"Ergonomic" standards in biomechanics

An examination of the draft standard on repetitive movements (prEN 1005-5)

Introduction

European standards (EN) that cover ergonomics issues under directive 98/37/EC – the Machinery Directive – are developed by the European Committee for Standardisation's (CEN) Technical Committee TC 122.

The ETUI-REHS' Health and Safety Department is an associate member of CEN. This European trade union participation comes out of the European trade union movement's aim to see free market principles balanced out by social and environmental imperatives.

European trade unions demanded that freedom of movement – of work equipment in this case – be compensated by a high level of protection for workers, which they are now working to monitor through organising and leveraging the feedback of information on user experience.

The Machinery Directive is the cornerstone of the New Approach standardisation process[1]. That process is kept under review through the ETUI-REHS's active participation in meetings of the working group of the Standing Committee for Machinery Directive 98/37, in the work done by CEN Technical Committees TC 114 "Safety of machinery" and TC 122 "Ergonomics", and through the ETUI-REHS's comments and policy positions on standards that affect workers' health and safety. For TC 122 specifically, the ETUI-REHS is actively involved in Working Groups WG 2 "Ergonomic Design Principles" and WG 4 "Biomechanics".

This article reviews draft standard prEN 1005-5 on repetitive movements, from the two angles of our collaboration in CEN's work, and the European debate on preventing work-related musculoskeletal disorders.

WG 4 has for several years been developing "ergonomic" standards on biomechanics. These include all five EN 1005 standards that apply to **human physical performance** in connection with the **safety of machinery**, namely:

- EN 1005-1:2001 – Terms and definitions
- EN 1005-2:2003 – Manual handling of machinery and component parts of machinery
- EN 1005-3:2002 – Recommended force limits for machinery operation
- EN 1005-4:2005 – Evaluation of working postures and movements in relation to machinery
- prEN 1005-5 – Risk assessment for repetitive handling at high frequency

The European environment

Poor working conditions compound the physical strain of work, and this takes an additional physiological toll – musculoskeletal, metabolic and psychosocial, amongst others – on workers. Our response to the European Union's (EU) recent social partner consultation and our article on this matter in the June 2005 *HESA Newsletter*[2] give an account of these work-related problems and possible ways of addressing them.

Musculoskeletal disorders (MSD)[3] and the consequences of work-related stress are the top two complaints voiced by workers in the Dublin Foundation's successive surveys.

European workers complaining of:

■ Back pain	33%
■ Generalised fatigue	23%
■ Muscle pains in:	
- neck and shoulders	23%
- upper limbs	13%
- lower limbs	12%

Source: Dublin Foundation[4]

In the United States, where the business costs of work-related diseases are calculated in forensic detail, concurring analyses[5] point to MSD being a major cause of absenteeism and a major aggregate cost burden on company budgets. It can be inferred from the available epidemiological data that the situation in the EU is similar, but the cost is split between governments, through social security schemes, and business[6]. There is little incentive for the least responsible European employers to improve employees' conditions, as mutualized intervention by social security schemes tempers the harmful effects (especially MSD and stress) of their mismanagement of working conditions: this "law of unintended consequences" might be avoided if their civil liability were to be more often challenged in the courts…

MSD is a problem of epidemic proportions, and steps have been taken to try and halt the spread. Biomechanical standards are one potentially important way. These Machinery Directive standards are meant to enable machinery designers not to develop machines that cause MSD. Sadly for workers, the scope of standardisation under the Machinery Directive stops short at the machine as a piece of kit.

[1] See: http://europa.eu.int/comm/enterprise/newapproach/index_en.htm.

[2] See: "Musculoskeletal disorders: where we are and where we could be", *HESA Newsletter*, No. 27, June 2005, p. 22-27.

[3] All joints: trunks and limbs.

[4] *Third European survey on working conditions 2000*, Dublin, European Foundation for the Improvement of Living and Working Conditions, 2001. Downloadable from www.eurofound.eu.int/ewco/surveys/index.htm.

