

Participative ergonomics for the improvement of occupational health and safety in industry: a focus group-based approach

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Abstract: This paper introduces a participative approach to the investigation and promotion of health and safety in industry. The proposed methodology promotes the active participation of the workers in the analysis of consequences and causes of unsafe behaviours that may result in work-related musculoskeletal disorders, accidents, injuries or near-misses. The developed participative technique is the Focus Group with Workers, based on the Fault Tree Analysis method (FGW-FTA). Focus groups are conventionally used by social and behavioural researchers to understand opinions, motivations, attitudes, and mental processes that underlie people behaviours. The innovative procedure in this paper addresses researchers and safety professionals during the focus groups with the workers for the identification of critical risk factors in the workplace. The result is a structured analysis, operated by and with the workers, for the identification of consequences and causes of unsafe behaviours. Finally, the developed methodology addresses the definition of a set of preventive and protective measures, and corrective actions for the improvement of health and safety in the workplace.

An experimental study in an Italian boiler manufacturer describes the proposed methodology and the results of the focus groups with the workers. An evaluation questionnaire was elaborated to investigate the workers' knowledge on occupational health and safety. A second questionnaire was developed to understand the workers' perception on occupational risks. Each participant was invited to fill in both the questionnaires before and after the focus groups with the workers. The results of the study proved the effectiveness of the developed methodology in improving workers knowledge and perceptions on occupational health and safety.

Keywords: Participative ergonomics; Focus groups; Industrial safety; Occupational health and safety

1. Introduction

The participation of workers and the integration of ergonomics and critical organizational features, e.g. work organization, product quality and productivity, have been reported to be important factors for the success of ergonomics interventions (Eklöf, Ingelgård, & Hagberg, 2004). In this study, a participative approach to the investigation and promotion of health and safety in industry is introduced to address the investigation of the deep causes of workplace hazards. The aim is to define a methodology for the identification of occupational risk factors following a participative ergonomics approach. The proposed methodology promotes the active participation of the workers in the analysis of consequences and causes of unsafe behaviours that may result in Work-Related Musculoskeletal Disorders (WMSDs), accidents, injuries or near-misses. The participative culture of the workers' involvement in the organization's processes is a common work practice in today's high performing companies, as well as employee empowerment and teamwork (Eklöf, Ingelgård, & Hagberg, 2004). The term “participative ergonomics” (PE) refers to the active involvement of workers in developing and implementing critical workplace changes which will improve productivity and occupational health and safety (Burgess-Limerick, 2018; Straker, Burgess-Limerick, Pollock, & Egeskov, 2004). PE developed from

the Japanese quality circles (Noro, 1991, 1999), and from the social participation in Europe and Scandinavia (Jensen, 1997, 2001). In a PE-based approach, work teams, usually involving a supervisor and a limited number of workers, analyse the potentially hazardous manual tasks and perform the risk assessment. The workers who perform such activities have a deep knowledge of those tasks and know the information required to complete the risk management process (Straker et al. 2004). Many variations in the models and techniques used in participative ergonomics have been proposed in the last decades (Haines and Wilson 1998). Hignett et al. (2005) analysed different case studies of participatory interventions in several industries, including health care, manufacturing, construction and transport. In their study, the authors analysed both micro and macro level interventions. Specifically, micro level interventions involved the workers to use their knowledge and skills to address ergonomics problems in the workplace. In macro level interventions, the analysis focused on the organization and on the work system at an organisational level. The results of their study revealed cultural differences in the participatory approach, e.g. US organizations are more likely to adopt a macro level PE approach, compared with EU organizations. Rivilis et al. (2008) investigated the effectiveness of PE for the improvement of workers' health and safety in several workplaces. The study revealed a significant reduction of

