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Similarities between Work Related Musculoskeletal Disorders and Slips, Trips and Falls

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Most occupational risks manifest themselves through movements performed at work, for example musculoskeletal disorders, slips, trips and falls. Research focusing on such risks often differentiates diseases from accidents. All these risks prove to be diffuse, widespread, emergent and devoid of an external harmful hazard, when analysed through their common vector, i.e. through the movements manifesting them. These characteristics have a strong impact on risk perception and on approaches necessary to ensure sustainable prevention. A participative search for local solutions to preventing these risks, integrating shared risk representation and several analysis levels, would seem helpful. A balance between defended and resilience-based conceptions of health and safety should be established. Research should also be extended to enhance in-depth understanding of controls impacting worker movements when performing a task, while safeguarding health and safety.

Practitioner Summary: Progress in the field of musculoskeletal disorders would contribute to preventing occupational accidents with movement disturbances. This paper highlights the significance of both establishing a balance between health and safety-defended conception and system resilience enhancement, and better understanding the individual controls involved in performing a task, while safeguarding health and safety.

Keywords: occupational injuries, slips trips and falls, musculoskeletal disorders, movement, sustainable prevention

1. Introduction

Statistical data and surveys involving health and safety at work often include different injury categories (falling from a height, injuries during manual handling, electrocution, musculoskeletal or psycho-social disorder, cancer, etc.). Each category involves an adverse outcome or manifestation of the relevant risk¹. The risks are different in terms of issue, social demand, injury mechanism and occurrence time, and they require locally different prevention actions. Most injuries, including work-related musculoskeletal disorders (WRMSDs) and slips, trips and falls (STFs), manifest themselves through the movements performed by a worker. These movements may be disturbed by a slip or a trip (STFs). They may also be repetitive and forceful, leading to WRMSDs. Working conditions, combined with characteristics specific to the operator and to his or her aims, determine his or her movements and hence the injury risk, to which he or she is exposed. Working conditions are therefore more or less favourable to emergence of an occupational injury arising through work-related movements.

The challenge of this study is to consider together the occupational risks, which manifest themselves through worker movements, and, in particular, risks of WRMSD and risks of STF. The aim is to highlight generic characteristics, which are shared by WRMSDs and STFs and have an impact on risk perception, and to derive prevention approaches and relevant applied research areas. At present, STF injuries are the subject of little prevention-related research and practice, so their prevention should gain from work dedicated to WRMSDs, at least from theoretical and methodological standpoints. Limitations to the above standpoint will be highlighted.

¹ There is no agreed definition of risk (Aven and Renn, 2009). In this paper, the risk is the probability of an adverse outcome (Graham and Wiener, 1995); a risk will be considered to exist in an occupational situation, if the probability of the associated adverse outcome is not zero, injury occurrence being the risk manifestation.

2. Occupational risks and worker movements

Table 1 shows that the majority of occupational injuries listed in statistical databases (50 to 82% of included injuries) are related to movements at work.

[Table 1 about here]

WRMSDs cover a variety of injuries which are most often considered a direct consequence of movements executed by the worker in performing a task. Force exerted, movement repetitiveness, joint amplitudes or posture maintained are explanations given for WRMSD occurrence (Kilbom, 1994; Bernard, 1997; National Research Council, 2001; Vezina, 2001; Straker and Mathiassen, 2009).

