This is the published version of a paper published in .

Citation for the original published paper (version of record):

Rose, L., Eklund, J., Nord Nilsson, L., Barman, L., M Lind, C. (2020)
The RAMP package for MSD risk management in manual handling – A freely accessible
tool, with website and training courses
*Applied Ergonomics* 86
https://doi.org/10.1016/j.apergo.2020.103101

Access to the published version may require subscription.

N.B. When citing this work, cite the original published paper.

Permanent link to this version:
http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-271904
The RAMP package for MSD risk management in manual handling – A freely accessible tool, with website and training courses

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1. Introduction

1.1. Background

In this paper, the challenges of creating sustainable work environments by reducing the exposure to risk factors related to manual handling at the workplace are addressed. There is an increased pressure on organisations and societies to create sustainable working conditions (UN, 2018). One area in need of attention is the risk management processes targeting decrease in musculoskeletal disorders (MSDs) as they constitute 40% of the global compensation costs of occupational and work-related diseases in the EU have been estimated to 3.3% of the gross domestic product (Tan et al., 2017). At the societal level, the costs of occupational injuries and work-related diseases in the EU have been estimated to 3.3% of the gross domestic product (Tan et al., 2017). To address this, much effort has been invested in reducing MSDs, including e.g. development and application of risk assessment tools (Takala et al., 2010; Lind, 2017). However, the prevalence and costs of MSDs remain high.

One of several limitations of most of the existing physical ergonomics risk assessment tools is that they do not support the whole risk management process, including systematic support of developing risk reducing measures and follow-up audits as described in ISO 31000 (2009). This may limit their potential contribution to risk management. Other limitations include that the tools often only target single body regions such as the upper extremities (the Revised Strain Index, Garg et al., 2017), or are only applicable for certain types of work operations, such as lifting operations (the Revised NIOSH Lifting Equation, Waters et al., 1993). However, most jobs include a range of different types of operations and induce hazards to multiple body regions. Generally, existing tools lack a comprehensive assessment of the risks for developing MSDs. Consequently, several tools are frequently needed to conduct a comprehensive assessment (Roman-Liu, 2014). However, applying different tools may produce incompatible results (Chiasson et al., 2012), which could hamper decisions for prioritisation of risk reduction measures within an organisation and may hinder comparisons between company sites when different tools are used. Furthermore, many of the assessment tools that target manual handling do not, or only partially, address organisational factors (Macdonald and Oakman, 2015) and psychosocial factors (Joksimovic et al., 2002), despite the...
growing evidence of the association between psychosocial, organisational factors, as well as individual factors (Dianat et al., 2015) and MSDs. Additionally, some tools lack a scientific rationale, e.g. WEST (Karling and Brohammer, 2002) and in-house developed risk assessment methods as described by Nordlander (2006), or have low reliability (Takala et al., 2010). Further, for some tools, e.g. Jack (Siemens, 2019), the use is associated with relatively expensive licence costs and requires high technical competence which may limit their use by practitioners (Perez and Neumann, 2010).

Thus, there is a gap between users needs and the accessibility and usability provided by currently available tools. The need for a comprehensive and easy to use tool that supports risk assessment and risk management has been identified in: the literature (e.g. Macdonald and Oakman, 2015), by the ISO (31000:2009), and within organisations in e.g. the manufacturing industry (Rose et al., 2011). Additionally, employers in the EU are, according to EU directives (European Union, 1989, 1990), required to organize measures so that manual handling is avoided, and if not, the risks need to be assessed and reduced as much as possible. The focus of this paper is to show how users’ needs of an accessible and comprehensive tool, including a method for risk assessment and risk management can be met. The intention is to facilitate the application of RAMP to manage MSD risks in a systematic way, and thereby contribute to the reduction of MSDs globally. In the following section, an overview of the RAMP tool (Risk Assessment and Management tool for manual handling Proactively), including how it was developed, is presented. Then, the method for the development of the Action module in RAMP and the strategies for making RAMP accessible globally are described. The RAMP tool, and the strategies for disseminating and strengthening its usefulness, are referred to as the RAMP Package and include the RAMP tool, the RAMP website, and open online training in systematic risk management with the use of RAMP.