absenteeism rates, musculoskeletal symptoms, lost time for injuries, sick leave and compensation claims. Critical factors and facilitators for the success of a PE intervention are communication (van Eerd et al., 2010), participation in decision-making processes (Morag & Luria, 2018), employee empowerment (Eason, 2010) and teamwork (Burgess-Limerick et al., 2007). Two common participative techniques for the management and the implementation of ergonomics and human factors in a PE intervention are interviews and focus groups (Wilson, 2010). Such techniques are useful tools for establishing issues to be evaluated using quantitative measures, e.g. a safety professional in a chemical plant may conduct interviews with workers to understand the areas in which atmospheric-related safety issues are most experienced, and to identify where sensors should be located. Focus groups are interviews conducted with multiple participants (Bisantz & Roth, 2009). Compared with the interview, the focus group encourages the synergy of the group interactions, promoting the discussions and providing more information about participants' perceptions, experiences and points of view (Huang, Yang, & Lv, 2018). This participatory technique is conventionally used by social and behavioural researchers to understand opinions, motivations, attitudes, and mental processes that underlie people behaviours. General recommendations suggest to limit the size of focus groups to 5–8 participants, and to avoid groups with mixed participants, e.g. employees and managers, physicians and technicians (Krueger & Casey, 2015). The aim is to give all participants the opportunity to contribute and to promote the spontaneous and sincere involvement. During the focus group, the discussion may be driven by structured questions, with the flexibility to accept any relevant topic arising from the discussions (Connaway & Powell, 2010). Among the qualitative research approaches, focus groups allow the spontaneous discussion among the participants, supporting the deeper comprehension of people behaviour during their lives, including their work and occupational roles (McQuarrie & Krueger, 2006; Schonfeld & Farrell, 2010).

This paper introduces an innovative methodology based on a PE approach to investigate workers behaviours, perceptions and knowledge on occupational risk factors in their workplace. The aim was to involve the workers in improving their workplace to reduce injuries from the manual tasks, musculoskeletal disorders and improve productivity. The participative technique used in this paper is the focus group with workers (FGW), in conjunction with the fault tree analysis (FTA). FTA is a popular method used in a wide range of industries to investigate the risks related to safety and the cause-effect relationships in critical assets, e.g. power plants and manufacturing processes (Ruijters & Stoelinga, 2015). The visual, structured and deductive approach of a FTA shows the temporal sequence of events and their interactions in a formal logical hierarchy. The result is a rapid identification of common pathways and cause-effect relationships which provide a quantitative and qualitative analysis of the events (Rogith, Iyengar, & Singh, 2017). The innovative methodology introduced in this paper addresses

researchers and safety professionals during the FGW for the identification of critical risk factors in their workplace, following a FTA-based approach (FGW-FTA). The proposed FGW-FTA methodology supports the definition of a set of preventive and protective measures, and corrective actions for the improvement of health and safety in the workplace. The benefits of the PE approach adopted in this paper include the improved support from the workers for the identification of high-risk manual activities and for the implementation of effective risk control measures, increased cooperation and team work, and improved safety culture within the organisation.

The following Section 2 describes the FGW-FTA methodology and the materials and methods for the development of the FGW. Section 3 shows an experimental study with the application of the FGW-FTA methodology in an Italian boiler manufacturer. Section 4 describes and discusses the results of the case study. Finally, Section 5 provides the conclusions and the future steps of this research.

2. The FGW-FTA methodology

The FGW is an active participatory technique based on the interaction between the participants, i.e. the workers. The moderator of the focus group is a safety professional who coordinates the discussion between the workers. The aim of the FGW is to support and share the knowledge between the participants about critical issues for health and safety in the workplace. In 2013, the research group involved in this study started the focus groups with the workers of several industries, e.g. manufacturing, food processing and construction. Since then, many focus groups were conducted aiming to identify an effective methodology. The result is the FGW-FTA methodology in Table 1. The adopted bottom-up approach addresses the gap between the centralised management and the workers by enabling the participants to express their concerns and perceptions about the risks of their work. The main idea is that who has been performing a complex task for a significant amount of time has the most conscious knowledge about the potential issues related to his job activity. A FTA-based procedure has been developed to guide the discussion with the participants of the FGW. Table 1 shows the structure and the steps of the FGW-FTA methodology. The FGW-FTA methodology starts with a first meeting which aims to introduce the FGW-FTA activity to the company. One to four meetings are usually necessary to introduce the methodology and the objective of the focus groups with the workers to the company. The safety professional (moderator), the company management, the workers' safety representative, the trade unions and the workers are invited to attend the meetings. The safety documentation produced by the company (e.g. document on risk assessment, register of injuries, near misses, etc.) is collected in this step, aiming to identify the structure of the organization. Images and other documents reporting information and details of the activities performed by the workers may help the safety professional to further analyse the work processes in the organization.

