due to the lack of specific information concerning the upstream processes, impacts about inputs supplied from external providers were only qualified, but not quantified (background data). In both case studies, the highest psychosocial risk is linked to musculoskeletal disorders (Low back pain and neck and shoulder pain) and visual fatigue and discomfort. These results are due principally to the postures needed during work, the concentration required, repetitive movements, static and dynamic loads, as well as the use of video monitors during some tasks (especially planning and CAD modelling). Apparently, the process of product "B" is more socially impacting than "A". Actually, this is due because of the internalization of some operations such as (part of) the fabric production and the dyeing processes, which can expose workers to hazardous chemicals and dusts, and the use of trichloroethylene for stain removal. These working conditions, indeed, expose workers to a higher risk of cancers, according to scientific literature. To reduce risks, it is suggested to avoid the use of bleach and trichloroethylene for cleaning, to reduce the exposure to textile dusts (for example with the use of vacuums or masks), to avoid skin contact with the azo dyes and azo pigments, by using protective individual dispositive such as gloves, long-sleeved shirts, and aprons. To improve the ergonomics workplace, it is recommended to take more breaks during the timework, ensure the firmness of chairs and add lumbar support, as well as control the height of chairs and worktops. Promoting employees' physical activity would be useful to prevent musculoskeletal disorders.

1. Introduction

There is a growing awareness, at the global level, about the importance of more sustainable production and consumption models throughout all sectors. Sustainable management, governance, production, and consumption patterns are under the attention of academics, business people, and politicians (Adnan et al., 2017).

Life cycle techniques have been widely accepted for the evaluation of the possible environmental consequences of goods and services (Life Cycle Assessment), economy (Life Cycle Costing), and society (Social Life Cycle Assessment) as tools to quantify human impacts. The advances offered by this family of tools relate to the ability to consider a

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product or service's whole life cycle, from conception to final disposal, indicating load shifts and hotspots. Goal and scope definition, inventory analysis, impact assessment, and interpretation are the four phases that make up the evaluation process. Although social life cycle assessment (SLCA) was the last instrument created, it has been difficult to agree on a uniform approach since the 90s (Iofrida et al., 2018). Numerous methodological propositions have been disseminated, exhibiting divergences on several aspects, as emphasized in several reviews already published. Among others, Wu et al. (2014), Mattioda et al. (2015), Di Cesare et al. (2018), Russo Garrido et al. (2018), Kühnen and Hahn (2017), Petti et al. (2018), and Iofrida et al. (2018) have explored this phenomenon. The object of assessment, whether it be an impact or a performance, and the source of said impact, either behavioural or physical, are the most frequent points of divergence (Grubert, 2018). Additionally, the assessment method and indicators applied, such as a description of the current situation or an explanation of cause-effect relationships, also contribute to this divergence (Dubois-Iorgulescu et al., 2016). UNEP-SETAC (2009, 2013) and UNEP et al. (2020) have issued first and second editions of guidelines proposing a general framework, in which they affirm that SLCA is synonymous with LCA, but with a focus on social impacts. Similarly, the Handbook for Product Social Impact Assessment (Goedkoop et al., 2020) and the Social Topics Report (Harmens et al., 2022) provided, respectively, step-by-step guidance in preparing, scoping and executing a case study, and the definitions of 25 Social Topics, the reference scales and performance indicators.

However, this translation from environmental impacts to social ones is not as straightforward as one may expect. LCA pertains to natural occurrences and environmental consequences that are clearly identifiable and objectively measurable. On the other hand, SLCA focuses on social phenomena, which are not always measurable and are often influenced by individual perception and interpretation. The scientific investigation of social impacts, as observed in the social sciences, can vary greatly depending on the researcher's epistemological stance (Iofrida, 2016). Because social sciences are multiparadigmatic, and their object of analysis is multi-layered, the rigorous principles and methodologies of the natural sciences may not always be appropriate when examining the social implications of a life cycle, which accounts for the absence of a universally accepted methodology for SLCA (Corbetta, 2003; Iofrida et al., 2018, 2019). Presently, there are two types of SLCA available for evaluating the social impacts of a life cycle: type I is primarily focused on assessing company performance through a qualitative and descriptive appraisal process, which involves comparing their behaviour to a reference performance, while type II evaluates the relationships between the product or service life cycle and possible social consequences, aligning epistemologically with environmental LCA (Bocoum et al., 2015).

The textile sector is well known as one of the most impacting productive sectors, generating pollution in terms of emissions to water, air and soil during the production and consumption phase, but also producing a huge amount of waste (Siliņa et al., 2024).

While environmental impacts are growingly under the attention of scientific research (Luo et al., 2023), the social impacts did not attract the same interest (Suarez-Visbal et al., 2023). Recently, some studies have been published, analysing different concerns linked to the textile industry.

For example, Fidan et al. (2023) highlighted that cotton cultivation bears considerable environmental consequences due to its extensive usage of water, space, energy, fertilizers, and pesticides, all of which can affect both the ecosystem and human well-being. According to the authors, the cotton industry accounts for 2,6% of global water consumption and 11% of pesticides consumption, reaching up to representing 1% of the total global warming potential when considering the whole life cycle and with consequences on human well-being. Life Cycle-oriented studies in the textile sector are mostly oriented to environmental impacts rather than to social ones. Among these latter, Muñoz-Torres et al. (2023) assessed the social performances of textile companies analysing their sustainability reporting compared to the hotspot issues used in the Social Hotspot Database and UNEP-SETAC guidelines (2020), but they noticed that the absence of uniform social metrics presents a potential lack of impartiality in the analysis study conducted by analysts, which is also relevant concerning the association between the impact categories employed by the SHDB and the social issues classified by UNEP-SETAC.