1.2. The RAMP tool

The development of the RAMP tool was carried out in close collaboration between researchers and practitioners at companies, using an iterative (Martin et al., 2008), participative (Wilson, 1991) methodology (Rose et al., 2011; Lind and Rose, 2016; Lind, 2017). Several studies related to particular aspects of the development and use of the RAMP tool have been published. The research base for the recommended risk and priority levels (RPLs) included in the tool and the development of the tool are described in detail for RAMP I in Lind et al. (2019) and for RAMP II in Lind et al. (2020). In addition, Lind (2018) described the development and evaluation of the model in RAMP II for assessment of pushing and pulling work, which constitutes one of the risk categories in the RAMP tool. Lind and Rose (2016) focus on the Results module and on visualising and communicating results of risk assessments, while Lind (2017) focuses on RAMP I and RAMP II, and observation-based risk assessment tools.

RAMP prototypes were developed based on needs analyses, which identified the tool requirements, and in addition, literature studies. The RAMP tool was based on over 250 research publications and feedback from more than 80 practitioners. The RAMP tool was tested regarding its reliability, validity and usability (Sandahl, 2013; Sandblad, 2015; Holm, 2015; Håkansson, 2015; Lind and Rose, 2016; Lind, 2017, 2018; Lind et al., 2019, 2020). The version of the RAMP tool launched in 2017 integrates research findings from epidemiological, biomechanical, physiological and psychophysical methodologies as well as assessment criteria from Global and European Ergonomics standards, and provision from the Swedish Work Environment Authority. Throughout the development process, user evaluations of prototype versions of the RAMP tool were performed by ergonomics experts and practitioners to test its usability. These experts and practitioners included researchers, ergonomists, occupational health services (OHS) personnel, managers and production workers. Furthermore, user tests with ergonomists and other OHS personnel, safety delegates, operators, team leaders, production engineers, and managers were performed. The feedback provided by local and global companies within the food manufacturing, vehicle manufacturing, and transportation sectors, Swedish labour market parties, and the Swedish Work Environment Authority gave input regarding various stakeholders’ needs (Lind, 2017).

The RAMP tool consists of four modules: RAMP I, RAMP II, the Results module and, the Action module (Fig. 1). Together they support the whole MSD risk management process from identifying and assessing risk factors, supporting presentation and communication of results and the development, implementation and follow-up of risk reduction measures (Table 2). RAMP I and RAMP II include seven risk categories: “Postures”, “Work movements and repetitive work”, “Lifting work”, “Pushing and pulling work”, “Influencing factors”, “Reports at the company on strenuous work”, and “Perceived physical discomfort”.

RAMP I is a checklist for screening of potential MSD risks. Responses to the assessment items are dichotomized (‘Yes’ and ‘No’) answers and the assessment results are presented with a three-colour coding regarding the RPLs (Fig. 2).

RAMP II permits a more in-depth analysis. Results are presented with a similar three-colour RPL coding system (Fig. 2), and additionally risk scores, to separate levels within each RPL colour code.

The Results module enables compilation and presentation of the RAMP I and RAMP II results at different levels of detail and scope in tables, including detailed results, results at risk category level and an overview level. The display can focus on the level of e.g. single workstations, or.

Departments or sites, or the entire organisation, depending on the specific users’ needs. For example, staff with functions to design and implement risk reduction measures can get detailed information of risks, enabling access to relevant information to develop adequate risk reduction measures. Management might prefer aggregated results at the overview level for a site as their base for decision making.

The Action module provides support for systematic risk management. The module (Fig. 3) includes the Action model, which provides a structure for developing risk reduction measures and automatically generated Action suggestions for those assessment items which have been flagged as high risk (red, Fig. 2) in RAMP I, or high risk or risk (red or yellow, Fig. 2) in RAMP II. The Action module also includes an Action plan template, including follow-ups to support the risk management
2.1. Development of the action module

The Action module was developed using an iterative methodology (Martin et al., 2008) with the support from 13 experts (six practitioners from companies and seven researchers) in the project’s international network. All had more than 10 years’ experience of applied work environment improvement and competence in subareas such as model development, organisational ergonomics and change management. In addition, they had relevant, complimentary competencies regarding aspects of risk management, including competencies within MSD risk factors, applied experience of MSD risk reduction, development and implementation of risk reducing measures, and legislation. The experts participated in both group settings and individually. In total over 40 meetings and individual discussions were held over a four-year period, including activities at workshops suggesting, discussing and providing feedback on development strategies, literature to include as a base in the development of the Action module, and on prototypes.