Table 1: Steps of the FGW-FTA methodology

Step
<p>0. Launch of the FGW-FTA activity</p> <p>Activity: Research Participants: Safety professional (moderator), Management, Workers' safety representative, Trade unions, Workers. Documents: Safety documentation of the company (e.g. document on risk assessment, register of injuries, near misses, etc.), images and other documents reporting information and details of the activities performed by the workers. Objective: Learn the structure of the organization, understand the role of safety and safety personnel in the organization. Meetings: 1 to 4.</p>
<p>1. FGW: First identification of risk factors and workers perceptions on health and safety issues in the workplace</p> <p>Activity: Research Participants: Safety professional (moderator), Workers' safety representative, Workers. Documents: First questionnaire for the workers aiming to identify the workers' knowledge and perceptions of the risks related to their work. Objective: Identify the activities performed by the workers, identify safety issues and risk factors related to the work, identify the risks of the work activity performed. Meetings: 1.</p>
<p>2. FGW-FTA Procedure: Identification of consequences, causes, preventive and improvement measures</p> <p>Activity: Analysis Participants: Safety professional (moderator), Workers' safety representative, Workers. Documents: FGW-FTA procedure Objective: Thorough analysis of the issues identified in Step 1. Identification of consequences, causes, preventive measures adopted in the workplace and improvement measures. Meetings: Multiple, as much as needed.</p>
<p>3. FGW: First identification of risk factors and workers perceptions on health and safety issues in the workplace</p> <p>Activity: Research Participants: Safety professional (moderator), Workers' safety representative, Workers. Documents: Second questionnaire assessing the workers' knowledge and perceptions of the risks related to their work, after the FGW-FTA procedure. Objective: Identify the contribute of the FGW-FTA procedure in improving the workers' knowledge and perceptions of the risks related to their work. The aim is to improve the workers' ability to identify the risk factors and the measures to improve their health and safety in the workplace. Meetings: 1.</p>

The aim is to learn the structure of the organization, understand the safety procedures and the role of the safety personnel in the organization. The focus groups with the workers start after the launch of the FGW-FTA activity. Focus groups are groups of 5 to 12 workers with similar characteristics in terms of performed activities within the organization. In Step 1, the safety professional moderates the discussion with the workers to identify the risk factors and the workers perceptions on health and safety issues in their workplace. An evaluation questionnaire is proposed to the workers, aiming to identify the workers' knowledge of the risks related to their work activity. The moderator drives the workers towards the identification of obstacles, inefficiencies and the risks for their health and safety. The aim is to identify the activities performed by the workers and to investigate their awareness about the safety issues and the risk factors related to their work. A second questionnaire is proposed to investigate the workers' perception on the effectiveness of the adopted preventive measures for the risks related to

their work. In Step 2, one or more FGW are organized to perform a thorough analysis of the issues identified in Step 1. The FGW-FTA procedure is applied to identify the consequences and the causes of the risk factors related to the work activity. The following Figure 1 outlines the FGW-FTA procedure and the key elements discussed during the FGW.