With regard to occupational accidents, the literature focuses mainly on “Slips, Trips and Falls” (STFs) occurring when walking (Buck and Coleman, 1985; Chang, 2008; Bentley, 2009). It most frequently overlooks injury cases, in which, for example, the victim catches his or her hand in a door or window, collides with an element of the environment, loses his or her balance because a wrench slips or suffers pain, when performing a movement not necessarily associated with major effort. Yet, accidents of this type are recurrent: they occur through movements performed at work and, contrary to generally accepted ideas; they are not only frequent but include serious occupational injuries (Leclercq, 2005; Jorgensen, 2011). Leclercq et al. (2009; 2010) have suggested grouping together Occupational Accidents caused by Movement Disturbance (OAMD) to specifically embrace the wide range of movement disturbances encountered in

occupational situations. If WRMSDs are clearly a set of work-related injuries, STFs at work are often reduced to simple² accidents and are not always specifically³ considered. There is strong social demand for WRMSD prevention, as witnessed by occupational health priorities expressed in government policies (EASHW, 2015 ; MTSFP, 2015). Multiple scientific studies have also been dedicated to these risks and a number of them have been presented at the PREMUS (International Conference on Prevention of Musculoskeletal Disorders) triennial conference. Furthermore many practices oriented towards WRMSD prevention have been implemented in the field (Denis et al. 2008). Similarities between WRMSDs and OAMDs are highlighted in the present study and they allow us to demonstrate the complexity of preventing risks of falling or collision, despite the apparent triviality that stigmatizes these accidents. These similarities also show that experience feedback from WRMSD prevention research and practice could undoubtedly be helpful (from a theoretical and methodological standpoint) in preventing movement disturbance-related accidents not addressed by practices related to the issue.

3. Similarities between WRMSDs and OAMDs

This section describes characteristics common to all injury risks arising through movements performed at work. These characteristics are determinant in the difficulties and constraints faced by prevention.

² Jorgensen (2011) in a paper related to “simple accidents” states that they “... happen in everyday situations, which people believe they are fully capable of controlling and where they therefore cannot really see any serious risk”.

³ Some accidentology studies concern falls, whether they occur at work, at home, during leisure activities or sport (Haslam and Stubbs, 2006).

3.1. Risks arising through movements

Results of the fifth European survey on working conditions (EASHW, 2010) and those of the SUMER survey (Arnaudo et al., 2006) show that WRMSDs arise in particular from “heavy”⁴ postural or articular stresses sustained in a work situation. At the same time, a large proportion of injuries occur when performing movements that are not necessarily associated with heavy physical activity: for example, neck disorders related to computer work or electronic component assembly activities (Lundberg et al., 2002) or tripping when walking. In common with these surveys, the literature reveals that WRMSDs may result from high musculoskeletal stresses (Bernard, 1997) or sustained low-level muscular contractions (Hägg, 1991; Forsman et al., 2002). The movements considered in this study therefore include muscular contractions leading to body segment displacement and “*muscular contractions when maintaining a given position or exertion of a force without displacing bodily segments with respect to each other, such as pushing a fixed object with a stretched upper limb*” (Gaudez and Aptel, 2008). In principle, injuries can arise through any purposeful movement performed by a worker: both specific task-related movements (sewing, cutting meat, etc.) and less specific movements such as picking up an object or walking.

The acronyms WRMSD and OAMD are used to refer to the set of injuries studied and described in this paper. These injuries result from movements made by workers and can be:

- Gradually emerging when performing movements that are often, but not only, characterised by stressful postures and/or major efforts and/or high movement repetition; these injuries manifest themselves after a fairly long exposure time

⁴Arnaudo et al. (2006) have defined heavy postural or articular stresses based on time thresholds, beyond which exposure to a type of stress (prolonged kneeling or head and neck in fixed position for example) can be considered a significant risk factor for the employee’s health.

- Sustained suddenly when performing a movement, which causes violent pain or improper interaction between the moving victim and the immediate physical environment (collisions, trips, jams, etc.); these injuries may relate to any type of movement and, in some cases, to a major effort of possibly short duration.

3.2. Risks to which every worker is exposed

In principle, any movement performed by an individual at work is liable to lead to injury: collision when walking, pain when handling an item, elbow bursitis due to prolonged pressure on a surface, carpal tunnel syndrome due to repetitive wrist extension movements. This partly explains the varied, frequent manifestations of these risks and why they affect all activity sectors to a greater or lesser degree (Buck and Coleman, 1985; Gaudez et al., 2006; Roquelaure et al., 2006; Luckhaupt et al., 2012). Furthermore, they arise in all jobs and socio-professional categories within every activity sector.