The Action module includes three parts, each selected to support risk management in a structured manner. One part is the Action plan template, inspired by the Swedish Provision on Systematic Work Environment Management, APS 2001:1 Eng (SWEA, 2001), and the ISO requirements on quality management systems, ISO 9001:2000 (ISO, 2000), including quality plans. Output from the two other parts, the Action model (a general model, based on literature suggested by the group and discussions with the group, for developing risk reduction ideas) and the Action suggestions (a section with examples of specific risk reducing measures for each identified risk factor, based on input from the group members) support forming the Action plan. The design with the two types of suggestions (general and specific) was chosen after feedback from the group on the benefits of including both a general and a specific part to enhance the Action modules usefulness (e.g. Wells, personal communication 2014).

In the development of the Action model we used Klein’s work (Klein, 2014) on how technology development is influenced by external factors, Davis et al.’s Hexagon model (Davis et al., 2014), which is based on a socio-technical perspective, Porras and Robertson’s work on organisation development (Porras and Robertson, 1992), Holden et al.’s SEIPS-model (2013), Eklund’s Human-Technology-Organisation-model (2003) and Berlin’s research on finding “ergonomics” pathways within organisations (Berlin, 2011).

2.2. RAMP application

During the development of the RAMP tool the activities in the ISO standard Risk management - Principles and guidelines, ISO 31000:2009 (ISO, 2009) were used for systematic comparison with the RAMP risk management activities to strengthen quality and make RAMP compatible with this ISO risk management process. A comparison was made between the types of risk factors included in RAMP and in 13 other risk assessment tools, based on results presented by Palm et al. (2014) and Lind (2017) on the other tools. The finding from these studies were further developed, by including work organisational factors and by presenting the risk factors, on a three-category scale (considered, not considered and partly considered) for those and for RAMP. The process of how to apply the RAMP tool was iterated (Kirwan and Ainsworth, 2014) and during the development of the RAMP tool and the creation of the training material. Documentation from workshops and feedback from practitioners and researchers were used to finalize the flowchart description.

2.3. Accessibility

The RAMP Package was created to make RAMP easy to access, and to provide open source training and user guides. In order to ensure a global distribution and usage of RAMP regardless of financial means, the strategy was to make the tool and its related training material available free of charge. To facilitate that the RAMP Package continuously will be up to date including new research findings, the dissemination strategy involved that information and training should be communicated from a stable organisation such as a university. RAMP was made available to download for free via KTH Royal Institute of Technology’s website at
www.ramp.proj.kth.se, with information in both Swedish and English. At the RAMP website the RAMP tool is presented, including current updates, and instruction regarding how to apply RAMP in practice (User guide (Rose and Lind, 2017) and FAQs), as well as links to the RAMP training and relevant research publications.

The massive open online courses (MOOCs) were designed iteratively in multi-disciplinary teams including instructional designers and tested on users with diverse backgrounds, e.g. engineering students, researchers and ergonomists, in accordance with the design-model described in Barman et al. (2019). Furthermore, collaborations between researchers and organisations from different manufacturing and service sectors in Sweden, Botswana, Iran and Estonia were established. These collaborations provided a variety of authentic examples for the training material and, hence potentially created a more meaningful learning experience for diverse users across organisations and countries (Barman et al., 2018). The RAMP training was made available online for global access, free of charge, and without preconditions regarding educational degree or professional training. The training is offered as three separate self-paced courses with focus on: MSDs and the RAMP tool in general, with extra focus on RAMP I (course 1); RAMP II (course 2); advanced course on the RAMP tool (course 3). There is also an option to obtain a Professional Certificate (fee involved) after all three courses are completed. The edx platform (edx.org), which is one of the largest platforms offering open online courses, was chosen to host the RAMP MOOCs.

Potential users were targeted via communication in a wide range of channels visited by researchers’ and practitioners’, such as professional networks, national and international conferences (i.e. PREMUS, IEA, and NES), networking, workshops, and tailored training courses, e.g. for OSH consultants. In addition, the development and contents are described in publications in peer-reviewed scientific journals, one doctoral thesis, and articles in trade publications intended for public scrutiny. The dissemination strategy also included presentations of the RAMP Package in international scientific conferences, such as IEA (Rose et al., 2019) and PREMUS (Rose, 2019).