Herrera Almanza and Corona (2020) made a social hotspot analysis using the PSILCA database to assess social issues in the supply chain linked to the Sustainability Development Goals, highlighting some difficulties in the suitability of SLCA indicators to evaluate their fulfilment. Then, they conducted a site-specific evaluation based on primary data and assessed the suppliers' performance considering the social categories proposed by UNEP-SETAC 2020, highlighting the need for improvement, especially in the selection of suppliers.

Zamani et al. (2018) conducted a social evaluation of Swedish clothing using input/output analysis and their results showed that certain unforeseen sectors, including commerce and business services, have been recognized in Asiatic countries as significant hotspots, along with key sectors in the production phase such as plant fibres, textiles, and garments. Furthermore, findings indicated that in the case of the child labour category, a significant proportion amounting to 92% of the total working hours was correlated with low and moderate levels of risk.

Lenzo et al. (2018) applied the SAM (Subcategory Assessment Method) and SHDB, both type I SLCA methods. SAM was used with primary data gathered from the companies to assess their behaviours about the fulfilment of basic requirements defined according to UNEP-SETAC (2021), while SHDB was employed to evaluate generic data of the upstream supply chain (at the national and global level). The authors found that SLCA has proven to be a viable means of quantifying social impacts concerning textiles and clothing products. Nevertheless, certain limitations hinder the method and its successful execution in this particular context. The primary issue pertains to the restricted accessibility of data or its complete absence in a variety of processes or activities. Additionally, complications have arisen for sourcing information from both customers and suppliers of the analysed company.

All the above-mentioned studies have in common the awareness of the difficulty of gathering primary data and the consequent weakness of qualitative evaluations of companies' behaviours, but also the generic information provided by methods such as PSILCA or the SHDB allow for a risk assessment that doesn't allow to aggregate results at micro-level.

Therefore, the present study aims to overcome these difficulties derived from qualitative and/or generic assessments, through an objective cause-effect evaluation that takes into account the possible impacts deriving from the production process, regardless of the context and the behaviour. Background data were retrieved from secondary sources. The method here presented allows to account for the potential impacts of a specific item, in this case, two garments produced by two Italian companies, for which potential social risks have been quantified in terms of hours of exposure.

The analysis conducted in this study draws from the "impact pathway methods", which are a family of techniques designed to examine and evaluate the effects that are causally connected to the operation of products and services throughout their life cycles (UNEP et al., 2020). Specifically, this research employs the Psychosocial Risk Factors (PRF) impact pathway for SLCA initially proposed by Gasnier (2012) and Silveri et al., 2014 and later advanced and applied by Iofrida et al. (2019) to appraise the social impacts on employees and labourers. Ensuring safety, health and security during working tasks is a crucial aspect of management processes and is of paramount importance in both European and global policies. Psychosocial risk factors, as explained by Amiri et al. (2015: 69), pertain to various elements that could affect employees' psychological responses to their work and working conditions, consequently resulting in psychological health issues. This study has considered the definitions offered by Cox and Griffiths (1995) and Cox et al. (2000), which describe the psychosocial risk factors as those features of working conditions and managerial choices that can

	Case: disease	Control: no disease
Exposed	A	B
Unexposed	C	D

$$OR = \frac{\text{Odds that a case was exposed}}{\text{Odds that a control was exposed}} = AD/BC$$

Fig. 1. Odd ratio explanation.
Source: Bottarelli and Ostanello (2011); Iofrida et al. (2019).

potentially bring harm to the psychophysical health of workers. The measurement of psychosocial risks was carried out using odds ratios (OR), a statistical measure of association. These odds ratios were obtained from prior scientific studies published in peer-reviewed journals, and that explored the correlation between certain working conditions and the occurrence of diseases or disorders. These working conditions were identified by characterizing each task involved in the product life cycle, quantifying the required hours for completion, and ultimately associating each task with a particular working condition. The literature review enabled collecting odds ratio for each working task and working condition and permitted the construction of a PRF matrix, which correlated these working conditions with specific risks of disorders or diseases. The epistemological stance underlying this methodology is aligned with the environmental LCA, as it permits a rational accounting of the potential long-term consequences of the life cycle's operations. Indeed, it is possible to use the same functional unit, system boundaries, cut-off criteria, background and foreground processes as in an LCA study, and the source of impacts is the product itself, independently from behaviours and contexts. The impact pathways methodologies aim to establish a cause-effect relationship while avoiding bias resulting from personal judgments or feelings. The statistical validity of the data ensures the quality of the evaluation process. To further analyse the methodology, a PRF pathway was applied to two case studies involving the manufacturing production processes of two similar jackets produced by two firms located in Tuscany, referred to as "A" and "B" for the sake of privacy. The research hypotheses are that the life cycle of a garment exposes the workers involved to specific psychosocial risks, that change according to specificities of the productive process; and that the PRF impact pathway allows accounting the exposure to these risks referred to the functioning of the life cycle and not to subjective behaviours or specific contexts, providing generalizable insights.

2. Material and methods

The PRF impact pathway developed in this study analyses the working conditions characterizing the life cycles of two garments, which have the potential to engender psychosocial health issues for individuals. The present investigation encompasses all categories of labourers who are directly engaged in the production processes of each garment, including both blue and white-collar workers, as well as cleaners. Notably, the managerial staff has been excluded from the scope of this inquiry. The choice was due to many aims. The health of workers is a significant concern for companies that embrace social responsibility. Working conditions have the potential to adversely impact the physical and psychological health of individuals, as well as the effectiveness of organizations (WHO, 2005). By utilizing this methodology, there is an opportunity to further develop impact pathway assessment methods that have yet to be fully explored in the SLCA literature. The epistemological posture of this approach is congruent with other life cycle tools that assess relationships between causes and effects.