The diversity of occupational situation characteristics that determine worker movements (cf. Sub-sections 3.6 and 4.3) suggests a wide range of situations that are potentially vulnerable to WRMSDs and OAMDs in every activity sector. Consideration of this diversity within a prevention framework makes it necessary to seek solutions locally (cf. Sub-section 4.2.), without excluding consideration of macroscopic determinants. The resulting combination of analysis levels forms the subject of Sub-section 4.3.

3.3. “Active” victims and fairly diffuse risks

Occupational risks manifesting themselves through worker movements are diffuse in space and time, unlike major industrial risks (toxic cloud, explosion ...), in which a

single accident causes multiple victims. Moreover, each victim of injuries arising from worker movements takes an active part in performing the movements through which these risks manifest themselves. Again, this differs from industrial risks, in which there are more victims with activities unrelated to accident occurrence.

These characteristics have consequences in terms of both perceiving the risk and its causes, and its acceptability. Furthermore, all such characteristics represent factors requiring consideration in prevention strategies.

3.4. No external harmful hazard in the injury mechanism

In cases of occupational injuries resulting from risks such as chemical, electrocution or cancer risks, an external harmful hazard (intrinsically harmful element external to the victim) is a direct cause of injury. This element may be a toxic or carcinogenic substance, or a high-voltage electric current. In WRMSDs or OAMDs, injury is most frequently a direct consequence of the musculoskeletal system being stressed beyond its functional capacities without the contribution of this type of external hazard. In many OAMDs, injury also depends directly on the characteristics of an element, which is external to the victim and is most frequently not intrinsically harmful. Such an element could be a wall in a collision case, stairs in a fall or part of a machine in the case of a wrench slipping and causing the victim's arm to graze against a machine frame. This characteristic of risks that manifest themselves through movements performed at work, influences their prevention, as shown in Table 2.

[Table 2 about here]

3.5. A combination of “usual” facts leading to injury

Characterisation of an injury-causing situation must reflect a difference with respect to a situation, in which the risk did not manifest itself. Causes of WRMSD and OAMD risks (all facts⁵ necessary to and sufficient for their occurrence) cannot be exhaustively and definitely identified because of their number and nature (cf. Sub-section 3.6).

In some cases, facts necessary to the occurrence of these injuries involve deviation(s) with respect to more or less formal instructions (regulations, procedures, best practices, usual working practices, etc.). For example, a risk of a WRMSD may involve repetitive movements, during which the employee needs to raise his/her arms above his/her shoulders, or a risk of an OAMD may involve a hole in the floor. These factors can be easily identified, when they are permanently present. Their role in injury occurrence must be understood and, if appropriate, they need to be neutralised as a priority in a prevention strategy. However, these types of deviation with respect to an injury-free situation cannot be the only targets for action, especially because many injuries occur without revealing a causing factor involving a deviation with respect to more or less formal instructions or usual practices. With regard to accidents involving movement disturbance, Leclercq et al. (2013) observe that the causing character of an occupational situation is most frequently expressed by a new combination of “usual” facts occurring at a given moment. *“Let us consider, for example, the following accident factors, none of which is permanent in the occupational situation, but each of which can be occasionally observed: “temporary storage of equipment for activity needs”, “arrival of a number of patients exceeding reception capacity” and “emergency call for nurse*

⁵ Variations, causes, latent conditions, risk factors or determinants are all terms used in the literature dealing with occupational accidents (Kouabenan, 1999) or occupational pathologies to distinguish the various facts that take place during the genesis of such injuries. In this paper, the term “factor” or the expression “risk factor” is used to evoke a fact, which increases the probability of injury occurrence, irrespective of the level at which this fact acts in the genesis of the injury or its nature.

busy elsewhere". None of these facts refers to non-compliance with instructions and they can occur more or less often in normal occupational situations. It is their combination at a given moment that causes the accident: "the nurse collided with the equipment". The presence of these types of risk factor can be inherent to the work (an emergency call) or tolerated to promote production continuity (congestion caused by the activity).