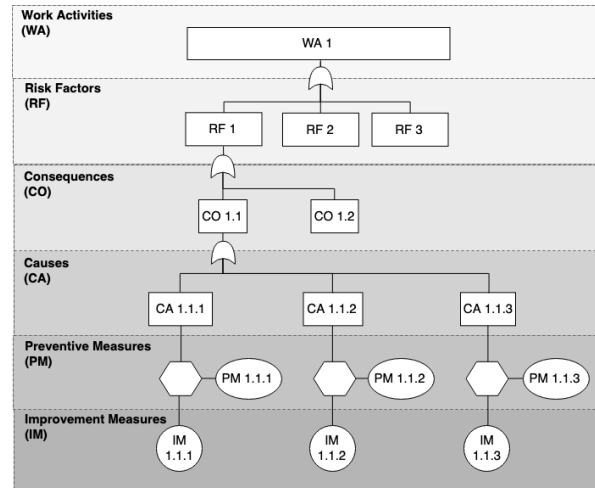


Figure 1: FGW-FTA procedure addressing the focus group with the workers in Step 2.

During the FGW in Step 2, the workers identify the risk factors for their health and safety, related to the work activities performed. The moderator addresses the discussion to identify the consequences and the causes for each identified risk factor. The result is a structured analysis, operated by and with the workers, for the identification of consequences and causes of unsafe behaviours. The workers are then encouraged to list the preventive measures adopted in their organization and to propose a set of solutions and suggestions for addressing the identified issues. The aim is to improve the workers' ability to identify the risk factors and the measures to improve their health and safety in the workplace. Multiple FGW may be necessary to investigate risk factors, consequences and causes for each work activity performed by the workers. The last step of the FGW-FTA methodology focuses on results of the FGW in Step 2. One focus group is organized with the safety professional (moderator), the workers' safety representative and the workers. Then, the workers are invited to fill in the evaluation questionnaire and the perception questionnaire. The aim is to identify the contribute of the FGW-FTA procedure in improving the workers' knowledge and perceptions of the risks related to their work.

3. Case study: the assembly of a mural boiler

This section introduces an application of the proposed FGW-FTA methodology for the assembly of a mural boiler in an Italian manufacturing company. The data introduced in this section were obtained in 2017, when the company was involved in the research. The study involved 31 assembly workers. The workers' job activity consisted in the manual assembly of mural boilers. The assembly activity was performed in different workstations.

Each workstation was devoted to the execution of a part of the assembly process and to the packing of the assembled boilers. The packing activity was part of the assembly process. The workers rotated among the assembly workstations during the work-shift. A job rotation program regulated the scheduling of the workers among the workstations during the day.

Step 0. Launch of the FGW-FTA activity

Two safety professionals met the management (the employer, the production manager and the safety manager), the workers' safety representative and the trade unions representative, aiming to explain the object of the activity. Two meetings were necessary to provide the company with a proper description of the FGW-FTA methodology and to retrieve the safety documentation of the company (e.g. document on risk assessment, the adopted preventive and protective measures, the register of injuries and near misses, etc.), images and other documents reporting information and details of the activities performed by the workers. Two additional inspections were necessary to show to the safety professionals the job activities performed by the assembly workers. Two experimental groups (Group 1 and Group 2) and a control group (Group 3) were identified. Specifically, the experimental group is defined as the group of people who receives a treatment or an experimental procedure. This group is exposed to changes in the independent variable being tested during the study. The control group is separated from the rest of the experiment in order to avoid the influence of the independent variable on the results (Chaplin, 2009). Homogeneity is the guiding principle for focus groups (McQuarrie, Stewart, & Shamdasani, 2006). Homogeneity within each group should be ensured to confirm the validity of the results (Bryk & Raudenbush, 1988). The researchers determine the nature of that homogeneity based on the purpose of the study. In this study, the participants are the workers performing the same assembly activity. A further essential characteristic for the focus groups is the limited number of people (McQuarrie et al., 2006). Despite the general idea that 6-8 participants are sufficient, some studies reported that 4-15 participants is the ideal number (Fern, 2006). A potential drawback of large focus groups is the possibility that some participants will not attend the discussion. 10 participants are therefore considered large enough to gain a variety of perspectives and small enough not to become disorderly or fragmented (Krueger & Casey, 2015). Focus group with more than 12 members are difficult to manage and may disintegrate into two or even three small groups, each having their own independent discussion (O.Nyumba, Wilson, Derrick, & Mukherjee, 2018). In the reference case study, 12 assembly workers participated in each experimental group. These workers experimented all the steps of the FGW-FTA methodology in Table 1. The remaining 7 workers in the control group participated to Step 0, 1 and 3, i.e. the assembly workers in such group did not experimented the FGW-FTA procedure.