[5] "Almost six million injuries happen in the workplace each year, costing over 60 billion dollars in lost wages, healthcare expenses, legal costs and worker's compensation claims, according to the AAOS. The majority of injuries resulted from over-exertion, repetitive stress injuries and falls in the workplace". American Academy of Orthopaedic Surgeons (AAOS): 31 August 2002.

[6] European businesses bear only part of the costs of the MSD that they create (essentially indirect costs), leaving State social security systems to foot most of the bill for MSDs that stem from physiologically unfavourable working conditions.

Trade union issues in ergonomics standards development

The plain fact is that the scope of ergonomics standards development is restricted by Machinery Directive 98/37 and, within that specific framework, by the mandates that the European Commission hands to CEN: the physical limits of machinery strictly circumscribe the development of ergonomic standards by TC 122. For ergonomists, this strict limitation of the coverage and applicability of ergonomic standards distorts the approach from what it should be – participatory, holistic and multidisciplinary. In the ergonomist's view, ergonomics standards development will be always too narrow.

This restriction of the ergonomic approach creates a clear, widening gap between the limits of machinery and its use in the overall setting of where it is sited. In fact, ergonomic standards under the Machinery Directive do not sufficiently protect workers[7] against the potentially harmful effects of use, which runs from the putting in place of the machinery, through all stages of its life and interaction with workers, to its dismantling. The operator is factored in, if at all, only for that part of his activities directly connected with use of or an intervention on machinery. In other words, the machinery designer can leave out all the shortcomings that stem from the machinery being included as part of a more complex production system, because that is not a Machinery Directive issue, but one under the Framework Safety and Health Directive (89/391) and the individual directives adopted under it[8].

This major, and particularly vexed, issue in the debate, therefore comes into play when the standard is being framed, the aim being to try and maximize the "operator" aspects in it, without compromising the future standard's potential for becoming a harmonised standard which will confer on machinery designed to its guidelines a "presumption of conformity to the Machinery Directive". The boundaries of this balancing act are dictated by the limits of the machinery.

The ergonomic approach in standards development

The ergonomic approach in framing machinery design standards consists of the following stages[9]:

- determination of the limits of machinery;
- hazard identification;
- risk estimation;
- risk assessment.

In this approach, determination of the limits of machinery relate to:

- the phases of machinery life: intended use but also assembly, dismantling, cleaning, maintenance, repair, etc;
- the limits of machinery, including the intended use, and the consequences of reasonably foreseeable misuse or malfunction;
- the foreseeable uses of the machinery by different classes of people (sex, age, dominant hand usage, etc);
- the anticipated level of operator training;
- the exposure of other persons to the reasonably foreseeable hazards of the machinery.

Factoring biomechanical risk factors into standard development (prEN 1005-5)

Draft standard[10] prEN 1005-5 offers machinery designers a two-stage method for "risk assessment for repetitive handling at high frequency", in line with the 1005 series of standards on "human physical performance".

Purpose and characteristics of the draft

Draft standard prEN 1005-5 concerns handling operations repeated at high frequency within the entire life cycle of a machine from its construction to its dismantling. The factors of duration and lack or absence of recovery time are not included in the standard. It concerns only the upper limbs, and not the neck, back (in fact, the trunk) or lower limbs, all of which are expressly excluded from the draft.

The future standard sets out to guide machinery designers first towards avoiding risks related to repetitiveness of movements. If this risk cannot be avoided, the designer is referred to the four-step approach described in Guide ISO 51 and standard EN 1050: (1) hazard identification; (2) risk estimation; (3) risk assessment; (4) risk reduction.

The key concepts specific to this standard are:

- **Repetitive task:** task characterised by repeated work cycles.
- **Work cycles:** sequence of technical actions that are repeated always the same way.
- **Technical action:** elementary manual actions required to complete the operations within the work cycle, such as holding, turning, pushing, cutting (note that the standard does not deal as such with the elementary movements that make up these actions).