In occupational diseases, which appear when performing movements, it is the combination of "usual" facts present in the long term that increases the risks. For example, shoulder blade injuries can result from a combination of factors, such as repeated and/or prolonged upper limb abduction, high psychological demand and poor job control (Roquelaure et al., 2011).

Hence, in most WRMSD and OAMD cases, the injury-causing character of a situation is reflected in a new combination of "usual" facts occurring at a given moment or in a set of "usual" facts combining in the longer term. From this standpoint, the comparison made by Leclercq et al. (2013) between the accident with movement disturbance and the industrial accident, described by Hollnagel (2004) as the uncontrolled combination of variabilities in normal operation, would also be valid for occupational diseases that manifest themselves when performing movements. This characteristic leads Hollnagel and his colleagues to replace the notion of causality by that of emergence (Hollnagel et al., 2006).

3.6. Risks revealing root causes

Individual factors are commonly advanced to explain a WRMSD or an OAMD, if a risk manifests itself through movements performed by a worker. This attitude currently prevails in relation to OAMDs (Jorgensen, 2011), but it is still encountered far too

frequently at certain companies in relation to musculoskeletal disorders. We wish to recall that all these risks have root causes, despite their manifestation through movements when working.

In this section, we simply illustrate the potential impact of macroscopic developments, such as technological advances or the advent of regulation, on the conditions under which an operator performs his movements and hence on the resulting risks in occupational situations. Three levels are distinguished in Figure 1, which illustrates a work organisation model developed by the National Institute of Occupational Safety and Health (NIOSH) (Sauter et al., 2002). This model displays the nature of different factors involved in occupational injury appearance, along with the limits within which these factors prove to be harmful.

In general, development of productive organisation characteristics never ceases under the specific effects of technical progress (automation, introduction of new technologies, etc.) prompting greater productivity (Wilpert, 2009), employment market developments (active population characteristics, etc.) and reorganisations (outsourcing, etc.) (Op de Beeck and van Heuverswyn, 2002). Based on productive organisation choices, these macroscopic developments affect the work situation (level of prescription, time and spatial constraints, etc.) in ways that will determine the conditions, under which the worker movements are performed.

[Figure 1 about here]

Working conditions therefore constitute preferred targets for prevention action along with the more upstream risk factors illustrated in Figure 1.

4. Consequences for prevention research and practices

Considering separately slips, falls, lower back pains, rotator cuff tendinopathy, carpal tunnel syndrome, etc. leads us to implement prevention actions aimed at neutralising risk factors fairly close to the injury (in the injury genesis) and specific to the type of event considered (e.g. slips). Such responses, while possible and relevant in some situations, are nevertheless insufficient for preventing all injuries arising through worker movements.

Conditions favouring sustainable prevention of risks manifesting themselves through movements at work are detailed in the following sections.

4.1. *Shared mental representations*

The conventional and undoubtedly prevailing mental representation of risks that manifest themselves through movements at work, currently involves focusing on individual factors (highlighted in Sub-section 3.6). Such representations do not favour integration into a prevention strategy, of all the factors involved, especially factors further upstream in the injury genesis. “Tendencies to act”⁶ in health and safety, as described in Baril-Gingras et al. (2010), are determined by perception of the problem experienced by those involved (stakeholders). Development of mental representations taking into account the complexity of occupational injury occurrence, in particular integrating factors upstream in the injury genesis, appears essential to actions aimed at preventing underlying causes.

WRMSD prevention studies have also shown that a mental representation (for example a representation of injury causes based on a model considering a combination of factors of different nature) must be shared by stakeholders, to make it useful.