2.4. Usability evaluation

The perceived usability of the RAMP tool was evaluated by a total of 62 participants at the end of three workshops (Table 1). The goal was to evaluate how potential users from various countries and organisations perceive that the whole RAMP tool can be applied for risk management. The participants designated themselves as ergonomists/ergonomic consultants (n = 27), managers or directors (n = 6), senior researchers (n = 10), and PhD/graduate/undergraduate students (n = 11), or not reporting their profession (n = 8). None of the participants had previously used the RAMP tool, which was launched 1–4 months before the workshops, respectively. The pre-training included an introduction and a walk-through of the RAMP tool. Thereafter, participants viewed and assessed a video of an authentic, highly repetitive, and typical food industrial job; a task of loading a machine with packaging material, as part of one RAMP analysis. The context and details of the work were provided, such as the work organisation, as well as weights of the goods handled and task duration. The workshop participants made the assessments in pairs, and thereafter the assessments were discussed in the whole group. A similar procedure was applied regarding developing risk reducing suggestions and parts of an Action plan. At the end of the workshop, the participants were invited to participate in the usability evaluation. Informed consent was obtained, prior to voluntarily answering a paper-based questionnaire about the usability of the RAMP tool. This questionnaire was based upon and similar to the one used to evaluate the usability of a prototype of the RAMP tool (Lind and Rose, 2016). In this paper four of the in total 58 questions about RAMP are included. The four questions, each with five-category rating scale response options dealt with the participants perception on whether the RAMP tool is useable for risk management, and as a decision base for prioritising risk reducing measures, as well how well it assesses the risk of developing MSDs and how well it supports the systematic risk management (Table 4). The answers were aggregated into three categories (positive, neutral or negative) and analysed using one-sample Wilcoxon signed-rank test since the data violated the assumption of a normal distribution based on the Shapiro-Wilk test ($\alpha < 0.05$). The statistical computation was performed in SPSS (IBM SPSS Statistics 26, New York, United States).

3. Results

3.1. The Action module

In cases where the risk assessment in the RAMP-analysis indicates an increased risk for employees to develop MSDs, risk reduction actions should be taken. The Action module, with its three parts, provides systematic support for the risk management process (Fig. 3) and the development of, as well as, implementation and follow-up of risk reduction measures. The inclusion of the Action module takes the tool from being a risk assessment tool to become a risk management tool. Further, as described below, RAMP is compatible with the ISO 3100:2009 risk management process.

The Action module can be used as a systematic support to develop risk reduction suggestions tailored to meet the specific needs in a specific case in five different areas:

- Technology and design (e.g. development of a machine),
- Organisation (e.g. work planning with schemes for rotation or how the job is designed from time perspectives – such as how many repetitions are performed per hour),
- Employees (e.g. competence and training),
- Vision and strategies (e.g. the company’s goals with the work environment work) and,
- Environment (e.g. lighting and noise).

The Actions Suggestions section provides automatically generated examples for the risks assessed as being elevated (red in RAMP I and yellow or red in RAMP II). For each such risk factor suggestions for possible measures are given in the five Action model areas, as illustrated in Fig. 3.

The suggestions derived from using the Action model and the Action suggestions can be used to form an Action plan with a presentation of the assessment results to facilitate planning and implementation of risk reduction measures, including when actions shall be implemented, by whom as well as follow-up audits. For this purpose, an Action plan template is provided in the Action module.

Table 1

| Work- | Dura- | Par- | Location | Type of participants |
|------|------|-----|----------|---------------------|
| shop | tion (h) | ici- | |
| 1 | 1.5 | 15 | Canada | Active ergonomists in one Canadian province, all from Canada. |
| 2 | 1.5 | 16 | Canada | International ergonomics conference participants, from many countries, including Canada, USA, New Zealand and Sweden. |
| 3 | 5 | 31 | Estonia | Work environment specialists including ergonomics specialists, managers, university faculty and students, all from Estonia except one from Brazil. |
3.2. RAMP in relation to the ISO standard about systematic risk management

The RAMP tool supports the entire MSD risk management process as described in ISO 31000:2009 (ISO, 2009) (Table 2). This includes identification and assessment of MSD risks, and the evaluation of risk reduction measures effects, as well as, communication and consultation with different stakeholders. RAMP, additionally, provides a structure for systematic development and implementation of risk reduction measures, and evaluation of the effects of implemented measures in systematic follow-up audits.

3.3. Types of risk factors addressed in RAMP and other risk assessment tools

When comparing the scope of addressed MSD risk factors between observation-based assessment tools, large variation can be found (Table 3), indicating the need of carefully selecting the suitable tools depending on the job tasks to be assessed. As indicated in Table 3, WSEC, QEC, RULA, REBA and RAMP cover (at least partly) most of the displayed risk factors related to manual handling and postures. In addition QEC and RAMP also address visual conditions, work organisational factors, doses (duration of exposures), and involve the worker in the assessment.