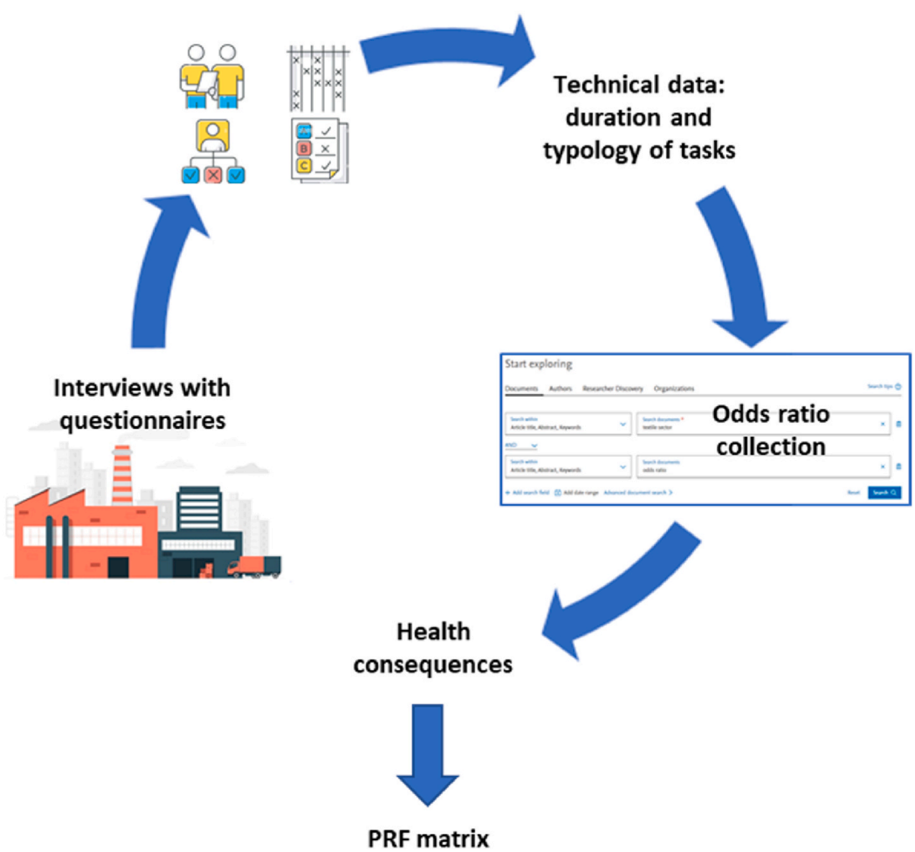
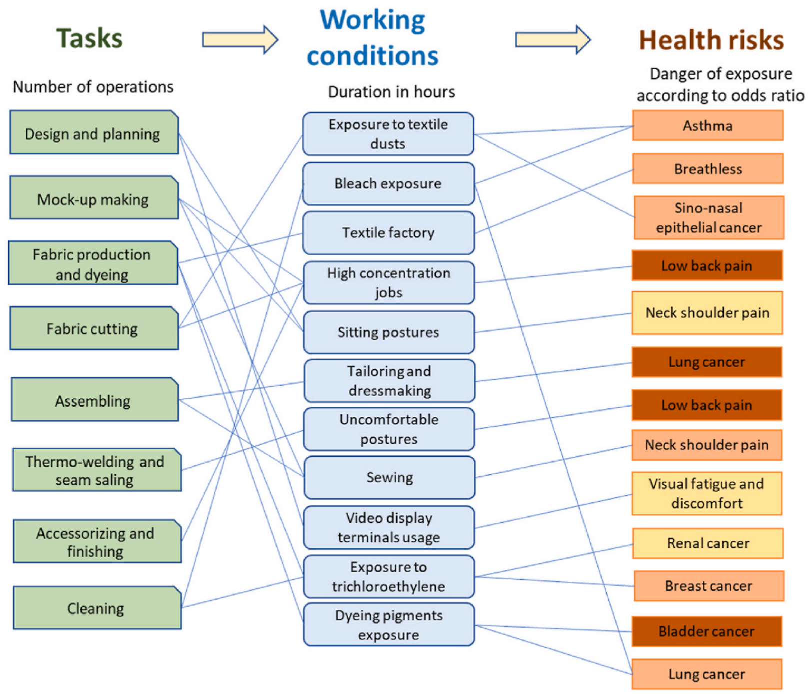


Fig. 2. PRF impact pathway methodology.



Negative association	No association	Weak	Moderate	Strong	Very strong
0<OR<1	OR=1	1<OR<1.3	1.3<OR<1.7	1.7<OR<8	OR>8

Fig. 3. Examples of PRF impact pathway.

This study accounts for the duration of each working task and operation entailing specific working conditions that can be associated with a health risk with different intensities of association.

