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# Prevention of so-called “accidents on the level” in occupational situations: a research project

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## **Abstract**

Accidents on the level occurring in occupational situations are of concern in France and abroad. INRS (French national research and safety institute) has integrated these accidents into its research and study program. In this paper, we propose a definition of targeted accidents and detail a number of obstacles to their prevention. We go on to describe the main factors governing the problem of preventing these accidents and we detail the two main lines defined in the research and study field: systemic analysis of contexts involving falls on the level in occupational situations and study of adjustment strategies for confronting the risk of falling or balance disturbance in these situations. Finally, we recall the methodological tools used at the start of this research project to meet its objectives.

*Keywords:* accident on the level, occupational accident, balance adjustment, prevention

## 1. Introduction

Accidents on the level occurring in occupational situations are of concern both in France and abroad (HSE, 1985; Leamon and Murphy, 1995; Leclercq, 2002). Relevant literature employs varied terminology to designate these accidents without always defining them explicitly. In fact, the literature focuses on “slips, trips or falls on the level” (H.S.E., 1985), “accidents on the level” (C.N.A.M., 1995), “falls” (Leamon and Murphy, 1995), “falls on the level” (Ballance et al., 1985), « underfoot accidents », i.e. accidents in which the first unforeseen event is an interaction between the casualty's foot and a support (Manning et al., 1988) or, again, “slips” (Gronqvist and Roine, 1993). This promotes a certain confusion, particularly concerning the nature of risk factors governing accidents on the level.

At INRS, efforts were initially directed exclusively towards preventing slips occurring inside premises. This work revolved around methods of measuring slip resistance of both safety shoes and floors (Leclercq, 1999a). The October 2001 Special Issue of *Ergonomics* magazine indicates that research into slip resistance measurement has been extensive and reports the proceedings of a symposium recently dedicated to this subject (Courtney et al., 2001). Whilst necessary, this work does not provide an adequate answer to preventing all accidents on the level, of which slips occurring on smooth, hard, greasy floors form a subset. Moreover, research revealed the necessity of focusing too, more generally on balance disturbance (Leclercq, 1999a).

INRS has integrated the topic entitled "Prevention of accidents on the level: case of balance disturbances in occupational situations" into its research and study program with the aim of providing other answers to preventing these accidents.

This paper proposes firstly a definition of the accidents relevant to the topic. After describing a number of obstacles to preventing these accidents, the INRS way to pose the problem will be described along with the two main lines to be developed in the research and study field: systemic analysis of contexts involving accidents on the level in occupational situations and study of adjustment strategies for confronting the risk of falling or balance disturbance in these situations. Finally, we refer to a number of methodological tools providing a short-term answer to the objectives of this topic.

## **2. Definition of accidents covered by the topic**

Everyone has an image of the accident on the level and it is perhaps partly because of this that these accidents are seldom subject to definition. Only Manning et al. (1988) provide a definition of the so-called "underfoot accidents" they studied: accidents in which the initial unforeseen event is an interaction between the casualty's foot and a support. These accidents are therefore not exclusively accidents triggered by the foot slipping on the ground; they can involve tripping or "twisting" of the foot. As in the case of slips however, this definition focuses on the initial unforeseen event, an interaction between the foot and a support.

Occupational accidents targeted within the scope of this project are accidents during which the balance of the casualty was unexpectedly disturbed during work not "performed at height". The casualty then recovered his balance or fell, sustaining injuries in both cases. Ground surfaces with or without changes in level, such as sidewalk curbs, steps or a slope, are considered. This definition focusing on

unexpected balance disturbance of the casualty “was motivated by both requests stemming from companies and research work. Aimed at preventing slips occurring on greasy industrial flooring, this research does not offer an adequate response to the concerns of companies, within which accidents on the level occur in highly varied circumstances. This work has also revealed the need to focus more generally on balance disturbance (Leclercq, 1999b). Consequently "Underfoot accidents" and, more generally, accidents during which the balance of an individual is disturbed are considered within the scope of this project. For examples, the case of an accident in which a person loses his balance when his wrench slipped whilst tightening a bolt or, again, cases of accidents in which a person strikes a component of the environment will be considered.

Initial research performed within the scope of this project involved analyzing in-company accidents on the level (Leclercq and Thouy, 2004) or serious accidents on the level taken from a database (Leclercq and Tissot, 2004). This work showed that accidents on the level occurring in occupational situations do not always result in the subject falling. Studies of in-company accidents on the level with or without days lost has revealed that casualties had rarely fallen (Leclercq et Thouy, 2004). This work led us to consider the concept of «balance disturbance" instead of “loss of balance”. These accidents are shown diagrammatically in figure 1.