Contents of the standard

The standard offers two methods, organized into two successive stages, one simple, the other detailed:

1. The simple method enables the designer to check the absence or presence of risk factors for each upper limb, and to move on to method 2 (detailed) if any are found.
2. The detailed or OCRA (OCcupational Repetitive Actions) method requires the designer to assess a series of risk factors by weighting them by multipliers which will enable him to calculate an OCRA index. The index value will indicate the acceptability or otherwise of a risk related to machinery whose design involves repetitiveness.

[7] User / operator / worker means a user of the machinery who is not the purchaser (firm X who buys and uses machine Y). It is the end user who is the main focus of concern, relating not only to the intended use of machinery but also foreseeable misuse (intended misuse), which the risk assessment must also take into account.

[8] The Machinery Directive is meant to achieve complete harmonization based on Commission proposals to ensure a high level of consumer and environmental protection (article 95 of the Treaty). This means that Member States must implement the Directive through measures to achieve exactly the objectives set, and cannot introduce rules that would provide a higher level of health or environmental protection other than as permitted by article 95. Framework Directive 89/391, by contrast, lays down minimum requirements, which means that States can introduce measures that give workers a higher standard of protection.

[9] See standard EN 1050:1996.

[10] The words "draft standard" and "standard" are used interchangeably.

The risk factors analysed are:

- Repetitiveness, which is central to the evaluation. The approach is based on B. Silverstein's definition[11]: *cycle time < 30 S or > 50% of the work cycle.*
- Frequency of technical actions: *< 40 technical actions per minute.*
- Forces whose recommended force limits are based on EN 1005-3.
- Awkward or uncomfortable postures and movements.
- Additional specific factors such as:
  - characteristics of the object handled;
  - vibration and impact forces;
  - environmental conditions;
  - individual and organisational factors;
  - durations and recovery times.

Restrictions and limits of the method:

- it applies only to simple working tasks (mono task);
- it applies only to upper limbs other than the neck/shoulders system, whose dynamics and physiology cannot be entirely dissociated from those of the arms, forearm and hands;
- it treats different joints that perform elementary actions (taking, holding, turning, etc) identically by applying the above criteria to them.

State of play on prEN 1005-5

The text is at the top of WG 4's agenda; it is in the final stage of development, but has suffered a series of setbacks over the years, most recently the CEN consultant's questioning[12] of whether it can be considered as a future harmonised standard, and his recommendation that it be given the status of a "technical document" i.e., not standard-setting. By contrast, the survey of CEN Member States finds more than 75% in favour of accepting the document as a future standard.

Where do the problems lie?

Both the CEN consultant and the Member States acknowledge the need to assess the risks related to high frequency repetitive actions when machinery or its components are being designed.

The purpose of the standard is not what is in question, therefore, but its contents because:

- not all the reference criteria are included in the standard, which means having to go back to the literature (which goes against the *standalone* principle of technical standardisation);
- the method proposed is too complex, it is not a "simplified" method that makes it possible to check whether the risk exists;
- there are gaps in the scientific evidence (acceptable frequency limits for the different joints concerned), and – proven (accepted) – evaluation criteria are not currently available;
- there is an over-emphasis on user-related requirements;
- the method is incomplete because it excludes the neck/shoulders system among other things, and takes no account of either mental aspects or working conditions (organisation);
- there is a limited consensus on the use of the OCRA method.

Where do we stand?

We want to stop MSD developing in the first place. In terms of a preventive strategy, that means eliminating MSD risk factors from the design of machinery or any other work system in order to prevent that machinery or system from producing harmful effects for the worker, the work environment or, more generally, anyone at all.

Even more to the point, we are deeply concerned about the harmful effects of repetitive work. These effects may be musculoskeletal, but also mental and social, and are copiously documented in a scientifically coherent and statistically significant way in the available literature. The risk factors that characterise repetitive work therefore need to be dealt with at a very early stage in order to eliminate them as far as possible[13] from the design of work systems. We therefore see any instrument that enables the designer of machinery (or of one of its components) to identify, estimate and eliminate a risk of repetitive work at the design stage as being a real asset.

Prima facie, we welcome the benefit that a standard on this matter would bring[14]: if the problem of repetitiveness is eliminated, the likelihood of having to deal with it later on is gone, which will also make the prevention time freed up available to get a better grip on other risk factors.