The system boundary considered is from cradle to the firm gate; however, due to the lack of specific information concerning the upstream processes, impacts about inputs supplied from external providers were only qualified, but not quantified (background data). The functional unit is the single product realized (1 garment for each company), and impacts are quantified in hours of potential exposure (psychosocial risks). The responsibility of firms is tacitly considered in the assessment of working conditions, which are contingent upon organizational determinations such as those about the scheduling and timing of operations, the provision of personal protective equipment, and the selection of suppliers. The data were procured via semi-structured interviews conducted with privileged witnesses. It is important to highlight that this kind of social impact pathway allows evaluating the social impacts attributable to the product process during its life cycle, and therefore many impacts that are not the responsibility of the companies. Scientific literature contains numerous studies that quantitatively demonstrated the associations among a diverse array of working conditions and many possible risks for human health, accounted in terms of Odds Ratio (OR), Hazard Ratio (HR), Risk Ratio (RR), among others, but few of them focused on the singular specific tasks of the garment industry. For reason of homogeneity and comparability, only those studies that assessed the correlation between occupational settings and the likelihood of experiencing health issues, as measured by the odds ratio, were included for consideration (Fig. 1). For the purposes of the present investigation, certain postulations were deemed requisite to facilitate the transference of the operational circumstances outlined in extant literature to the domain of textile and apparel manufacture. Indeed, very often epidemiological and ergonomics studies are designed for a specific context. Pairwise, the lack of specific studies for the same context of the assessment can be a limitation. When interviewees provided vague answers, data were retrieved from literature hypothesizing an average scenario (e.g., typology of pigments for dyeing).

During the inventory phase, working hours associated with multiple psychosocial risks were tallied multiple times. In instances where an impact was influenced by multiple sources, the hours were apportioned proportionally. This was exemplified in the case of various postures adopted while performing the same task. Some studies of the literature reviewed did not pertain exclusively to textile production; thus, comparable situations were assumed. The absence of specific studies precluded the consideration of crossed effects. Among the restrictions of this investigation, it is noteworthy to acknowledge that at present, SLCA remains in a preliminary scientific phase. There is an absence of unanimity on a mutually accepted methodology, and the current methodological proposition has not attained sufficient scientific soundness to establish SLCA as a dependable assessment instrument.

The current methodology is an evolution of the methodological proposals by Gasnier (2012) and Silveri et al. (2014) and was first applied by Iofrida et al. (2019) for the evaluation of PRFs' effects in SLCA. Looking for a definition, and according to Amiri et al. (2015:69), psychosocial risk factors are the causes of employees' psychological responses to work and living conditions, potentially leading to health issues. For the present investigation, the definitions posited by Cox and Griffiths (1995) and then Cox et al. (2000) were duly considered; these definitions postulated that PRF encompasses various aspects and features of work planning and management that may potentially result in physical or psychological harm. Specifically, the objective of this study is to take into account the duration of time spent in working conditions that are associated with individual operations and to characterize them in terms of the magnitude of their association with health complications. The odds ratio (OR) is a statistical measure that quantifies the degree of association between two variables; in the context of people's exposure to disease risk factors, it can be defined as the ratio of the odds of exposure among individuals with a disease to the odds of exposure among healthy individuals (refer to Fig. 1).

The probability of the onset of a disease or disorder in relation to a specific exposure as compared to its likelihood without exposure is denoted by the odds ratio, as stated by Szumilas (2010).

Table 1
Possible working conditions per each life cycle step considered.

Life cycle steps	Possible working conditions
Background processes	Dye manufacturing, employment in textile product manufacturing industry <2 years, textile factory workers, textile processing occupation, textile products machine operators <2 years, textile workers (spinners, weavers, knitters, dyers), printer and plotters production
Design and planning	Demands on attention (medium), sitting, video display terminals usage
CAD modelling	Demands on attention (medium), sitting, video display terminals usage
Mock-up making	Demands on attention (medium), sitting, video display terminals usage
Materials supplying	Demands on attention (medium), sitting, video display terminals usage
Weaving and Dyeing	Dyeing of clothes, textile bleaching, dyeing and cleaning machine operators <2 years, textile work (spinners, weavers, knitters, dyers)
Fabric measuring	High-concentration jobs, standing
Fabric layout	High-concentration jobs, standing, video display terminals usage
Fabric cut	High-concentration jobs, standing, video display terminals usage
Assembling	Textile and tailoring workers, exposure to organic textile dusts, exposure to textile dusts, high concentration jobs, standing
Thermal-taping & sealing	High-concentration jobs, standing, repetitive load, Repetitive precision movements (medium), uncomfortable postures
Accessorizing and Finishing	High-concentration jobs, sitting, sewing machines usage, tailoring and dressmaking, uncomfortable postures
Ironing & quality control	Dynamic load, high concentration jobs, repetitive load, standing, uncomfortable postures
Packaging and shipping	Demands on attention (medium), dynamic load, repetitive load, standing
Workplace and fabric cleaning	Stooping (bent posture), bleach exposure, exposure to trichloroethylene
General conditions	Night shift work, frequent noise exposure, effort reward imbalance, fairly paid overtime, wage equality, fair wages, accidents and professional diseases

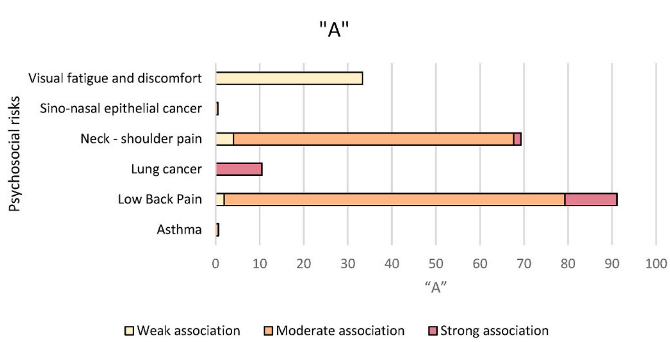


Fig. 4. PRF assessment of "A" garment.

