A practitioner model for assessing manual lifting and lowering operations - included in the RAMP tool

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A recently developed model intended to be used by practitioners and ergonomists in the manufacturing and logistics industry for assessment of physical ergonomic risks related to manual lifting and lowering operations is presented. The model is constructed using the revised NIOSH lifting equation (RNLE) as a basis, but it has been modified to enhance its usability, regarding (1) simplifications of the existing factors in the RNLE, (2) adding new factors and (3) a more conservative judgment of lifts performed at low and high vertical heights. In addition, a survey regarding the usability of the new lifting model including twenty-two ergonomists/physiotherapists is presented.

**Practitioner Summary:** This paper presents a lifting model intended to be used by practitioners and ergonomists to assess manual lifting and lowering operations. The model is based on the revised NIOSH lifting equation and has been modified in order to enhance its usability.

**Keywords:** Risk assessment, Risk management, Manual Handling, Lifting

1. Introduction

The purpose of this paper is to present a recently developed lifting model for assessing physical risks in manual lifting and lowering operations and to evaluate its usability on a population consisting of ergonomists/physiotherapists. The lifting model is part of the risk management tool RAMP (Risk Assessment and Management for manual handling Proactively), intended to facilitate measures for reducing musculoskeletal disorders and symptoms related to manual handling operations in the manufacturing and logistics industries (Rose et al., 2011; Lind et al., 2012; Lind et al., 2015). RAMP (see figure 1) consists of two assessment modules (RAMP I and RAMP II), a Results module which visualizes the results from the assessments in RAMP I and RAMP II, and an Action module which provides a method for constructing action plans (Rose et al., 2015). RAMP I is intended for a quick screening of the occurrence of possible risk factors, while RAMP II provides a more detailed analysis of risk factors related to manual handling. RAMP I and RAMP II provide assessments of: work postures, lifting/lowering and pushing/pulling of loads, repetitive movements and recovery allowance, hand grip, hand-arm and whole body vibration, heat and cold stress, psychosocial factors, reported physically demanding work and perceived discomfort.

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Figure 1. The four modules in the RAMP tool.

RAMP was developed in a project formed by researchers at KTH Royal Institute of Technology and by two global manufacturing companies in the food and vehicle industries. These companies were unable to find an assessment tool which they could use to assess a broad range of manual handling operations (MHO) and...
which supported the whole risk management process, from identification of risk factors (related to MHO) to the construction of action plans.

Manual handling (e.g. lifting, lowering, carrying, pushing and pulling) is a major contributor of work-related musculoskeletal disorders and symptoms (N.R.C, 2001), causing human suffering, loss of production and high economic cost to the society (Palmer et al., 2012). Manual handling is commonly performed in the industry, for example, more than 30% of the workers in Europe are daily handling heavy loads manually at least a quarter of their workday (Eurofound, 2012). Heavy lifting is related with both low-back pain/disorders (LBP/D) (N.R.C, 2001; Heneweef et al., 2011) and knee disorders (Jensen, 2008). Both peak and cumulative loads are believed to independently contribute to an increased risk of low back pain (Norman et al., 1998; Coenen et al., 2013). Furthermore, lifting at or above shoulder height has been associated with an increased risk of musculoskeletal disorders or pain in the shoulder and neck region (Harkness et al., 2003; Andersen et al., 2007; Choobineh et al., 2010).