⁶ « dispositions à agir » translated from French in the original paper

Existence of multiple representations of the same risk can lead to inhibiting social dialogue on occupational risks or managing individual factors (Daniellou et al., 2008). A complex process governs development of mental representations. This process is based on individual and collective characteristics such as status, position held, training, professional experience, challenges raised by the risk, belonging to a group, company culture, stakeholders' perception of other people's work or the fact of having been a victim or witness of risk manifestations (Daniellou et al., 2008.; Baril-Gingras et al., 2010). In practice, mental representation development and sharing are more than absolute prerequisites: they must be integrated through the social construct on which the intervention is based, by information, action learning, exchanges between company players exploring the activity or simulations (Daniellou et al., 2008; Baril-Gingras et al., 2010; Saint Vincent et al., 2011). It would, therefore, be up to the preventionist to lead thinking on methods of developing a shared mental representation enabling underlying causes to be reached and tools to be made available for company players to deploy them through actions in the field (Daniellou et al., 2008).

4.2. Local participatory search for solutions

Standard solutions can be helpful in preventing these risks, as long as they suit a number of specific characteristics of the situation. Laying slip resistant flooring at a company manufacturing food products and reorganising storage are typical standard solutions to prevent slipping and musculoskeletal disorders respectively. This type of solution is usually first considered at companies, which decide to enhance their level of health and safety, but it cannot meet the requirements of every injury-causing situation. In some cases, this type of solution may lead to new risk situations, if it does not respond to the overall nature of the situation, as witnessed by many WRMSD studies

(e.g. Bourgeois et al., 2006). Moreover, injury factors can be subject to ambivalence, depending on the context; they can be health/safety factors or disease/unsafeness factors. For example, knowledge of a location is a safety-related factor, when a person anticipates a step at a place where it is unexpected (e.g. in the middle of a corridor). This same knowledge can be an unsafeness-related factor, when there is an unusual obstruction and the person, trusting his/her knowledge of the location, does not notice it. Another example is greater autonomy, which is most frequently considered a health-related factor in relation to WRMSDs. Yet, this can prove to be a disease-related factor, if there are insufficient resources or no recognition. It is therefore difficult to draw together a set of solutions applicable to every situation. Movement performance conditions and their determining factors are effectively specific to the activity sector, the company and the occupational situation. In the prevention field, needs are local and response relevance requires consideration of local specific characteristics.

“Complex” interventions, as defined by Denis et al. (2005), have been developed based on situation diagnosis and aimed at solutions designed for the specific context. These would achieve more and a greater variety of changes and would be based on a participatory search process. Research into WRMSDs therefore highlights the leading roles played by “worker participation and involvement” and “decision-maker support and management availability” as factors most positively influencing prevention approaches (Saint Vincent et al., 2010; Van Eerd et al., 2010). Participation must nevertheless not be limited to worker consultation, but must be aimed at solution building by positioning workers and their management as top specialists in relation to work (Kuorinka, 1997; Haines and Wilson, 1998; Denis et al., 2005) and by involving them in the process of deciding on and implementing solutions. These types of approach will positively influence the search for, and introduction of, solutions by allowing

“additional solutions to be created”, “mistakes to be avoided” and “solutions to be refined” (Denis et al., 2005).

Finally, active participation of workers and their management will enable risks to be better faced by encouraging comparison of different activity performance methods and allowing exchange of each participant's thinking on his/her activity. More specifically, operators develop certain aspects of know-how, control strategy, adaptation or protection every day (Derosier et al., 2008; Major and Vézina, 2011) in order to achieve expected performance and/or confront a risk. Sharing these elements of knowledge allows us not only to develop health and safety conservation skills, but also make them visible and understandable to management (Caroly, 2010; Simonet et al., 2011a and 2011b), and even to integrate them into the organisation.