Bottarelli and Ostanello (2011) describe the odds ratio as a non-dimensional value that represents a retrospective analysis of a phenomenon. This value has a range from 0 to $+\infty$. The value of 1 denotes a lack of association between variables, i.e. exposure and disease, whereas values greater than 1 indicate an affirmative association, wherein the risk factor can trigger the onset of the disease. High values confirm a high association between variables. Specifically, an OR ranging between 1 and 1.3 is considered weak, an OR between 1.3 and 1.7 is considered moderate, an OR between 1.7 and 8 is considered strong, and an OR greater than 8 is categorized as very strong (Bottarelli and Ostanello, 2011). It should be noted that the OR is not, in and of itself, a measure of risk as it pertains to the probability of already having a disease. However, if it is assumed that the average duration of a disease is the same for both exposed and non-exposed individuals, then the OR can be considered an efficient measurement (Bottarelli and Ostanello, 2011). As an example, an OR of 2 means there is a 100% increase in the odds of an outcome with a given exposure. Further explanations about the calculation of the intensity of association between two variables in a retrospective perspective in provided in Appendix 1.

The PRF impact pathway methodology (Fig. 2) was organized into the following phases:

1. Assessing the working hours for every job, like creation and design, CAD modelling, mock-up creation, providing materials, dyeing, fabric measuring, fabric placements, fabric cutting, fusing, putting together, thermal-taping and sealing, accessorizing, completing, ironing and quality reviewing, packing and delivery, and workplace tidying. The duration (hours) of each task was specified through interviews conducted with questionnaires.
2. A study of literature related to work settings that involve exposure to PRF, and a categorization of each association based on its intensity.
3. The creation of a matrix for PRF (as detailed in Appendix 2) has been undertaken to establish a correlation that exists between every one of the working conditions that have manifested in the given scenarios, and their potential association, through statistical means, with both physical and psychosocial ailments.
4. The evaluation of societal ramifications via the measurement and categorization of labour duration during periods in which labourers may be susceptible to one or more ailments, whether physical or psychological.

The analysis of the inventory was performed through the utilization of data acquired from the questionnaires or, in the absence thereof, based on literature sources. The average data was taken into account while considering the expertise of local professionals in the relevant field of study. The inventory comprised two spreadsheet files, one for each garment, encompassing the various phases of the life cycle, scenarios, tasks, duration, and work typology.

The present study conducted a thorough literature review utilizing prominent scientific research databases, specifically Scopus and Web of Science. The queries employed for this investigation pertained to specific occupational conditions, such as dyeing, tailoring, and sewing machine usage, and were matched with the terms "odds ratio", "psychosocial risks", and "cohort study" using Boolean operators in the search query, such as for example:

- (TITLE-ABS-KEY (odds AND ratio) AND TITLE-ABS-KEY (dye*) AND TITLE-ABS-KEY (occupational AND exposure));
- (TITLE-ABS-KEY (night AND shift) AND TITLE-ABS-KEY (odds AND ratio) AND TITLE-ABS-KEY (cohort AND study));
- (TITLE-ABS-KEY (sewing) AND TITLE-ABS-KEY (odds AND ratio));
- (TITLE-ABS-KEY (textile) AND TITLE-ABS-KEY (psychosocial AND risks)).

After an extensive review of the studies, the odds ratios were categorized based on the level of intensity (chromatic scale: yellow-weak; orange-moderate; red-strong). Furthermore, the total duration of exposure per risk was accounted for and qualified based on the strength of the association.

The present study utilized all of the odds ratios (ORs) gathered from the literature search, which explicated the relationships between the working conditions of the two scenarios and some typology of disease, to construct and finalize the Psychosocial Risk Factor (PRF) matrix (Appendix 2). Most of the studies cited concerned textile production working situations. The ORs were categorized following the classification (weak, moderate, strong, very strong) system proposed by Bottarelli and Ostanello (2011), and the social impacts were quantified and subsequently characterized as illustrated on the previous Fig. 2. Finally, the total hours for each working condition were grouped (Fig. 3). In situations where an individual was exposed to more PRF, it was counted

Table 2
PRF of "B" and "A" garment (hours per life cycle).

	Garment B				Garment A			
	Weak	*Moderate*	*Strong*	*Very strong*	*Weak*	*Moderate*	*Strong*	*Very strong*
Asthma*		0.33				0.6		
Bladder cancer			1.3					
Breast cancer (female)			0.47					
Breast cancer (male)		0.5						
Breathless				0.05				
Chest tightness			0.05					
Cough			0.05					
Low Back Pain	10.4	25.9	14.08		1.9	77.38	11.8	
Lung cancer	0.05	1.3	4.9				10.5	
Neck - shoulder pain	29.6	43.9	7.3		4.1	63.6	1.7	
Prostate cancer			0.05					
Renale cancer	0.5							
Sino-nasal epithelial cancer		0.33				0.5		
Systemic sclerosis			1.5					
Visual fatigue and discomfort	21.3				33.3			
Wheezing		0.05						

* The firm of garment B is equipped for dust aspiration with vacuum tables.