Step 1. FGW: First identification of risk factors and workers perceptions on health and safety issues in the workplace

The aim of Step 1 is to identify the risk factors and the workers perceptions on health and safety issues in the workplace. One meeting was organized with each group. Before the FGW, each participant filled in a questionnaire. The questionnaire investigated the workers' knowledge on health and safety issues in his workplace. The moderators built the questionnaire, with the support of the safety manager. The questionnaire consisted of 32 questions (both open questions and multiple choice options) examining the assembly activities performed by the workers and the related risks. The workers in Group 1 and Group 2 were involved in the first FGW with the safety professionals, after completing the first questionnaire. During the FGW, the workers described the assembly activity performed and the related risks. The moderators stimulated the discussion among the participants. Table 2 lists the risks identified by each experimental group.

Table 2: Risk factors identified by the workers in Group 1 and Group 2.

Risk	Group 1	Group 2
Burn	x	x
Cut	x	x
Electrocution	x	x
Ergonomics of the workstation	x	
Fall of pieces	x	x
Fall of the boiler	x	x
Fall of the bumper	x	
Fall of the module		x
Impact	x	x
Investment	x	x
Manual material Handling		x
Repetitive movements		x
Slingshot effect	x	
Slip	x	x
Whiplash		x

The experimental groups identified a total of 15 risk factors related to the assembly activities performed during the work-shift. After the FGW, all the 31 participants were invited to fill in the second questionnaire. The questionnaire investigated the workers' perceptions of the adopted preventive measures for risks identified during the FGW. Group 3 referred to the risks identified during the FGW with the workers in Group 2. For each identified risk, the workers provided their perceptions of severity and probability, on a scale of 1 to 10, and the opinion on the suitability of the adopted preventive measures.

Step 2. FGW-FTA Procedure: Identification of consequences, causes, preventive and improvement measures

Step 2 includes the operational part of the FGW-FTA methodology. Multiple FGW are necessary to apply the FGW-FTA procedure in Figure 1. Krueger & Casey (2015) state that the focus groups should be repeated until the participants produce redundant information. In this case study, two FGW for each experimental group were conducted. The safety professionals (moderators), the workers' safety representative and the assembly workers joined the discussion during the FGW. Each FGW lasted 90 minutes. Group 3 was not involved in this step. The FGW of Group 1 and Group 2 were conducted in different moments of the same days. The same safety

professionals moderated the discussions. This choice ensured no differences in the FGW conduction modalities. The FGW-FTA procedure in Figure 1 was applied during the FGW in this step. The first part of the FGW-FTA procedure allows the deep investigation of the consequences and the causes of the risks identified in Step 1. The discussion among the participants allowed the identification of the potential consequences and causes of each selected risk factor. The application of the FGW-FTA procedure in this case study focused on the risk factor “Fall of the boiler” (see Figure 2). The results of the discussions of both Group 1 and Group 2 were collected in Figure 2. Specifically, the investigated risk factor was present during both the assembly and the packing activities. The workers agreed that the main consequences of fall of the boiler would be various injuries to different parts of the body. The causes of such injuries are multiple. The boiler may fall and cause injuries to the assembly workers because of four main reasons: the boiler dashboard is open, the pipes are not disconnected after testing, the workers apply an excessive push force to proceed the boiler in the assembly line, and the forklift impacts the boiler which causes it to fall. Other causes may determine the fall of the boilers during packing activities, e.g. positioning high stacks of boilers on pallets, falling of not firmly secured staplers on the conveyor, and leaving the front door of the boiler open while lifting with the manipulator. During the FGW, the moderators guided the discussion to the analysis of the preventive measures adopted in the workplace. Finally, the workers proposed a set of improvement measures, for each identified cause of the risk factor.