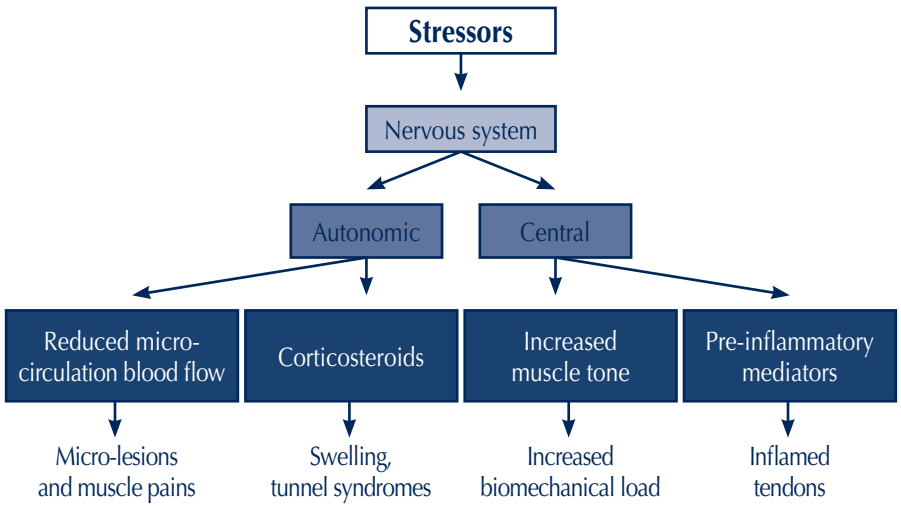
Finally, no "golden standard" for the prevention of musculoskeletal risks has been developed yet as far as we know, and conclusive quantitative criteria are not always available, which calls forth the following observations.

1. There may not be a "golden standard" available, but we could settle for the best currently available approach, and leverage its use to develop and gradually improve it. The argument does not therefore stand up alone.

2. The user-friendliness of analysis methods and the standards that propose them is a key criterion. The OCRA method, used here, is complex and quite unwieldy. It requires special training and is time-consuming to implement. Its designers are currently trying to produce documentation and automate the calculations by turning the method into a more workable computer program that may address some of the complaints levelled against it.

3. Some of the frequency criteria proposed to distinguish "highly repetitive" from all other movements are debatable because they are applied without distinction to different joints; however, some fine-tuning could probably be done here through future versions of the method. This is not

[11] Operational definition for epidemiological studies (Silverstein *et al.*, 1986).
[12] The CEN consultant's judgement is based on the merits of the draft as a future standard, the linkages with the Machinery Directive's essential requirements, and the quality of the technical information.
[13] By reference to the state of the art in technology, the overriding need have repetitive tasks done by a man/woman because there is no other alternative, and they cannot be automated. In other words, because the human factor is an irreplaceable added value in and of itself.
[14] Bearing in mind, however, that it is a relatively weak because non-binding instrument.



an undue concern, but does enable the two following points to be developed: one concerning the need for measurement, the other on the holistic approach to MSD.

4. Does credibility, or factoring the MSD risk out of work system design, depend on being a numbers game? A blinkered measurement focus can bring its own risks[15]. On the other hand, criteria with which to distinguish the "highly repetitive" from the rest are certainly needed. Let us be clear about this: we believe that simple observation of movements or those of the production capacities of machinery with a human interface can enable an opinion to be given on the presence (as opposed to the absence) of highly repetitive movements without the use of sophisticated measurement techniques provided the discriminators are specifically known for the different joints[16] concerned and the conditions of observation are good.

5. The holistic approach to musculoskeletal risks cannot be limited to the observation of frequencies, because the risk factors are more complex by far. An exhaustive list is outside the scope of this article, but the main categories are listed below.

Mechanical and biomechanical risk factors in the strictest sense

1. Interface characteristics:
   - quality and comfort of coupling points;
   - temperature;
   - force transfer to and from the object.