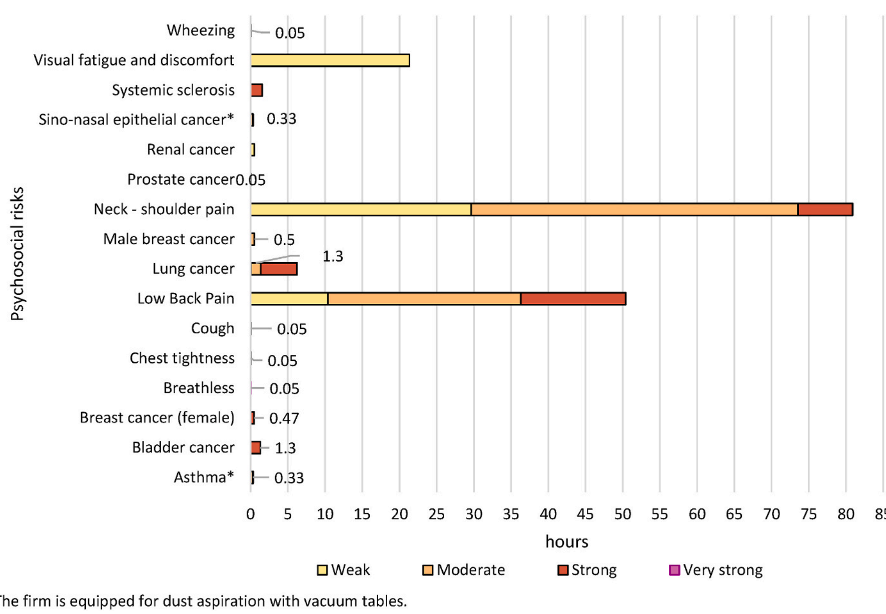


Fig. 5. PRF impacts of "B" garment.
*The firm is equipped for dust aspiration with vacuum tables.

twice, i.e., once per risk factor. Similarly, when a working condition comprised more sub-operations, the impacts were attributed proportionally (e.g. sitting and standing positions during a task). The present study did not consider crossing interactions among more working conditions, as no specific information was found in the literature.

The Life Cycle Inventory consisted of outlining the following tasks, which were accounted for in terms of hours (duration) necessary for each garment production:

1. Design and planning
2. CAD modelling
3. Mock-up making
4. Materials supplying
5. Weaving and Dyeing

Table 3
Avoided impacts of life cycles analysed.

a. Avoided impacts of "A" garment

Working conditions	Health risk	odds ratio
Exposure to trichloroethylene	Male breast cancer	1.4
Effort reward imbalance	Metabolic syndrome	1.14
Exposure to trichloroethylene	Renal cancer	1.3
Effort reward imbalance	Sleep disturbances	3.16
Frequent noise exposure (men)	Upper limbs pain	1.58
Frequent noise exposure (women)	Upper limbs pain	1.62
Night shift work	Vitamin D deficiency	1.4

b. Avoided impacts for "B" garments

Working conditions	Health risk	odds ratio
Bleach exposure	Asthma	1.41
Effort reward imbalance	Metabolic syndrome	1.14
Effort reward imbalance	Sleep disturbances	3.16
Frequent noise exposure (men)	Upper limbs pain	1.58
Frequent noise exposure (women)	Upper limbs pain	1.62
Night shift work	Vitamin D deficiency	1.4

Table 4
Possible impacts linked to the background processes (cradle) of "A" garment.

Health risk	Working conditions/tasks	odds ratio
Bladder cancer	Dye manufacturing	3.62
Bladder cancer	Dyeing of clothes	4.63
Breast cancer (female)	Textile workers (spinners, weavers, knitters, dyers)	2.4
Breathless	Textile factory workers	9.4
Chest tightness	Textile factory workers	2.5
Chest x-ray abnormalities	Printers and plotters production	1.87
Chronic wheeze	Printers and plotters production	2.14
Cough	Textile factory workers	7.2
Lung cancer	Textile bleaching, dyeing, and cleaning machine operators < 2 years	1.69
Lung cancer	Textile products machine operators < 2 years	1.23
Lung cancer	Employment in textile product manufacturing industry < 2 years	1.89
Polydactyly in the offspring	Exposure to a textile factory (chemicals) environment during pregnancy (China)	3.08
Prostate cancer	Textile processing occupation	1.8
Systemic sclerosis	Textile and tailoring workers	2.00
Wheezing	Textile factory workers	1.6

6. Fabric measuring
7. Fabric layout
8. Fabric cut
9. Assembling
10. Thermal-taping & sealing
11. Accessorizing and Finishing
12. Ironing & quality control
13. Packaging and shipping

Each task and sub-operation are described in Appendix 3. All phase was characterized in quantitative and qualitative terms, referring especially to the postures assumed, the workplace ergonomics, the use of personal protective equipment, the types of machinery used, possible chemicals handled, as well as indoor temperature, lighting, noises, dust, and odours.

Concerning the background processes, data were not fully available. Therefore, upstream data referring to "cradle" phases were only qualified, but not quantified.

As represented in Fig. 3, per each task it was quantified the corresponding working condition, and then qualified according to the possible risks as retrieved from the scientific literature. For example, "design and planning", "CAD modelling", and "Materials supplying" tasks entail the use of a PC, for 1 h per each task in garment A, i.e. the exposure to video displays in total for 3 h per each garment A, while for garment B the hours declared are 20; according to Filon et al. (2019), this condition is linked to visual fatigue and discomfort with an odds ratio of 1.27 (moderate risk); therefore, the production of garment A entails 3 h of exposure to a moderate risk of visual fatigue and

Table 5
Possible impacts linked to the background processes (cradle) of "B" garment.

Working conditions	Health risk	odds ratio
Dye manufacturing	Bladder cancer	3.62
Textile workers (spinners, weavers, knitters, dyers)	Breast cancer (female)	2.4
Textile factory workers	Breathless	9.4
Textile factory workers	Chest tightness	2.5
Printers and plotters production	Chest x-ray abnormalities	1.87
Printers and plotters production	Chronic wheeze	2.14
Textile factory workers	Cough	7.2
Textile products machine operators < 2 years	Lung cancer	1.23
Employment in textile product manufacturing industry < 2 years	Lung cancer	1.89
Exposure to a textile factory (chemicals) environment during pregnancy (China)	Polydactyly in the offspring	3.08
Textile processing occupation	Prostate cancer	1.8
Textile and tailoring workers	Systemic sclerosis	2.00
Textile factory workers	Wheezing	1.6

discomfort, while garment B to an exposure of 20 h. Exposure to dyeing pigments is linked to bladder cancer with an odds ratio of 4.63 according to Risch et al. (1988) and lung cancer with an odds ratio of 1.69 according to Corbin et al. (2011). The result will show, for the selected life cycle, the total amount of hours of exposure to different risks with different intensities.