3.4. The process for applying the RAMP tool

The RAMP tool can be used to assess an entire job, single or multiple work tasks, a workstation or an employee’s full workday. The RAMP tool (version 1.03), is available through Microsoft Excel and PDF files, which support the assessment using a computer or paper-pen. The workflow in the eight-step iterative process is described in Fig. 4 and an applied example demonstrated in Appendix A. RAMP user groups include staff; responsible for or carrying out risk assessments, responsible for production and the work environment and, decision makers at the company. In addition, RAMP can be useful for researchers, educators and students and, representatives of governmental agencies and non-governmental organisations.

3.5. Accessibility via the RAMP package

The RAMP tool was downloaded by approximately 1300 users from 86 countries within the first 26 months. Since the launch of the online training in 2018, more than 2443 learners from over 135 countries enrolled. Of these learners approximately 1/3 reported being women. The proportion of learners from low- and middle-income countries (World Population Review, 2019) was 47%, whilst 45% came from high income countries (eight % unidentifiable). Approximately 1/6 of the learners stated that they had at the most a high school/secondary school degree (about one third unidentifiable for education level). Each course
was provided in two tracks, one free of charge, and one track where learners who pass the course are eligible for a Certificate. Almost all participated in the free of charge track and 62 participants (3%) pursued a certificate.

3.6. Potential users’ perceptions of the RAMP tool

A vast majority of the participants in the three workshops introducing RAMP reported that they perceived the RAMP tool as useful for management of MSD risks, as Table 4 shows. In summary, over 90% fully or partly agreed that RAMP is useable for risk assessment, risk management and communication as well as a decision base for risk reduction measures and that MDS risks can be assessed well or very well.

4. Discussion

The RAMP tool and the RAMP Package were developed to fill the gap between on the one hand, companies’ needs for a research-based, comprehensive, easy-to-use tool for risk assessment and risk management of MSD risks in manual handling jobs, and on the other hand, the availability of such tools. Risk management tools should support the internal organisational processes for managing risks, not solely assess and present the results of risk assessments. The RAMP tools Action module contributes to this. Integration of ergonomics in the companies’ internal processes has been highlighted as a success factor for sustainable management of ergonomic risks (Dul and Neumann, 2009; Hendrick, 2008). As reported by Tornstrom et al. (2008), methods, systems and structures which support the management of risks within organisations can contribute to positive outcomes such as a more effective ergonomic improvement processes, learning and awareness about ergonomics. The RAMP workflow and risk management process are aligned to the ISO 31000:2009 standard to support a structured risk management approach and easier integration into the organisations’ internal processes.

Risks are visualised with the RAMP tool at different levels of detail and scope, such as at detailed level of single workstations at a department. Some user organisations display RAMP assessment results as well as the progress in the risk management process (see Fig. 3C) at each workplace, or on notice boards for each unit and that the organisation perceives an increased awareness about work environment within the organisation (e.g. Lars Samuelsson, 2018, personal communication). This is in line with research showing that visualisation contributes to increased awareness about the work environment and readiness for change within the organisation (Tornstrom et al., 2008). Also, managers and first line supervisors do not want their domains to be classified as “high risk” (red), since that may contribute to a negative image, potentially hampering recruitment of new personnel. The experience is that managers, therefore, may be inclined to act in order to eliminate or reduce risks, especially the “high risk” (red) assessments. However, openly displaying risk assessment results could be problematic for managers, since this could create conflicts between management and the unions if the risks are not reduced (Törnström, 2007).

4.1. RAMP accessibility and usability

The global accessibility of the RAMP tool and the RAMP Package including the online training courses has likely contributed to the extensive spread of the tool. Learning a new tool can be time consuming and in particular if the training takes time away from regular work. The flexibility of the online training, together with updated information on the website and possibilities to discuss with other users is hypothesized to be particularly important for learners working in small scale business. Given that approximately half of the enrolled MOOC learners came from low- and middle-income countries indicates the need of and demand for risk assessment and risk management tools that are readily accessible and affordable or free of charge.