Step 3. FGW: Second identification of risk factors and workers perceptions on health and safety issues in the workplace

The research activity in Step 3 investigated the workers knowledge and perceptions on their health and safety in

the workplace, after the application of the FGW procedure. Two FGW of Group 1 and Group 2 were conducted in different moments of the same day. The same safety professionals moderated the discussions. This choice ensured no differences in the FGW conduction modalities. The discussion of the FGW focused on the results of the FGW-FTA procedure in Step 2. All the workers in Group 1, Group 2 and Group 3 were invited to fill in the evaluation and the perception questionnaires. The aim was to assess the variation of their knowledge and perceptions on the occupational risks related to the manual assembly of the metal boilers, after the application of the FGW procedure during the FGW in Step 2.

4. Discussion

The case study in Section 3 showed the application of the developed FGW-FTA methodology in the assembly lines of metal boilers in an Italian manufacturing company. Two experimental groups (Group 1 and Group 2) and a control group (Group 3) were identified. 12 assembly workers participated in each experimental group. These workers experimented all the steps of the FGW-FTA methodology. The 7 workers in the control group participated to Step 0, 1 and 3, i.e. the assembly workers in such group did not experimented the FGW-FTA procedure. The workers were invited to fill in both the evaluation questionnaire and the perception questionnaire before and after the FGW in Step 1 and Step 3 of the FGW-FTA methodology. Few workers did not return the questionnaires. Table 3 shows the results of the evaluation questionnaires. The comparison between the results of the questionnaires for each group revealed an increased learning of occupational risks, which lead to an higher average number of correct answers per worker in both Group 1 (+ 13.5%) and Group 2 (+ 16.0%).

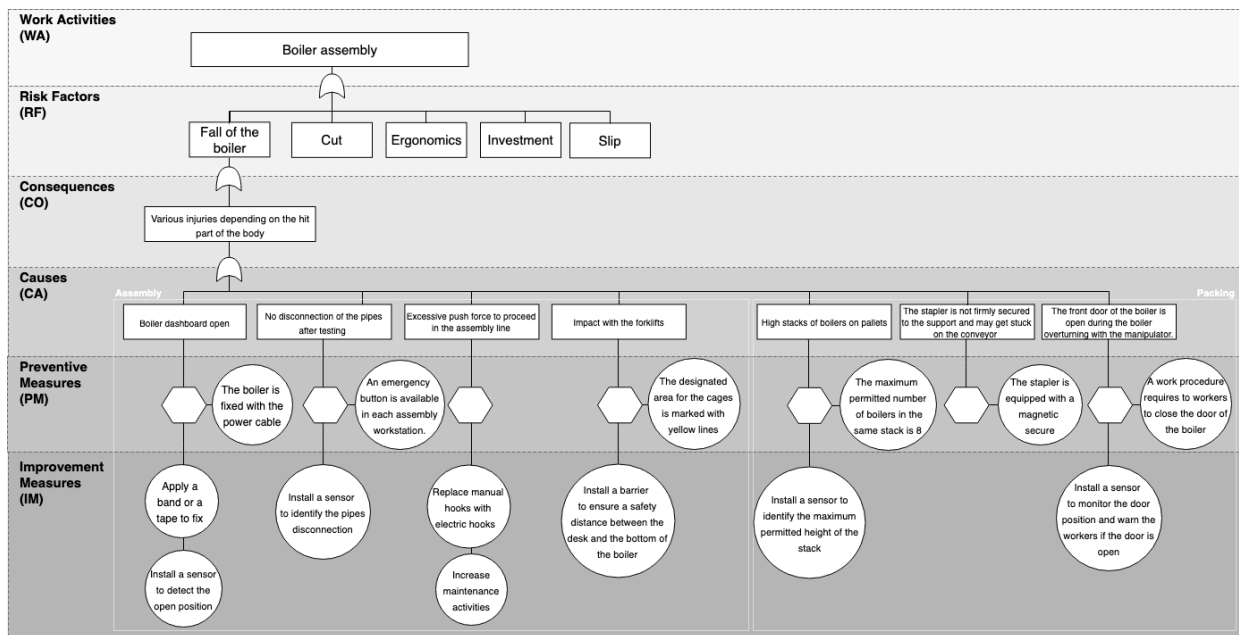


Figure 2: FGW-FTA procedure applied to the analysis of the risk factor “Fall of the boiler”.