3. Results and discussion

Technical data were gathered using a semi-structured questionnaire; workers were interviewed to ask for details about each working task, their postures, and the duration and responsibilities of each employee involved. The following Table 1 provides details of all the possible working conditions per each task listed in the previous paragraph, according to data gathering. Some conditions were different in the case of Garment A and B because of organizational and material differences in the productive processes.

A social hotspot is defined by UNEP (2020:26) as an "activity in the life cycle where a social issue (as impact) and/or social risk is likely to occur". In the case of our studies, hotspots have been detected in very frequent working conditions such as sitting and stooping posture, demands on concentration and attention, the use of video terminals, and the use of sewing machines, representing in both cases almost 90% of the total duration of exposures and that exposes to musculoskeletal disorders (low back, neck and shoulder pain) and visual fatigue discomfort (see Figs. 3 and 4).

As numerically represented in Table 2 and graphically in Figs. 4 and 5, the highest psychosocial risk in garment A is linked to musculoskeletal disorders (Low back pain) for a total of 91.1 h, of which 77.38 with moderate association, and 11,8 with strong association. The second most important impact refers to neck and shoulder pain (of which 63,6 h with moderate association), followed by visual fatigue and discomfort (33.3 h with weak association).

Concerning some positive aspects of garment A, it is worthwhile to underline that the company avoided some impacts linked to the absence of the use of trichloroethylene, fair wages, the noise level within the limits of the law, and the absence of night work shift (Table 2).

Concerning the garment B, Fig. 5 shows the list of possible social impacts, then listed in Table 3. As it can be noticed, apparently the process is more impacting than Garment A. Actually, this is due because of the internalization of some operations such as (part of) the fabric production and the dyeing processes, which can expose workers to hazardous chemicals. Therefore, the impacts are just moved from the background to the core process, but the overall impacts are very similar. It is also important to underline that the company provides workers with specific individual protection equipment, which surely reduces the risks. Another difference remains in the use of trichloroethylene: according to the scientific literature, exposure to this chemical increases the risk of male breast cancer and renal cancer.

More in detail, Garment B shows the worst results for "low back pain" and "neck shoulder pain" (both with weak association) because declared more time for tasks entailing dynamic and repetitive load postures, standing and sitting postures, that have been found in literature as linked to the above-mentioned risks (Hildebrandt et al., 2001). Garment A shows the worst results for working conditions such as "visual fatigue" (weak association), "low back pain" (moderate association) and "neck and shoulder pain" (moderate association) because declared more hours of work for tasks that entail the use of video monitors (Filon et al., 2019), and others that entail sitting, static load and stooping postures that expose to the formerly mentioned musculoskeletal disorders according to Hildebrandt et al. (2001), Keawduangdee et al. (2012) and Gupta et al. (2015).

Garment B shows additional impacts compared to Garment A, which are low from a quantitative point of view (from 0.05 to 1.5 h per garment life cycle), but dangerous because potentially lead to diseases with mortal course. It is because the firm of garment B internalizes the production of some input, such as the fabric production and dyeing, and recur to the use of trichloroethylene for stain removal. It has been found in the literature that the working conditions linked to dyeing, working in textile production, textile processing and the use of trichloroethylene can expose workers to the risk of bladder cancer (Risch et al., 1988), male and female breast cancer (Lynge et al., 2020; Villeneuve et al., 2011), prostate cancer (Sauvé et al., 2016), systemic sclerosis (Bovenzi et al., 2004), and breathlessness, chest tightness and cough (Zele et al., 2020).

Table 3 reports the avoided impacts of A and B garments, thanks to the positive strengths of the working environment (such as fair wages, no night shift work, no use of bleach for cleaning, noises under the limits, and equality in wage payments).

Concerning the background processes of garments A and B, it was not

Table 6
Recommendations to reduce social life cycle impacts of garments' production.

To reduce the risk of	Suggestions	Reference
Asthma	Avoid the use of bleach for cleaning Reduce the exposure to textile dust (for example with the use of vacuums or masks)	Lemire et al. (2020) Zhang et al., 2019
Bladder cancer	Avoid skin contact with the azo dyes and azo pigments, by using protective individual dispositives such as gloves, long-sleeved shirts, and aprons. Use protective masks or dust/mist respirator	Risch et al. (1988) NIOSH (1997) Singh and Chadha (2016)
Female breast cancer Male breast cancer	Reduce exposure to night-shift work, endocrine-disrupting chemicals, or solvents.	Villeneuve et al. (2011) Lynge et al. (2020)
Breathlessness Chest tightness Cough Wheezing	Reduce exposure to dusts, introduce workers' respiratory protection program	Zele et al. (2020)
Low back pain Neck - shoulder pain	Improve ergonomics of the workplace Take more breaks during the timework Assure firmness of chairs and add lumbar support Control the height of chairs and worktop Promote employees' physical activities	Nakadate et al. (2006) Eisele-Metzger et al. (2023) Hildebrandt et al. (2001) Jakobsen et al. (2018) Ekberg et al. (1995) Keawduangdee et al. (2012) Gupta et al. (2015)
Lung cancer	Use of protective individual dispositive, improve security protocol in the factory, avoid exposure to toxic substances, and dusts from wool, silk, synthetic fibre dusts, formaldehyde, silica, dyes, and metals	Corbin et al. (2011) Singh and Chadha (2016)
Prostate cancer	Use of protective individual dispositive, improve security protocol in the factory, avoid exposure to toxic substances, and dusts from wool, silk, synthetic fibre dusts, formaldehyde, silica, dyes, and metals	Sauvé et al. (2016)
Renal cancer	Avoid the exposure to trichloroethylene recurring to substitutes with low toxicity	Moore et al. (2010)
Sino-nasal epithelial cancer	Reduce the exposure to textile dusts (for example with the use of vacuums, masks or other dispositive of protection)	D'Errico et al. (2009)
Systemic sclerosis	Even though the causes of systemic sclerosis are unknown, reducing exposure to chemicals is recommended	Bovenzi et al. (2004)
Visual fatigue and discomfort	Control the light of the monitors, take frequent breaks to look at something 20 feet away for 20 s	Filon et al. (2019) Munshi et al. (2017)