The results show that a clear majority of the participants introduced to RAMP in a workshop setting had an overall positive perception of the tool. Furthermore, the results indicate that RAMP is useful in systematic risk management of MSD risks and assesses the risk of developing MSDs very well or well, which indicates good face validity. It should be noted that all participants had shown an interest in risk assessment for their regular work, but lacked experience of using the RAMP tool in practice, which may have decreased the number of usability problems noted, as also found by Sauer et al. (2010). Further, during the workshops only parts of the risk management process and the RAMP modules were tested. However, these findings are in line with a previous usability evaluation after a half-day training in the RAMP tool use among OSH experts of a RAMP tool prototype (Lind and Rose, 2016). A few studies have investigated usability aspects of earlier, paper-based, versions of the RAMP tool in different industries including the restaurant sector (Håkansson, 2015) and logistics work in the trade sector (Sandahl, 2013). The results from these studies indicate the RAMP tool to be easy to use, the time required for assessment to be acceptable and that the tool’s usefulness exceeds that of QEC and REBA. The results from the present evaluation indicate that the results from assessing MSD risks with RAMP are presented clearly and that the RAMP tool is useable as a decision base for risk management. These qualities are considered as important for ergonomists (Ellasson et al., 2019) and occupational health and safety practitioners when they choose what tool to use in their risk management work (Diego-Mas et al., 2015).

The rapid global spread of RAMP is an indication of its usefulness.

| Table 2 | RAMP tool support for the main risk management activities included in ISO 31000:2009 risk management process. |
|---------|---------------------------------------------------------------------------------------------------------------|
| Main activities in ISO 31000:2009 risk management process | Activity in RAMP | Available in |
| I Communication and consultation | Discussions with stakeholders (e.g. managers, OSH & HR professionals and employees performing work tasks) | Online training material, MOOCs |
| | Consult employees in assessment | RAMP I & RAMP II |
| | Visualisation & communication of risks | RAMP I & RAMP II |
| II Establishing context | Definition of scope with stakeholders | Action module |
| III Risk assessment | Assess risks, develop risk reduction actions | Info in RAMP MOOCs |
| IV Risk identification | Identify risk factors by screening | RAMP I |
| B Risk analysis | In depth analysis of risk factors | RAMP II |
| C Risk evaluation | Present results at risk and priority level | RAMP I & II & Action module |
| D Risk treatment | Develop risk reducing suggestions & Action plans, implement and follow up | Action module (Action Model, Action Suggestions & Action Plan) |

| Activity in RAMP | I Communication and consultation | Available in |
| Risk evaluation | Present results at risk and priority level |
| Risk assessment | Assess risks, develop risk reduction actions |
| Risk identification | Identify risk factors by screening |
| Risk analysis | In depth analysis of risk factors |
| Risk evaluation | Present results at risk and priority level |
| D Risk treatment | Develop risk reducing suggestions & Action plans, implement and follow up |
| IV Monitoring and review | Risk visualisation |
| | Follow-ups |
| | New Risk assessment | RAMP I & RAMP II |
Another indication is that multiple Swedish nationwide OSH service providers, e.g. Avonova, educate all their ergonomists in the RAMP tool use and use the RAMP Package as a standard procedure with their clients. Also multi-national manufacturing industries, such as Scania, use RAMP as their global standard ergonomics method in MSD risk management in logistics and machining departments. The development of RAMP was based on research and user needs. The significance of tools being research based has been found important for user acceptance among professional ergonomists, exceeding the importance of e.g. being easy to learn or requested by the client (Eliasson et al., 2019). However, only when the tool has been used in industry for a longer time-period will it be possible to study the effects and gain further insights regarding usability, reliability and validity of RAMP.

### 4.2. Considerations regarding the RAMP tool

The RAMPs tools inter-rater reliability has been investigated, using early, paper-based, versions of the tool, and overall acceptable level of reliability was observed. For some areas, such as assessment of upper arm postures, a lower degree of reliability has been identified (Lind et al., 2019, 2020). The assessment of e.g. upper arm postures would likely improve by being accompanied by technical measurement instruments (Vignais et al., 2017). The intra-rater reliability of earlier versions of the RAMP tool have been studied with acceptable results (with percent agreement of 81% or higher in repetitive manual handling in a trading industry (Sandahl, 2013) and 84% or higher in a manufacturing industry (Holm, 2015). However, the RAMP tool, like all other observation methods, must deal with threats to precision and repeatability. For example, tasks involving rapid movement of the fingers and/or wrist are more difficult to assess compared to assessing tasks involving the thighs and trunk (Takala et al., 2010; Eliasson et al., 2017). In addition, practical considerations might limit the length of time periods for observation. Another limitation with the RAMP tool and other observation methods for risk assessment is that the risk criteria are partly based on observation methods, something that further limits their validity. In the future, observation methods may be replaced by new measurement technology, e.g. smart workwear (Yang et al., 2018). Meanwhile, the RAMP tool and other observation methods are practical for assessing MSD risks and they provide a basis for the development of new measurement technologies.