Table 3: Results of the evaluation questionnaires filled in by the assembly workers in Step 1 and Step 3 of the FGW-FTA methodology.

	Group 1	Group 2	Group 3
Number of filled in questionnaires in Step 1	10	9	7
Average number of correct answers per worker, in Step 1	17.1	17.8	19
Number of filled in questionnaires in Step 3	10	11	5
Average number of correct answers per worker, in Step 3	19.4	20.7	18.4
Percentage variation	+ 13.5%	+ 16%	- 3%

This trend was not confirmed in the control group (Group 3), where the variation of correct answers was minimal (- 3.0%). The application of the FGW-FTA procedure allowed the learning improvement for the workers in the experimental groups, in terms of identified risks, consequences, causes, adopted preventive measures and suggested improvement measures. Specifically, the workers revealed the weaknesses of the adopted preventive measures, suggesting a set of affordable and easy-to-apply improvement measures. Furthermore, the results in Table 3 confirmed that the deep investigation of the activities performed by the workers lead to an increased operational awareness about the risk management. The second questionnaire investigated the workers' perception on the effectiveness of the adopted preventive measures. Each worker filled in the perception questionnaire in Step 1 and in Step 3 (see Table 4).

Table 4: Results of the perception questionnaire: “Do you believe that the adopted preventive measure are effective to prevent the occupational risks of the assembly activity?”.

	Group 1	Group 2	Group 3
Answers in Step 1			
Yes	8	9	3
No	2	0	2
No answer	0	0	2
Answers in Step 3			
Yes	6	6	2
No	1	3	1
No answer	3	0	2

The results in Table 4 show that the workers' perception on the effectiveness of the adopted preventive measures decreased after the application of the FGW-FTA procedure in Step 2. Such variation is minimal for the workers in the control group. The results in Table 3 and Table 4 confirmed the effectiveness of the developed methodology in improving the workers knowledge and perceptions on occupational health and safety.

5. Conclusion

The participative technique introduced in this paper is the Focus Group with Workers (FGW), in conjunction with the Fault Tree Analysis (FTA). This methodology addresses researchers and safety professionals during the FGW for the identification of critical risk factors in their workplace, following a FTA-based approach (FGW-FTA). The result is a structured analysis, operated by and with the workers, for the identification of consequences and

causes of unsafe behaviours. The proposed methodology is based on the active involvement of the workers and on their ability to learn from their direct experience. The last step of the methodology leads the workers to define a set of preventive and protective measures, and corrective actions for the improvement of health and safety in their workplace. The test of this methodology in both small and large organizations allowed the authors to improve the FGW-FTA methodology. The final structure introduced in this paper allowed the following results: active involvement of the workers in the choices related to their occupational health and safety; recognition of near misses and potential high-risk conditions that may result in accidents; improvement of workers' attention and caution during work activities, which lead to a reduced risk of carelessness due to excessive confidence with the workplace and the performed tasks. The application of the FGW-FTA methodology leads to a detailed activity and risk mapping, which results in the development of a detailed document on risk assessment focused on the organization necessities. The consequence is an operational awareness of the risk management and an improved organizational information flow between employees, employers and all the safety professionals inside and outside the organization. Finally, the FGW allows the deep investigation of the causes of improper behaviours and the identification of the solutions to prevent their appearance. The introduced methodology may provide a strong contribution to the identification of leading indicators (LIs) of occupational health and safety. Examples of LIs are the adequate task and safety knowledge, situation awareness, norms that support safety, and functioning teamwork and cooperation (Reiman & Pietikäinen, 2012). The future developments of this study will investigate the contribute of this methodology to the identification of such indicators.

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