possible to account for them due to a lack of data concerning the time needed to produce the quantities used in the company under assessment; however, according to the scientific literature it has been possible to qualify the possible social impacts linked to input supply, as reported in Tables 4 and 5. The most impacting process is linked to fabric production and dyeing, because of the use of chemicals, that can increase the risk of mortal diseases such as cancers and can increase the risk of respiratory symptoms.

Most of the studies that analysed the social performance of the textile industry and clothes production put their attention to the macro- and meso-level of analysis, i.e. to the consequences of companies' behaviours in terms of impacts on workers' well-being, fairness of wages, environmental pollution, gender equality, and child labour, among others (Suarez-Visbal et al., 2023). No studies are available concerning the micro-level, i.e. the impacts deriving from the productive process and not the company behaviour, that can be very variable according to places and social contexts. To fill this gap, the present study employed the PRF impact pathway, a SLCA methodology situated within the domain of post-positivist paradigms. Through this approach, the authors were able to quantify possible relationships between the life cycles of garments and their potential psychosocial impacts on affected workers. This approach enabled an objective evaluation of differences between two productive scenarios and can be applied to different contexts. While the study was limited to a specific group of affected actors (workers), future research can extend its scope to other potentially impacted groups, such as local communities, suppliers, etc.

4. Conclusions and recommendations

The methodology demonstrates a primary strength in its ability to predict the possible consequences of the garments' life cycle and how impacts change according to the process, and the research hypothesis is satisfied.

Indeed, while most previous studies analysed the social impacts of garment and textile industries in terms of legality and exploitation (Oral, 2019), child labour and human rights (Crinis, 2019), wages and employment (Peters et al., 2021), workers' vulnerability (Mishra, 2023), this study allowed to disclose the impacts deriving from the garments' life cycles, i.e. the functioning of the productive process itself. Moreover, it has been possible to account for the social impacts of two single garments, at the micro-level, while most of the SLCA studies assessed impacts at the macro-level, such as the national sectors (e.g., Zamani et al., 2018), or take into consideration impact categories depending on corporates social responsibilities (Herrera Almanza and Corona, 2020; Lenzo et al., 2018).

Both private and public decision-making processes can find in the PRF matrix a valuable tool to make decisions rationally and objectively, separating those impacts deriving from behavioural choices or contexts. As mentioned in the former paragraphs, this methodology is confirmed to be able to facilitate assessments that are coherent with the environmental LCA (Iofrida et al., 2019), i.e. based on causality relationships between matter and energy flows accounted and environmental impacts. This would further simplify the implementation and enhancement of Life Cycle Sustainability Assessments (LCSA), conceived as the integration of the environmental, social and economic dimensions of the sustainability discourse.

Concluding, and going back to the case study, some suggestions can be made to garment producers to reduce the social impacts on workers' health deriving from the functioning of the life cycle, as synthesized in the following Table 6.

The universality of the methodology is that it can applied to many different contexts; it is just required to have technical information about the productive process (if primary data are not available, secondary data can be used). Results are transposable to other contexts without losing meaning because impacts refer to the life cycle, not to companies' behaviours in a specific context. The PRF impact pathways has been already successfully applied to citrus growing (Iofrida et al., 2019), to olive growing (Iofrida et al., 2020; Stillitano et al., 2022; De Luca et al., 2023). Few SLCA type II studies have been published and our paper contributes to deepening the knowledge about the possibility of quantifying social impacts attributable to the functioning of the life cycle of a garment. This is the first study of SLCA type II applied to the textile sector to our knowledge and surely the first applying the PRF impact pathway. The methodology also allows the evaluation of positive impacts and the accounting for risks on other typologies of stakeholders; however, with this approach, the workers are those mostly impacted because directly involved in the productive process.

Concerning the limitations, the methodology is susceptible to improvements, especially regarding the evaluation of input from suppliers, the crossed effects of more working conditions occurring at the same time; the screening and choice of scientific studies and the odd ratio to be taken into account needs accuracy and therefore somehow subjective.

CRediT authorship contribution statement

Nathalie Iofrida: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Koldo Saez de Bikuña Salinas:** Data curation. **Marina Mistretta:** Writing – review & editing, Visualization, Supervision. **Giacomo Falcone:** Writing – review & editing, Validation, Investigation, Conceptualization. **Emanuele Spada:** Writing – review & editing, Supervision, Formal analysis, Conceptualization. **Giovanni Gulisano:** Validation, Supervision. **Anna Irene De Luca:** Writing – review & editing, Validation, Supervision, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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