INTRODUCTION OF ERGONOMICS AND COMFORT IN THE SELECTION OF PERSONAL PROTECTIVE EQUIPMENT (PPE); CONCEPTS FOR A NEW APPROACH

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Abstract

This paper describes an initiative to integrate aspects of ergonomics and comfort into a selection system for personal protective equipment (PPE). Selection criteria intended for PPE mainly focus on the efficiency of chemical protection to reduce respiratory and skin exposure. However, the efficiency of PPE is not exclusively determined by the protection aspects of respiratory protective equipment (RPE) or skin protection equipment (SPE), but it is also dependent on the suitability of devices for actual work situations. Aspects associated with the individual worker (*e.g.* anthropometrics), the task (*e.g.* work load) and the work environment (*e.g.* temperature and humidity) are often neglected and do not form an integrated part of a selection system. This paper provides a generic concept for a RPE and SPE selection system that intends to translate the conditions of use to objective evaluation points, and subsequently link these with the features of the PPE. By categorising and scoring different ergonomic and comfort aspects associated with the wearing of PPE, the system systematically incorporates the conditions of use into a risk-driven selection process. Based on a literature review, seven), respectively three main groups of ergonomic- and comfort factors were identified for RPE (respirators) and SPE (gloves). Semi-quantitative or subjective evaluations of the work situation were used to assign values to the “task relevance” factors, whilst “PPE performance” aspects were derived from literature or manufacturers. By means of a simple scoring system an overall evaluation could be made, where PPE can be prioritised by distinguishing between ‘less suitable’ types or brands (negative end-score) and ‘suitable’ types (zero end score).

This conceptual model needs to be developed further in order to construct a selection tool. Further developments include the refinement of the task analysis and an upgrade of the PPE performance data for the factors identified.

Introduction

It is generally assumed that the 'overall' effectiveness of personal protective equipment (PPE) is determined by the ability of the PPE to retain workplace contamination, *i.e.* the 'technical' protection provided, as well as the conditions of use in the workplace, *i.e.* the human factor. During Technical Meetings of the European Chemicals Bureau (ECB) two key issues related to PPE and exposure to chemical were identified, *i.e.* proper functioning and proper use (Doc. ECB4/32/98). Proper functioning implies that PPE should be designed and tested to ensure reproducible and quantifiable reduction of exposure. Chemical protection in workplace conditions is determined by an assessment of the toxicological properties of a substance or product (hazard), the exposure level of the chemical and the protection factor of a PPE device or brand. Protection factors are assigned for various RPE designs based on field studies that have been conducted to assess workplace protection factors (WPF), as reflected in US and UK standards (ANSI, Z,88.2,1992; BSI, BS 4275, 1997). For SPE no such protection factors have been assigned, hence the effectiveness of chemical protective equipment is derived from laboratory test data on chemically integrity, *e.g.* degradation, or data on permeation or penetration.

In addition, proper use criteria are vital to ensure that PPE is both suitable and fitting for a given work task. Moreover, wearers should be instructed and trained in the proper use and maintenance of PPE.

In the past, the emphasis was often placed on the 'efficacy' during PPE selection, and little attention has been given to the ergonomic and comfort aspects associated with the wearing of PPE. Until now, a systematic approach to incorporate ergonomic and comfort aspects into a selection system is lacking. This paper describes an initiative to develop such an approach, and to optimise the protection of individual workers during performance of their individual tasks.

Methodology

The selection system presented here incorporates the current decision logic used for the selection of adequate types of RPE and SPE. First, ergonomic and comfort factors are selected that are relevant for performing tasks and that are known to be affected by the use of PPE. Our basic assumption is that the use of PPE limits a worker's task performance and comfort compared to a zero-situation, *i.e.* a non-PPE use scenario.

Therefore, we only consider PPE types that are the least uncomfortable and the most compatible with a specific task.

The following criteria are considered relevant for the actual selection of the most appropriate PPE.

- task: what tasks must be performed by the worker, and what are the requirements in terms of vision, mobility and reach, dexterity, communication etc.

- work environment: under what environmental conditions must the task be performed.

- worker: this category includes workers dimensions, and personal aspects such as use of glasses, allergies etc.

The selection strategy applies the criteria given above to systematically select PPE in two consecutive steps: (1) *ergo-comfort* selection to determine the suitability of a type of PPE for a given work situation and 2) *personal fitting selection* to establish how fitting the PPE is (or tailored to the wearer in question; this may involve a field-test and try-out in practice).

All reported ergo-comfort factors obtained from literature studies were categorised and clustered in main categories (Goede et al., 2001, Brouwer et al., 2002). For the RPE selection system seven major categories could be distinguished, whereas for the SPE system three categories were identified (tables 1 and 2, respectively).