An active individual is in a more or less stable state of balance. As accident accounts show that, irrespective of their extent, certain balance disturbances occurring during particular activities can cause unrecoverable loss of balance of the individual. This is indeed the case of the following accident taken from the EPICEA database (Ho et al., 1986): “ .....whilst tightening the last bolt, one of the wrenches slipped causing the casualty to lose his balance,..... ". Falling of an individual is also highly probable

when he walks onto a surface, whose slipperiness he has not anticipated, and when his shoe slips on the floor without any braking possible.

In these situations, the casualty produces a response “ often reflected by extensive movements of body segments in an attempt to regain balance. Although we encountered no cases in which the casualty had suffered injuries following heavy muscular contractions arising during these responses, such injuries could occur without collision with a component of the environment necessarily occurring.

In other cases, individual’s balance is not threatened. It can be said that it is disturbed inasmuch as there is unforeseen contact with a component of the environment, contact which causes a difference between foreseen and actual body movements. Indeed, it is this contact that can cause an injury. For example, we can quote the following part of an accident account: «....the person placed his foot on a stone while walking and sprained his ankle... ". Many accidents occur in this way in companies. The individual suffers a more or less serious sprained ankle and, in most cases, he has not fallen. Disturbance of his balance caused by the event of placing his foot on a stone, in a hole or on an obstruction when walking normally is too mild to cause him to fall, but nevertheless leads to injury. In the following accident account: “ ... the person struck a column, when walking.... ", it is also understood that the risk of falling is low if the individual walks normally. However, collision with a component of the environment can lead to injury.

The multi-factorial nature of accidents and the difficulties in modeling this phenomenon in all its dimensions mean that it is not possible of identifying comprehensively targeted accidents from a large number of accidents emanating or not emanating from a database. Whilst Anderson and Lagerlöf (1983) call into question the unicausal accident classification model, when explaining slip under-

estimation in national statistics, Lortie and Rizzo (1999), for their part, cite lack of conceptual definition in relation to loss of balance, when explaining the fact that falls are under-estimated by these systems.

### **3. Prevention of falls on the level encounters many obstacles**

Accidents involving falls on the level are perceived as frequent and minor. It is true that, in a company, they can constitute the majority of accidents without days lost, but they also represent a large proportion of accidents leading to days lost. For all companies belonging to the French national health insurance scheme, accidents on the level represented in 2001: 22% of occupational accidents with days lost, 21% of occupational accidents leading to permanent disablement and 23% of days lost due to temporary disablement (C.N.A.M., 2003). Analysis of falls on the level that occurred between 1998 and 2001 was conducted at a regional operations center for a major industrial company. In this center employing a workforce of approximately 500, these accidents were the most frequent, no less than 31% of accidents with and without days lost. After road accidents, it is accidents on the level that lead to the most days lost (Leclercq and Thouy, 2004).

Whatever the terminology used to describe these accidents, the literature leaves no doubt, in terms either of frequency or seriousness, as to the challenge represented by their prevention (Strandberg, 1983; Ballance et al., 1985; HSE, 1985; Leamon and Murphy, 1995; Leclercq, 2002). Neither research and studies nor in-company practices are capable of meeting this challenge. Several factors contribute to this situation and constitute as many obstacles to preventing these accidents. Firstly, even

if they occur when working, they are not considered as "trade-related accidents" and often only the behavior of the casualty is questioned. The risk of falling on the level is an accepted risk in relation to which safety practitioners remain unconvinced that they can do something and they have no specific tools for confronting the risk. Moreover, this risk is widespread; in other words, these accidents involve usually just one person. The impact is therefore less than that due to a rare accident with many casualties. The first challenge to be met in the area of preventing these accidents therefore involves providing objective data aimed at changing the general view on these accidents.

Occupational accidents are usually addressed by considering their specific component, which can be the task performed (e.g. accidents occurring during handling), the tool used (e.g. accidents occurring when using such machines), the working environment (e.g. accidents occurring on smooth, greasy floors or when noxious gases are present). With regard to accidents on the level, the common factor shared by these is balance disturbance, which is liable to occur in different environments, using various tools and when performing multiple tasks. They are therefore more difficult to apprehend. Methods suited to their analysis will therefore need to be acquired.