Although the RAMP tool covers a wide range of risk factors related to manual handling, some risk factors are only partially covered. Examples

### Table 3

Overview of exposures and MSD risk factors addressed in commonly used or newly developed observation-based assessment tools. Further development from Lind (2017) and Palm et al. (2014).

| Type of work | General | Adverse postures | Repetitive manual handling | Heavy Manual handling |
|--------------|---------|------------------|---------------------------|----------------------|
| Risk factors | WSEC | QEC | RULA | REBA | RSI | HAL | OCRA | ART | HARM | KIM 3 | KIM 2 | KIM 1 | RNLE | RAMP |
| ✈ | [1] | [2] | [3] | [4] | [5] | [6] | [7] | [8] | [9] | [10] | [12] | [12] | [13] | [14] |
| Heavy full body manual handling | Pushing & pulling | P | P | P | - | - | - | - | P | x | - | - | x |
| Lifting | x | x | P | - | - | - | - | - | x | x | x | - | - |
| Carrying | - | P | - | - | - | - | - | - | - | x | - | - |
| Repetitive non-heavy manual handling | Repetitive movements | x | x | P | P | x | x | x | x | x | - | - | P | x |
| Postures (excluding manual handling) | Neck | x | x | x | - | - | - | x | x | P | - | - | x |
| Trunk | x | x | x | - | - | - | x | x | - | P | - | - | x |
| Upper arms | x | x | x | - | - | x | x | x | - | - | - | - | x |
| Wrist | x | x | x | x | x | x | x | - | - | - | - | - | - |
| Secondary factors | Dose (time) | x | x | - | - | x | x | x | x | x | x | x | x |
| Inclusion | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Vibration | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Worker participation | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Working time/pauses | - | - | - | - | - | - | - | - | - | - | x | x | x |
| Visual conditions | - | - | x | - | - | - | - | - | - | - | - | - | - |
| Work organizational factors | - | - | x | - | - | - | - | - | - | - | - | - | - |

*x* = considered; ‘-’ = not considered; 'P' = Partly considered.

† [1] Washington State Department of Labor & Industries, 2017a & b; [2] David et al., 2008; [3] McAtamney and Corlett, 1993; [4] Hignett and McAtamney, 2000; [6] Moore and Garg, 1995, Garg et al., 2017; [6] Armstrong, 2006, Latko et al., 1997; [7] Occhipinti, 1998; [8] Ferreira et al., 2009, 2008; [9] Douwes and de Kraker, 2014; [10] Klussmann et al., 2010, 2015; [12] Steinberg et al., 2006; [13] Waters et al., 1993; [14] Lind 2017, Lind et al., 2019, Lind et al., 2020.
4.3. Practical implications and future work

Several studies have shown that improved physical and psychosocial working conditions are associated with positive system effects, such as improved quality via decreased amount of errors and quality deficiencies, and increased productivity (Abrahamsson, 2000; Eklund and Yeow, 2015; Ivarsson and Eek, 2016; Goggins et al., 2008). From a systems perspective, improved work environments, which result in positive human effects, such as decreased injury and sickness absence, also result in positive system effects such as increased quality (Neumann and Dul, 2010). Further, the tool can be used at an early decision stage, e.g. as a means for evaluating new equipment such as load carriers or machinery prior to purchase. This type of application of the RAMP tool is another way to work proactively with risk management of MSDs. The RAMP tool may reasonably be expected to contribute to the dual goals of ergonomics: to optimize human well-being and overall system performance (IEA, 2018).

Evaluations of the long-term use of the RAMP Package, including studies of the validity, usability and dissemination of the tool and package use are needed. Studies on the effects of usage of the RAMP Package are also needed, e.g. on the effect of implementing risk reduction measures, but also on implementation methodologies, and for a wider range of organisations. Further development of the RAMP Package is needed to expand its application range. Smart, workwear-based risk assessment systems are developing rapidly (Yang et al., 2018), as this technology may soon be readily available. This technology will enable tools which currently are predominantly observation-based risk assessment tools to become to a greater extent measurement-based. This is expected to lead to more accurate, precise, reliable and valid assessments and be less time and labour consuming (Eklund and Forsman, 2019).