2. Characteristics of demands, movements and postures:
   - weights of the objects and/or tools handled;
   - static or dynamic character of demands:
     - movements performed
     - postures adopted
     - joints used
     - movement ranges
     - repetitions (cycle time)
     - time-bound variability of repetitions
   - length of exposure;

3. Presence of hand-arm or whole-body vibration.

Movement/handling-related sensory and cognitive requirements

1. Specific sensory requirements (sight, hearing, touch, etc.) and/or precision work (increased static load).
2. Specific cognitive requirements: complex movements with multiple choice options, non-compliance with movement stereotypes (acceleration, incrementing, movement direction, etc).

Work environment-related requirements

Biomechanical factors may be the principal causal agents of work-related MSD, but restricting prevention to them alone is misguided: there is a wide consensus of evidence in the scientific literature that all points towards organisational, environmental and psychosocial factors being major contributors to the occurrence of MSD or, conversely, to preventing them if properly managed.

The classification of risk factors into physical and other factors (organisational, psychosocial, environmental) is an artificial distinction that over-simplifies the understanding of causal mechanisms by distorting the overall or holistic approach advocated by ergonomists.

For example, precision work will require one kind of muscle work to ensure limb stability (placing), and at the same time, another kind of muscle work to enable the same limbs to perform precision micromovements. This demand increases muscular tension and conflicting demands on the musculoskeletal system, and constitutes a stressor (stress factor), i.e., it turns into a mental stressor.

By contrast, neurophysiology offers a ready explanation for how stressors[17] can cause MSD where there are no typified biomechanical stressors present (see diagram) or where biomechanical stressors are particularly low (the "Cinderella fibres" scenario) as with computer work.

[15] If there is an accident risk that can be immediately overcome – such as a hole in the ground where someone could injure themselves – does it necessarily have to be measured before deciding to act, or can immediate preventive measures be taken on the evidence of gross observation alone?

[16] These critical frequencies are not identical for fingers, wrists, elbows, etc.

[17] Stressors here meaning risk factors for work-related stress.

■ **Organisational and psychosocial risk factors:**
- role conflict;
- conflict between prescribed work and tasks actually done;
- too little skill discretion and reduced scope for manoeuvre (organisational, temporal and/or spatial);
- unpredictability of operations (rush or unexpected jobs);
- time pressures (just in time, lean production);
- new stressors following an attempt at remediation through job rotation (job enlargement, job enrichment), e.g., qualitative stressors and customer-/patient-facing work, etc.;
- productivity pay (piece-rates, production bonus).

■ **Environmental and workspace-related risk factors:**
- accessibility: of work locations, control devices; reaching distances; lifting and lowering distances; angles of vision;
- movement-related risks: slipping, stumbling, falling;
- noise;
- air quality, cleanliness and hygiene of facilities: chemical, biological, infection and other risks;
- accident risks: fire, explosion, burns, cuts, etc.

Conclusion

Standards are one instrument that can help prevent MSD, but we must be under no illusion about their scope – they are voluntary, and go no further than the strict physical limits of machinery, at least not those under the Machinery Directive. Voluntary or not, however, harmonized standards find considerable favour with the public authorities: e.g. presumption of conformity to the Directive and market access.

Draft standard prEN 1005-5 on highly repetitive movements applies only to a very small part of the musculoskeletal system, in this case, the upper limbs excluding the shoulders and neck. As a result, the standard's impact and contribution to MSD prevention can clearly only be judged in terms of this restricted area of the anatomy.

The future standard could play into the prevention of MSD, but only if that prevention is organised as a coherent whole of which technical standardisation is one part.

The European trade union movement, responding to the social partner consultation carried out by the European Commission, called for prevention of MSD to be made the focus of a resolute policy to tackle MSD at source based on tried and tested prevention principles like those offered by contemporary ergonomics, and instruments dedicated to preventive action, including in small and medium-sized, and very small firms.

Any addition to this preventive structure that works towards promoting health and safety for workers, and more specifically helps, if not to defeat then at least stem the epidemic spread of MSD, is welcome. ■

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