Table 1 Principal categories of ergo-comfort factors for respirators

Main category	**Example of factors**
Vision	Visual field Visual acuity
Communication	Audibility of users’ speech Users’ hearing
Respiration	In/ exhalation CO_2-retention
Physical task performance	Mobility Body posture Dexterity/ stability/ precision
Environment	Heat stress/ Cold

	Other hazards
Comfort	Overall-fit (skin, eyes, head) Put-on, removal Combination with other PPE
Mental	Responsibility, stress

Table2 Principal categories of ergo-comfort factors for protective gloves

Main category	**Example of factors**
Biomechanical	Grip Force
Task performance	Precision/ dexterity Mobility Fit
Comfort	Thermo-physiological Put-on removal (Fit)

The level of relevance of the factor is divided into three categories of 'work task relevance scores' ranging from low priority to high priority. Similarly, PPE device or equipment was categorised into three categories of 'performance scores' ranging from slight hindrance to severe hindrance. Assigned values of the categories are according to a log scale, *i.e.* 1, 3 and 10 (table 3). For each factor the work task relevance score is subtracted from the performance score. All end-scores equal to or above zero are set to zero. The overall outcome of the scores gives an indication of the 'suitability' of the PPE, *i.e.* negative end-scores indicate the level of unsuitability of the PPE to perform the work task.

Table 3 Overview of scoring and weighing method

Factor (i-j)	**Work task relevance**	**W-score**	**PPE performance**	**P-score**	**Endscore**

I	Very relevant	10	Slight/ no hindrance	10	PS_i-WS_i
	Relevant	3	Moderate hindrance	3	
	Not relevant	1	Severe hindrance	1	
j	Very relevant	10	Slight/ no hindrance	10	PS_j-WS_j
	Relevant	3	Moderate hindrance	3	
	Not relevant	1	Severe hindrance	1	
Total					$\Sigma_{I,j}(/n)$

The last evaluation step addresses both the individual workers' (antrophometrical, such as facial, hand) dimensions, as well as personal aspects such as use of glasses, allergies, etc. As a final component of the system, it is recommended to give the user an opportunity for a try-out of the PPE-type during an actual trial run.

Ergo-comfort factors

For respirators many factors have been identified that are considered relevant to evaluate the degree of hindrance and the ability to perform the task. Factors associated with physical parameters (*e.g.* heat stress, breathing resistance, moisture, noise) has been quantified for several types of respirators. Most research emphasises the importance of (thermo) physiological effects. Examples of methods to evaluate respiratory performance are listed in table 4.

Biomechanical parameters such as angle of affection, grip patterns, etc., have been identified as relevant to characterise hand and finger movements. No readily available field methods are known to evaluate related factors such precision and dexterity, force, grip and mobility for a specific task either quantitatively or qualitatively. For experimental evaluations of grip and force, however, quantitative methods are used. Research in this field mainly focuses on the hindrance caused by the use of protective gloves or clothing. Examples of methods to evaluate glove performance are also listed in table 4

Table 4 Examples of methods to evaluate the performance of RPE and SPE

PPE-type	Factor	Method
RPE	Visual field	Apertometer

	Breathing resistance	Breathing simulator; controlled negative pressure
	Comfort	Comfort Perception Evaluation Questionnaires
		Temperature/ moisture sensors
GLOVE	Grip/ force	Dynamometer/Force-meter
		Grip contact-strips
	Precision/ dexterity	Purdue Pegboard test
		Minnesota rate of manipulation placing
		Time test(s)
	Mobility/ reach	(electro) Giniometer
		Slide-ruler
	Comfort	Comfort Perception Evaluation Questionnaires
		Temperature/ moisture sensors

Discussion and conclusion

The concept presented here forms an initiative to integrate ergonomic and comfort aspects into a PPE selection system. The actual translation and quantification of the work task and work environment, and the PPE 'performance' for each ergo-comfort factor depends on scientific evidence, and has to be worked out in more detail. No scientifically-sound work task analysis is available to evaluate the 'relevance ' of ergo-comfort factors for the work situation. Hence, major parts of the assessment will be based on subjective estimates. In addition the availability of data on PPE(type) 'performance' (*i.e.* the level of hindrance) is very limited and might be a key factor for further development. Another major challenge is the development of justifiable classification bands for each ergo-comfort factor. An important aspect to keep in mind during the system development is the time factor, because the perception of comfort is largely dependent on the duration of use of PPE.

In conclusion, it can be stated that relevant and identified ergo-comfort factors have been clustered in such a way that these factors can be addressed systematically during selection of appropriate PPE for chemical protection. Such an approach could be helpful to improve acceptance of PPE by the worker and, consequently, significantly increase the efficiency of protection afforded by PPE in the workplace.

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