4.3. A complex combination of analysis levels

Figure 1 illustrates the effect of macroscopic developments on the occupational situation through productive organisation choices. The relationships between specific organisational characteristics and employee working conditions have been studied in many activity sectors. Valeyre (2006) shows that working conditions and occupational health differ widely according to the form of work organisation based on data provided by the third European survey on working conditions at companies in the industry, construction, trade and services sectors, excluding agricultural companies. Here, organisation is characterised by variables such as working autonomy, team work, versatility at work, task repetitiveness and monotony or the quality control method. It would seem that occupational health and several working condition aspects, such as physical arduousness, atypical working hours, working times, flexi-hours, unexpected

work interruptions and work intensity, effectively differ in relation to the work organisation format

These observations in certain activity sectors cannot be directly transposed to other sectors or from large to small enterprises because of the different activities developed within them and their specific organisational characteristics. The interdependence of organisational variables, working conditions and occupational injuries has been revealed in particular by case studies (Stock et al., 2006) or epidemiological studies (Leclerc et al., 1998; Bongers et al., 2006; Deeney and O'Sullivan, 2009) in specific activity sectors. Their results agree with those of the above survey (Valeyre, 2006) and they substantiate the thesis that causes of occupational injuries are firmly rooted in performed activities and their context.

Controls are continually implemented at different levels depicted in Figure 1 and their analysis helps in understanding occupational injuries. Different disciplines (sociology, economics, ergonomics, biomechanics, etc.) can be involved depending on the level(s) of analysis and ultimate aim of the study. Implementation of different levels of analysis would seem necessary to display relationships between prevention action at a given level and risk manifestation in an occupational situation. This represents a true challenge for both researchers and prevention specialists.

With regard to risks leading to WRMSDs and OAMDs, an analysis focusing on worker movement, which is part of the activity performed, should be systematically carried out. Its results should be integrated with those of the activity analysis performed using a larger observation mesh. A model considering WRMSDs and OAMDs, adapted from the Vezina (2001) model and presented in Figure 2, could be used for this purpose. The original model has been developed by Vezina (2001) to analyse WRMSDs. It considers

worker movements within worker activity and the trade-off between production, and health and safety.

[Figure 2 about here]

The trade-off between production and health and safety, highlighted in Figure 2, frequently favours production. In this connection, Leclercq and Thouy (2004) have shown that sales representatives, who are late for their appointments because of snow on the road, try to make up for “lost time” by hurrying when moving, on foot and alone, between their vehicle and the customer's home. It is during these displacements that slips and falls occur on the snow. With regard to WRMSDs, occurrence of recurring breakdowns on the production line may be followed by a temporary increase in productivity to “make up” for lost time and meet manufacturing orders. The ensuing time-related pressure then becomes a source of greater movement repetitiveness, a factor favouring the occurrence of musculoskeletal disorders. Such controls can be observed and the individual strategies they serve can be examined in detail through individual interviews. Other control mechanisms, often automatically implemented, are harder to grasp; they cannot always be observed and their detection requires a much finer observation mesh, which accurately describes movements such as heel strike angle when walking, grasping for support, forces produced, etc. This type of control mechanism, readable in the movements, is also designed to ensure production whilst maintaining health and safety. They are established by the worker to control continuously his/her movement and to adjust his/her posture in order to perform the task, whilst preventing pain and disturbances. For example, control mechanisms need to be implemented to adapt to surface characteristics: a worker anticipates a slippery floor,

reducing his/her heel strike angle when walking (Andres et al., 1992) or a worker is unable to exert sufficient force on an object with his/her hand (sufficient as far as task requirements are concerned), if the support surfaces are too slippery (Kroemer, 1974; Gaudes et al., 2008).

Combining analyses of the same occupational activity at two levels (i.e. using different observation meshes) offers us the best possible understanding of individual and collective controls implemented in an occupational situation for performing a task, while avoiding injuries.