Several tools exist that can be used by practitioners in order to assess physical risks in manual handling operations but few of these have been validated in longitudinal studies for their ability of predicting musculoskeletal disorders and symptoms (Fallentin et al., 2001; Takala et al., 2010). However, the revised NIOSH lifting equation (RNLE) (Waters et al., 1993) has been shown to predict an increased risk of LBP/D in several longitudinal studies (e.g. Sesek et al., 2003; Garg et al., 2014; Lu et al., 2014). The RNLE has several restrictions which have been found to hamper its use when assessing lifting and lowering tasks. For example, the RNLE is restricted to two-handed and single-person lifts, with a horizontal distance of less than 64 cm performed at moderate ambient temperatures (19-26°C). Sesek et al. (2003), Dempsey (2002) and van der Beek et al. (2000) found that 44, 35 and 57% of the lifting task in their studies had at least one parameter that could not be assessed using the RNLE (often due to one-hand lifting). In addition, Waters et al. (1999) and Dempsey (2002) reported that horizontal distance (63 cm) was exceeded in 30% and 18% of the tasks. Furthermore, several recent studies show that the RNLE is not enough conservative when lifting from low vertical heights (e.g. Marras et al., 1997; Marras et al., 1999; Lavender et al. 2003; Hoozemans et al., 2008). In an evaluation of five assessment tools (OWAS, MAC, REBA, RNLE and QEC), the assessors ranked the RNLE and QEC as the most difficult to use (Pinder, 2002). Dempsey (2002) found that users had most difficulties of assessing the hand grip (coupling), load asymmetry and lift duration and that the users judged the hand grip subjectively and not strictly based on the quantitative and qualitative definitions. A similar result was reported by Waters et al. (1998) who found that the assessment of the hand grip (coupling) and the load asymmetry had the lowest accuracy of the assessed factors. For example, only 59% made the correct assessment of the coupling factor. In addition, Burdorf and van der Beek (1999) raised concerns regarding its reliability when assessing more varied lifting jobs, common in the industry.

Based on the needs identified from the participating companies and the restrictions identified in the RNLE, it was decided to develop a model that can be used by practitioners for assessment of lifting and lowering operations with:
(1) less restrictions than the RNLE and with
(2) higher level of usability, and which is
(3) more conservative of low and high vertical lifting heights compared to the RNLE and
(4) which can be used by practitioners at companies and the occupational health services.

2. Development of the lifting model

The RAMP-tool was developed by researchers at KTH Royal Institute of Technology in cooperation with small-, medium-, and large-sized companies in the manufacturing and logistics industries. The tool was developed using an iterative process, with feedback from managers, production personnel and ergonomists (Lind et al., 2014). The lifting model presented here, is constructed using the RNLE as a basis. Additional factors (one-handed lifting, team lifting and lifting in hot ambient temperatures), included in the models, are mainly based on psychophysical and biomechanical studies, European ergonomic standards (EN 1005-2:2008) and judgment from an expert group (consisting of researchers and experienced ergonomists. A short presentation of the background is presented below while a more thorough presentation of the background is presented in Lind and Rose (2015).
2.1 Development of model criteria

Team lifting increases the lifting capability, but is often related with a decline in the individual lifting capacity by about 10-20% for teams of two (Lind and Rose, 2015). Furthermore, one-handed lifting can significantly increase spinal lateral shear force and a reduction in the maximum acceptable weight of lift (MAWL) and EN 1005-2 suggest a reduction of 40% of the weight for one-handed lift. A reduction in MAWL is also found when lifting is performed in hot ambient temperature. Hafez and Mital (1991) found a mean reduction in the MAWL of about 13% when lifting was performed at 32°C, compared to 22°C at various frequencies. In addition, a new more conservative weighing to the vertical height of the lift was added based on recent experimental studies (Marras et al., 1997; Marras et al., 1999; Lavender et al. 2003; Hoozemans et al., 2008; Marras and Hamrick, 2006) and expert judgements. In order to facilitate the assessment, lift-asymmetry and hand grip (coupling) was dichotomized as more than 30° or not, and poor coupling or not based on suggests by Dempsey and Fathallah (1999) that the level of detail of the asymmetry factor in RNLE is too high, and the low accuracy of the assessment of the coupling factor (Waters et al. 1998).