#### **4. The Problem of preventing accidents on the level in occupational situations**

Prevention of these accidents represents a challenge for both the individuals and the company. Little work in the research and study field and few in-company practices take up this challenge. The purpose of this section is to introduce key

components of the problem of preventing these accidents, as formulated by INRS. Firstly, analysis of the literature shows that a systemic approach to these accidents is relevant and that emphasis should be placed on improving interactions between the individual (who fulfills an adjustment role) and other components of the work situation. We will also highlight:

- the importance of pursuing two prevention field objectives: preventing balance disturbance and limiting injury seriousness, as well as,
- the need to characterize accident-causing situations as a whole.

#### *4.1. An accident on the level is a systemic accident.*

Let us consider the work situation described by Monteau (1974) as a system comprising four interacting components: the individual, the task he is performing, the equipment he is using and the environment in which he is moving (cf. figure 2).

Analysis of the literature on different risk factors influencing accidents on the level has shown that these factors are linked to all work situation components. Leclercq (2002) summarizes risk factors identified from accident analysis or the literature or, again, known factors likely to influence the occurrence of accidents on the level and their consequences. These risk factors reflect disturbances in one of the four interacting components (effect of age on balance mechanisms, for example) or in the relationships between work situation components (effect of familiarity or unfamiliarity with the environment on the individual's operation, for example).

#### *4.2. The individual is the system adjustment component*

It appears effectively that many risk factors reflect disturbances associated with interaction between the individual and other work situation components. We can give as an example:

- factors reflecting disturbed functioning of the individual due to performing the task. The activity can effectively prevent the risk of a balance disturbance being detected, for example because a load is carried or because attention focused on the task. The activity of the individual also affects balance stability (Grieve, 1983) and possible responses if balance is lost. The time constraint induced by the task can also influence individual functioning (Haslam and Bentley, 1999);
- factors reflecting disturbed functioning of the individual because of the working environment. Working environment design, congestion and organization has effectively an impact on the risk of balance disturbance (Albin and Adams, 1989; Fothergill et al., 1995; Kemmlert and Lundholm, 1998).

Design faults, maintenance shortcomings, inappropriate installation, as well as unsuitable tools and accesses, defective tasks structuring and absence of ergonomic consideration are all factors that are almost systematically invoked in the case of accidents on the level occurring in occupational situations. These aspects condition the individual's activity and the chance of detecting the risk. The literature is unanimous with regard to the priority these aspects should be given in the field of preventing accidents on the level at work (Albin et Adams, 1989 ; CNA, 1994 ; Fothergill et al., 1995 ; Pierdet, 1996, Kemmlert and Lundholm, 1998). Whilst the influence of individual factors, such as age, alcohol or drug consumption, on the occurrence of occupational accidents on the level can be questioned, the adopted systemic approach and the emphasis placed on interactions between different work

situation components appear more relevant and operational from a prevention standpoint than an approach focusing exclusively on individual factors.

#### *4.3. Two prevention field objectives: prevent balance disturbance and limit injury seriousness*

In figure 1, we can see that in some cases, the balance 's casualty is not threatened. For example, the individual walking at a normal pace, strikes a component of the environment (a column; a printer, a machine, etc.) or sprains his ankle. In other cases, the casualty loses then recovers or not his balance and sustains injuries most often when making contact with components of the environment. In most of the cases, injury seriousness depends on the casualty's immediate environment. An individual who has unexpectedly lost his balance will produce a response in order to regain his balance. At that moment, action causing injury is possible, even if there is a visible risk of injury. Accident seriousness will then depend on the presence of "aggressive" components likely to cause injuries. For example, we read in the following EPICEA database (Ho et al., 1986) extracts:

- " .... The casualty struck the pedal of the electropneumatic press and lost his balance. He first restrained himself by placing his right hand on the table, then in the tooling..... ";
- "..... The employee slipped, tried to stop himself falling and inserted his hand in the wetting system, in which there is a point of entry formed by two rollers belonging to this system.... ";
- " .... The casualty lost his balance, tried to restrain himself and his hand came into contact with the belts just when the compressor restarted.... ";

- " .... The casualty tripped on the case on the floor. He fell against the machine, actuating the pneumatic control for the press inflation membrane. His hands were then between the platen and the press....".

This is why within the scope of this project, we will research from in depth accident analysis, , not only actions aimed at preventing balance disturbance, but also those concerning the environment design aimed at limiting injury seriousness.