5. Conclusion

This paper addresses systematic risk management and how that is facilitated by the RAMP Package, in order to reduce MSDs at the workplace. Risk assessment is performed through the RAMP I and RAMP II modules and the results are visualised using the Results module. In this paper we introduced RAMP’s Action module which makes the tool useful for not only risk assessment, but also supports the whole risk
management process. RAMP is compatible with the ISO 31000 standard’s risk management process. A comparison between RAMP and 13 commonly used risk assessment tools shows that RAMP is the most comprehensive tool in terms of number of, and types of risk factors included, and it is the only tool that supports the whole MSD risk management process systematically. Evaluations of the RAMP tool indicate highly perceived usability. Furthermore, the results indicate that packaging the RAMP tool together with support for the implementation, such as open online training and easy to access information, is a useful strategy to facilitate the interest in taking risk management seriously. With the freely accessible RAMP Package, available worldwide, ergonomists and others desiring to reduce MSDs can download, learn how to use, and implement RAMP for risk management regardless of financial means and higher education.

**Acknowledgements**

Financial support from AFA Insurance (Afa Försäkring), Sweden [Grant 090168]; and the Swedish Research Council for Health, Working Life and Welfare (Forskningsrådet för hälso, arbetsliv och välfärd (FORTE)), Sweden [Grant 2010-1563] is gratefully acknowledged, as is the participation of all the organisations and companies who have contributed with their in-house resources and knowledge. The compilation of the epidemiological literature studies in a structured way by Liyun Yang is gratefully acknowledged.

**Appendix A. An example of applying the RAMP tool**

The process is demonstrated by using an assessment of neck postures (Fig. A1), focusing upon head inclination \(>30^\circ\) for approximately 1.5 h per workday. Using RAMP I, the assessment targets whether or not the head is ‘clearly bent or twisted – forward or towards a side’ for about 1 h per workday or more. Hence, the neck posture is assessed as a potential risk factor (‘Yes’) and visualised as grey RPL. The grey marker signals that this posture needs further investigation before the RPL can be established, for which RAMP II can be used. Using RAMP II, the exposure renders a yellow RPL with a risk score of ‘2’. The yellow colour signals that the physical exposure may contribute to an increased probability of MSDs in the neck/shoulder region, based on association found in epidemiological studies (Lind et al., 2020), and that risk reduction measures should be implemented.

![Fig. A1.](imageURL) Assessment of one assessment item in RAMP I and RAMP II, posture of the head – twisted or bent forwards, and the colour coded results of the assessment.

Fig. A1 illustrates how the results can be presented at detailed, risk category and at overview level as visualised by the yellow cell (1.1 Posture of the head/Workstation, WH1_1) in Fig. A2A. Additional assessment results from other workstations are illustrated in the columns marked WH1_2–DP2_3 (Fig. A2A). This visualisation shows where the RPLs are elevated. This information can then be used for planning work, avoiding rotation from workstation WH1_3 to WH1_4, since these workstations expose the same body region in a similar way. Fig. A2B shows the results displayed at risk category level and the colour in each cell displays the highest RPL measured within each risk category. The number in the cell shows how many assessments in that risk category that are included in that RPL.
Once the MSDs are identified, the Action module (Fig. 3) can be used to support the process of generating risk reduction measures. The Action model facilitates development of solutions in the areas: Technology and design, Employees, Organisation, Vision and strategies, and Environment. In addition, the Action module automatically generates suggestions of measures regarding manual handling flagged red or yellow. For the previous example of identified risk for the neck, the Action module renders 'Action suggestions' (Fig. 3) such as: ‘investigation of the visual conditions’ (Technology & Design) and ‘consider work organisational changes, e.g. job rotation’ (Organisation). Finally, based on the developed suggestions on how to reduce the risk, the risk management agenda can be summarised in an Action plan, as illustrated for this example in Fig. 3. Applying the Action plan includes a follow-up, which in turn is suggested to lead to a new risk assessment et cetera in an iterative process, as Fig. 4 illustrates.

Fig. A2. RAMP II Results illustration (Excel). Results displayed A) at detailed level for the risk categories ‘Postures’ and ‘Work movements and repetitive work’ and B) at risk category level including all risk categories, and at the bottom of the table a results summary at overview level is displayed.

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