3. Presentation of the lifting model

The lifting model (figure 2) enables assessment of physical ergonomic risk related to manual lifting or lowering of objects. Both an average and a peak lifting situation, representing both the cumulative and peak loads, are assessed. The assessment results in a risk/action level using a traffic light colour-code-system and a score (figure 3), indicating the severity of the assessed task. A red colour indicates high risk and loading situation and that improvement measures should be given high priority. A yellow colour indicates a lower degree of risk but that improvement measures should still be taken. A green colour code indicates a generally low risk, but some individuals with reduced physical capacity may still be at risk of developing musculoskeletal disorders, symptoms and or low back pain.

Figure 2. Visualizing the lifting model and how to calculate the risk/action level and score using the multipliers in the lifting model in RAMP II.
High risk. The loading situation has such a magnitude and characteristics that many employees are at an increased risk of developing musculoskeletal disorders. Improvement measures should be given high priority.

Risk. The loading situation has such a magnitude and characteristics that certain employees are at an increased risk of developing musculoskeletal disorders. Improvement measures should be taken.

Low risk. The loading situation has such a magnitude and characteristics that most employees are at a low risk of developing musculoskeletal disorders. However, individuals with reduced physical capacity may be at risk. Individually tailored improvement measures may be needed.

Figure 3. The risk/action levels in the lifting model.

A risk/action score is calculated by multiplying seven factors that affect the lifting capacity and/or the risk of developing musculoskeletal disorders (and or low back pain):

- Frequency of the lift/lower and the weight of the load (“Frequency-and-weight factor”)
- Vertical and horizontal location at the origin or destination of the lift/lower (“Lifting area factor”)
- One-handed lifting/lowering
- Trunk twist of more than 30°
- Hand grip (coupling)
- Lifting/lowering in hot ambient temperature (27-32°C)
- Team lifting (two people)

The score is calculated by using the following equation:

\[
\text{Score} = \text{“Frequency/weight-factor”} \times \text{“Lifting area-factor”} \times \text{Influencing factors (One-handed lift-factor} \times \text{trunk twist-factor} \times \text{hand grip-factor} \times \text{hot environment-factor} \times \text{team-lift-factor)}
\]

It is recommended that the assessment should be carried out by or together with a person with knowledge of the work or work task to be assessed and on individuals representing those who carry out the task. Careful sampling of the work is also advocated, to minimize the effect due to intra- and inter variability and to enhance the accuracy of the assessment.

3.1 Example

A hypothetical lifting case is used to give an example of how to use the lifting model:

A person lifts 450 boxes containing apples each workday. The boxes have an average weight of 6.5 kg and are lifted at hip height from a horizontal distance of 3/4 arm-reach distance (the center of gravity of the box) to a position close to the body also at hip height. In addition about five times per day, heavier boxes (30 kg) are lifted from floor height (handles about 15 cm above floor height). Both types of boxes lack handles and require the person to twist the trunk 60° (measured from between the feet and between the shoulders).

First, the average lift is calculated and then the peak lift (“worst case”). The peak lift (“worst case”) could for example, be either a heavy lift that occurs seldom or a lighter lift occurring frequently. For simplifications, the five heavier lifts can be neglected here, when calculating the average lift. The calculation of an average and peak lift is visualized in figure 4-5.
Figure 4. Calculation of an average lift.

Figure 5. Calculations of the peak lift ("worst case").

If the origin of the lift would have been further away from the body (e.g. more than 63 cm) outside the boxes in of the "lifting area", an extra point would have been added to the closest box value. This would mean that a lift at hip-height, with a horizontal distance exceeding 63 cm (from the knuckles to the midpoint between the inner ankles bones) would have resulted in an extra score compared to if the vertical distance was 63 cm.

4. Usability trials

Twenty-four Norwegian ergonomists/physiotherapists gave their informed consent and answered a questionnaire regarding the usability of the RAMP-tool (modified after Sandahl, 2013). The median number of years they had worked as ergonomists/physiotherapists was six years (range 0-30). Two thirds (65%) performed risk assessments about once every third month or more frequent and 39% performed a risk assessment about once every month or more frequent.