4.4. *Better understanding of worker movement*

Movement has been broadly considered in its biomechanical and physiological dimensions within a WRMSD and OAMD prevention framework (e.g. Strandberg and Lanshammar, 1981; Mathiassen et al., 1995; Veiersted, 1996). This approach leads to prevention actions close to the injury in its occurrence genesis. Biomechanical studies of slips, in particular, have helped in evaluating the slip resistance of shoes or floors, when recommending products suited to certain situations involving a high risk of slipping (e.g. Strandberg, 1983). With regard to WRMSDs, prevention has mainly involved reducing musculoskeletal stress factors (effort and repetitiveness). Greater understanding of WRMSDs and OAMDs and progress in their prevention require us to consider not only the biomechanical and physiological dimensions of the movement, but also its cognitive, psychological, organisational and economic dimensions (Bourgeois and Hubault, 2005). Hence, some authors favour the use of the term “gesture”, thereby highlighting consideration of these multiple dimensions (Bourgeois and Hubault, 2005; Chassaing, 2010).

Movements performed at work are subject to continuous adjustment with respect to the required task as well as individual, organisational and environmental constraints (Chassaing, 2010). Thus, time required and time imposed for the action, mistakes made (Chassaing, 2005; 2010), tiredness, pain (Gaudart, 2000; Derosier et al., 2008), previous working life, colleagues' practices, life outside work (Chassaing, 2005; Derosier et al., 2008), past experiences (Daniellou et al., 2008) are all movement building determinants. Movements result from a compromise made at a given moment (Bourgeois et al., 2006) and are subject to a continuous development or building process (Cuvelier and Caroly, 2009).

Daniellou et al. (2008) considers that the occupational gesture and its building represent an avenue of development towards sustainable prevention of musculoskeletal disorders. The ensuing question is whether knowledge that furthers our understanding of the occupational gesture remains specific to understanding development of musculoskeletal disorders or whether it is equally helpful in understanding accidents caused by movement disturbance. This paper supports the hypothesis, already advanced by Chassaing (2010), that such gestural knowledge may prove helpful in understanding better the type of relationship that exists between occupational accidents and gestures and is therefore also helpful to prevention specialists in terms of safety at work.

Considering movements performed at work in every dimension leads naturally to combining several levels of analysis and considering simultaneously the goals to which it leads (cf. Sub-section 4.3). Understanding movement in an occupational situation is therefore an extremely broad issue involving a wide variety of movements (all more or less job specific and irrespective of the level of muscular contraction governing them), whose construction and control depend on multiple determining factors. This process demands the viewpoints of different disciplines (physiology, psychology, ergonomics,

neurosciences, etc.), as pointed out in Leplat (2013), who has discussed gestures in occupational activity analysis based on literature from different disciplines.

4.5. Balance between defended and resilience-based health and safety conception

In response to the emergent nature of industrial risk (cf. Sub-section 3.5.), Hollnagel et al. (2006) introduce the concept of resilience⁷, which is designed to strengthen the adaptive and anticipative capacities of the system. This mode of action compensates for subsistence of residual vulnerability in so-called complex socio-technical systems, despite implementation of preventive barriers⁸. Thus, increasing the resilience of the system should allow progress in the prevention field, when the risks manifesting themselves through movements performed at work are emerging risks (cf. Sub-section 3.5).

From an operational standpoint, implementation of preventive barriers has shown its limits for at least two reasons. Firstly, residual risks remain and, secondly, increasing the number of barriers sometimes leads to system rigidification, which may prove harmful in the long term. Prevention must therefore broaden its modes of action and achieve a balance between:

- Following recommendations on implementing barriers, which have proved efficient in some situations, especially those in which we would constantly observe risk factors, such as no guardrails, absence of fire detection devices or alarm, lack of training in equipment usage or, in the present study, carrying of heavy loads or a staircase whose design obviously makes movement difficult and

⁷ Intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions (Hollnagel, 2010)

⁸ Unlike the increase of the system resilience, implementation of preventive barriers refers to a defensive conception of health and safety (Hollnagel, 2008)

- Developing other approaches such as increasing system resilience, i.e. increasing its capacities to confront disturbances. These approaches are specifically suited to injury-causing situations featuring a combination of “usual” facts (cf. Sub-section 3.5.), in which each victim plays an active part in performing the movements through which the risk manifests itself (cf. Sub-section 3.3). Increasing the “*margin of maneuver*” (Coutarel, 2004) or increasing system resilience (Hollnagel, 2010) falls under this kind of approach in cases respectively of WRMSD and industrial risk.