#### *4.4. Characterizing accident-causing situations by risk factor combinations*

Accidents on the level are seldom subjected to in-depth analysis. Actual analysis is often limited to the most obvious phenomena, which leads to general conclusions on the influence of factors such as carelessness, presence of obstacles, lighting and age. Each recommendation refers to an identified factor and, for all that, the many recommendations leave the prevention practitioner just as powerless when confronted by this type of accident. Two explanations can be advanced:

- these recommendations are both very numerous and highly general (cf. Leclercq, 1997, for example). They are difficult to put into practice because they are so general. Moreover, a company is not necessarily concerned by all the recommendations and prevention practitioners do not know which priorities to establish because these accidents are seldom analyzed in companies;
- these recommendations are not very convincing because they are based on eliminating only one risk factor. Take the example involving presence of obstacles or insufficient lighting. We can identify such risk factors in every company and yet, very often, they are not linked to accidents. When a risk factor is isolated, it contributes only very little to accident occurrence, but there is a high probability

of it being observed. It is a combination of risk factors that constitutes an accident-causing situation (Monteau, 1997a).

As a result, we will attempt, within the scope of this project, to extend in-company accident analysis and characterize accident-causing situations as a whole or by accident factor combinations. This work will allow us to propose a number of priority guidelines in the accident prevention field, for the company concerned.

## **5. Two main lines of research and study within the scope of this topic**

Considering the components of the problem stated above, research and studies conducted within the scope of this project are structured in practical terms around two main lines:

### *5.1. Systemic analysis of accidents on the level in occupational situations*

Emergence of different occupational accident prevention actions and their relevance depends on understanding in depth the sequence of events leading to injury. However, contexts involving accidents on the level in occupational situations are highly variable (Strandberg and Lanshammar, 1981; Kemmlert and Lundholm, 1998; Leclercq, 1999c; Leclercq and Thouy, 2004). Prevention of such occupational accidents is therefore likely to depend on actions as varied as design, maintenance and working environment organization, as well as equipment suitability to the task, operating cycle and procedure suitability or, again, general information to individuals.

Understanding accidents on the level in occupational situations depends on their in-depth analysis, which will not be limited to the most immediate phenomena (e.g. obstacles) and will consider all work situation components. This analysis will be conducted with the twin objective of not only preventing balance disturbance, but also limiting injury seriousness by researching possible actions likely to reduce environmental aggressiveness.

Each in-depth accident analysis allows one to isolate the events necessary to its occurrence and to derive options for action within the prevention field. Capitalization of these analyses can lead to causing a typology for these accidents to emerge, their circumstances being highly varied in occupational situations. Review and generalization of knowledge resulting from accident case studies will be sought. Several cases can effectively present similarities in their process and can lead to similar preventive measures. Accident causing situations will be characterized as a whole or through accident factor combinations.

### *5.2. Study of adjustment strategies to confront the risk of falling or balance disturbance in occupational situations*

Unlike other work situation components (cf. figure 2), the individual fulfills an adjustment role. He more or less consciously adopts a strategy that will allow him to keep his balance whilst performing his task according to situational constraints. Beyond the sequence of events leading to injury one should therefore try to understand the reasons for the unsuitability of the strategy adopted by the individual to keep his balance, in order to propose actions aimed at improving interactions between the individual and other work situation components.

Mechanisms involved in balance adjustment are complex. In particular, they integrate visual and physical interactions with the environment, the memory, etc.. Furthermore, task characteristics and requirements will influence resources devoted to keeping or recovering balance. Keeping balance or response to balance disturbance are global, complex and specific to the implemented activity, to the environment and, more generally, to situational constraints. This is why further study of adjustment strategies should be directed towards contexts representative of those in which occupational accidents on the level occur. There is abundant literature concerning balance keeping, although relatively few studies have been conducted in the field of fall prevention. In most cases, this research concerns normal walking and highlights the understanding of adjustment mechanisms in relation to inter-individual differences. Differences can be due to deterioration of sensorial perceptions resulting from age or various pathologies, for example. With regard to studies conducted within the scope of fall prevention, most research concerns the biomechanics of slips occurring when walking normally. These studies describe the biomechanical variables at the shoe/floor interface (Strandberg et Lanshammar, 1981 for example). Other studies deal with anticipating visually the risk of balance disturbance (Patla, 1991 for example) whilst others study recovery strategies following unforeseen balance disturbance, which can occur at different moments within the walking cycle (Eng et al., 1994 for example). Redfern et al. (2001) review what is known regarding the kinematics and kinetics of walking on surfaces under a variety of environmental conditions. However, the authors emphasize that, “it must be realized that the biomechanics are dependant upon the capabilities of the postural control system, the mental set of the individual and the perception of the environment.” The role played by cognitive factors is probably essential to balance disturbances occurring in