The participants participated in a one-day training course which included about 2-2.5 hours of assessment of manual handling operations from video footages using the RAMP tool. At the end of the training day, the participants responded to a questionnaire regarding the usability of different aspects of the RAMP tool. The questions concerned how easy or difficult the user perceived the assessment to be, of the factors in the model, as well as the assessment of an average and peak lifting case. The factors (see figure 6) were assessed using a Likert-scale (1=easy, 2= somewhat easy, 3=neither difficult nor easy, 4= somewhat difficult, 5=difficult). The questions were in Swedish and were tested in advance on one Norwegian physiotherapist in order to validate its readability in a Norwegian ergonomist/physiotherapist population. The researchers participated during this session in order to answer potential questions regarding the questionnaire.

Of the 24 participants, 22 answered the questions regarding the lifting model. Of these, 22 participants, 81% and 90% responded that they found it easy or somewhat easy to assess an average and the worst lifting case respectively using the model. Furthermore, all of the respondent answered that the assessment of ambient temperature and team-lifting was easy or somewhat easy to assess, while 86%, 82% and 73% responded that it was easy or somewhat easy to assess hand grip (coupling), single-hand lifts and vertical and horizontal origin or destination of the lift ("lifting area"). Assessment of trunk twist and the weight-frequency-factor was perceived as the most difficult of the factors. Fourteen percent found it to be difficult or somewhat difficult to assess while 64% reported that these factors were easy or somewhat easy to assess.
5. Discussion

The new practitioner model presented in this paper gives the users the possibility to assess a broader range of lifting and lowering operations by including several commonly observed factors in industrial jobs. Furthermore, the lifting model is more conservative when lifts are performed at low and high vertical height compared to the RNLE, based on results predominantly from recent experimental studies (Marras et al., 1997; Marras et al., 1999; Lavender et al., 2003; Hoozemans et al., 2008). When assessing a lift task, the assessment results in a risk/action score for both cumulative and peak load, since these are believed to independently contribute to an increased risk of low back pain (Norman et al., 1998; Coenen et al., 2013). The goal should be to design a job so that both scores are in the low risk action/risk level. In order to increase the ease of use of the new model, it was designed with fewer levels (discrete steps) of the task parameters compared to the RNLE. Although this could increase its usability when assessing jobs with a large variability, it could on the other hand reduce the accuracy when designing a work station due to its lower precision. The lifting model is focusing on lifting tasks with high physical strain. Therefore, it is assumed here that a lower strain implies a lower risk. Although this might not be the case, for many sedentary jobs where an increased physical loading is often suggested in order to improve the physical health. However, these sedentary jobs are outside the scope of the lifting model and the RAMP tool.

The result from the survey shows that a vast majority of the participants included in the study finds it easy or somewhat easy to make assessment of an average and peak lifting task although some factors (combination of weight and frequency and trunk twist) might still need some improvement to enhance the usability of the tool. One question, concerning the overall usability of the model (regarding how easy or difficult they perceived it to make assessment using the model) was only answered by nine respondents and was therefore excluded. Of the nine respondents, eight responded that it was easy or somewhat easy to assess lifting using the model, while one responded that it was neither difficult nor easy. A recent evaluation of the model, consisting of three physiotherapists/ergonomist and three physiotherapists, found high level of inter-rater agreement (87%) for the assessment of both average and peak lift (Holm, 2015). The risk/action level of the model should be treated as a hypothesis until studies have evaluated its predictive validity. Further evaluation of the model is advocated, to tests the models intra- and inter-rater reliability on a larger population.
6. Conclusion

This paper presents a new model, intended for practitioners for assessing manual lifting and lowering operations. The model, which is to large extent based on the revised NIOSH lifting equation, can be used for assessing a broader range of lifting tasks commonly observed in industry including one handed lifting, team lifting and lifting in hot ambient temperature. In addition, several of the factors included in the RNLE have been modified in order to enhance its usability for practitioners and due to the variability of lifting parameters observed in industry. An evaluation of usability of the model shows, that a large majority (81% and 90%) of practitioners, found it easy or somewhat easy to assess an average and peak lift using the model.

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References