5. Limitations and implications for theory and practice

Most occupational injuries result from worker movements. However, while analysing these injuries is helpful to progress in the prevention field, we also need to understand the movements performed in "usual" occupational situations. The model illustrated in Figure 1 shows that generic factors related to the external context, the organization and the work context are applicable regardless of the type of incident (WRMSD, OAMD or any occupational injury). Factors become less general and more specific to the sample considered, when the model is instantiated. The broader the sample, the more general the factors and the less operational the resulting model. Hence, the frame of reference involving a large set of risks adopted in this case does not provide prevention solutions that are directly applicable at a specific company. The main objectives are to change the current view of OAMDs, generate research on movements in occupational situations and highlight conditions necessary to OAMD prevention approaches in the field. Lastly, WRMSDs remain prevalent despite theoretical advances. This suggests that the best hope for further improvement involves addressing factors upstream in the injury genesis and specific to a health and safety culture. Specific characteristics of the risks

highlighted in this study, which manifest themselves through movements performed at work, could be used to change the current view on such risks. This represents a necessary condition for enhancing health and safety culture in relation to WRMSDs and OAMDs.

6. Conclusion

Most occupational risks manifest themselves through movements performed at work: musculoskeletal disorders, falls, collisions, etc. Since the 1980s, musculoskeletal disorders have formed the subject of many research studies and practices in the prevention field. Research has been less comprehensive with regard to collisions, trips and other accidental movement disturbances, despite the importance of their prevention challenge. OAMD prevention continues to be confronted by multiple obstacles. Highlighting similarities between OAMDs and WRMSDs, on which progress has been more significant, can only contribute to enhancing prevention by providing a systemic vision, in particular. While many companies are aware of and possess tools for preventing musculoskeletal overstress, this is unfortunately not the case for injuries caused by sudden movement disturbance (collisions, tripping, jamming, etc.) or occupational diseases, when they do not embody the notion of major effort. This type of context is not favourable to organisational anticipation of such risks and, hence, these risks are very often managed by the operator on an individual level. While individual management of such risks is natural and automatic in certain circumstances, it is made more difficult in others, such as those encountered in a work intensification context.

This study reveals similarities between different risks usually considered separately in the literature. WRMSD and OAMD risks are diffuse, emergent, present in every

activity sector and they affect every socio-professional category. In most cases, no external harmful hazard is a direct cause of injury. Yet, these risks have root causes in common with all occupational risks. These characteristics determine clearly that prevention strategies and approaches should be based on a local, participatory search for solutions that take into account shared mental representations of the risk.

Understanding and preventing occupational risks generally require us to combine several levels of analysis, especially involving the work situation and the company, and a macroscopic level integrating influences external to the company. With specific reference to risks, which manifest themselves through movements performed at work, it would seem helpful to develop, at a “microscopic level”, in-depth understanding of controls that have an impact on worker movements during task performance, while maintaining health and safety. Finally, a balance should be achieved between defended and resilience-based prevention approaches.

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Figure captions

Figure 1. Organisation of work model developed by the NIOSH, taken from Sauter et al., (2002).

This model illustrates the repercussion of macroscopic developments on occupational situations based on productive organisation choices.

Figure 2. Model of occupational situation understanding based on the person and his/her activity (integrating movement in the activity), adapted from the one developed by Vezina (2001) for WRMSD.