occupational situations. This role is not very well documented. Woollacott and Shumway-Cook (2002) evoke research into the relationship between attention and posture control as a new expanding field. The systemic approach adopted within the scope of this project and the emphasis placed on interactions between different work situation components require research into balance adjustments in occupational situations, in particular taking into account characteristics of both the task performed and the physical environment, as well as cognition-based adjustment of motor sensorial treatments.

## **6. Methodological tools**

Initial work performed within the scope of this topic involved analyzing accidents on the level. A first analysis was conducted on a sample of 459 particularly serious falls on the level taken from the EPICEA database (Ho et al., 1986). Statistical description and accident typology determination was carried out using SPAD data analysis software: variable characterization, multiple correspondence factorial analysis and hierarchical ascending classification (Leclercq and Tissot, 2004).

In-company studies are based on a smaller number of accidents (e.g. Leclercq and Thouy, 2004). They are conducted in large companies to capitalize sufficient accidents and information concerning them. Analyses are performed after the event and information used is available for accidents that took place during the last 4 years. This is to avoid distancing current reality (work situations evolve constantly) and to be able to collect maximum information on past accidents from its casualties.

This information is analyzed statistically (frequency indicator calculation, links between variables) to see whether, for example, certain populations are more affected by these accidents or certain times are more conducive to their occurrence. Typology for these accidents is then determined, based on the activity at the time of the accident and its location. Several accident-causing situations emerge from this process. Each situation is then analyzed in depth by means of interviews with persons, who were casualties in these accidents, and work activity observations. The causal tree method is applied to represent diagrammatically the logical sequence of events that led to injury (Monteau, 1997b). Scenarios common to several accidents are sought and priority courses in the field of preventing falls on the level, are derived for the company.

Methods used today within the scope of this project are not specific to analyzing accidents on the level. The project should also result in proposed analysis tools adapting existing methods or new methodological tools. It would be interesting, for example, to adapt the accident prototypical scenario concept, used in diagnostic studies of road accidents (Fleury and Brenac, 2001), to accidents on the level. These scenarios, close to accident concrete phenomena, are built up from several accident cases involving similar processes.

## **7. Conclusion**

Prevention of accidents on the level in occupational situations represents a challenge for both individuals and companies. Apart from general recommendations provided within the scope of prevention campaigns and very specific research into

preventing slips occurring on hard, smooth, greasy floors, prevention specialists remain powerless faced with these accidents. The literature reports few studies concerning analysis of circumstances of accidents on the level within a company and the different accident prevention options. Proliferation of these studies should enable the diversity of contexts or accident factors combinations involving accidents on the level to be better covered, the reasons for their occurrence to be better understood and knowledge about them to be capitalized in the search for scenarios that can be generalized. Initial analyses of in-company accidents on the level conducted within the scope of this project (Leclercq et Thouy, 2004) have revealed the diversity of accident-causing situations and the emergence of recurrent accident scenarios. Actions in the prevention field derived from understanding these accidents relate particularly, not only to the environment, but also to work organization. Certain observations can probably be generalized to other work situations. For example, the fact that it is when walking that people try to “save time” or “recover lost time “. However, it would seem that there is no recipe for preventing these accidents and that an analysis approach is a prerequisite to this prevention. Development of such an approach appears to us premature and post-event accident analyses necessary, given the limited knowledge concerning the sequencing of injury-causing events.

Many different factors are likely to have an impact on balance adjustment strategies adopted by individuals. Consequently, better knowledge of circumstances involving accidents on the level in occupational situations will enable research into balance adjustment strategies to be directed towards contexts representative of those in which accidents on the level occur at work. Proposed actions designed to improve interactions between the individual and other work situation components could be derived from this work.

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Figure 1: diagrammatic representation of injuries resulting from balance disturbances. Here, the notion of balance disturbance does not necessarily mean that balance is threatened. A collision or sprain may be involved.

Figure 2: work situation model. 4 interacting components: the individual, the task performed, the equipment used and the working environment, in which the individual moves.



