An investigation into mechanical aids and automation for reducing the risks of repetitive handling tasks involving the upper limbs

Prepared by the Health and Safety Laboratory for the Health and Safety Executive 2012
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The Health and Safety Executive (HSE) produced a document (INDG 398; [1]) that provides practical advice on mechanical aids that reduce the risk of heavy manual handling. However, there is little information on the mechanisation and automation available to reduce upper limb disorder risks that can arise with repetitive handling (ie handling light loads at least every few seconds). HSE guidance ‘Upper limb disorders in the workplace’ [2] suggests a hierarchical approach to risk reduction and asks ‘can machinery do the highly repetitive functions and leave more varied jobs for the workers?’ However, no further information on this important risk reduction measure is provided. As such, it is difficult for HSE and Health and Safety Laboratory (HSL) specialists to advise Inspectors and duty holders on whether mechanisation or automation is a reasonably practicable control option to reduce upper limb disorder risks.

The introduction of the ART tool [3] has provided inspectors and duty holders with a risk assessment tool where tasks that predominately use the upper limbs can be assessed. This is likely to lead to an increased knowledge and awareness of ULD risk factors. However, there is little guidance for inspectors and duty holders regarding reasonably practicable control measures where the tasks are performed manually and there is no mechanisation or automation in place. The aim of this document is to provide practical examples of risk control measures used in industry.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.
ACKNOWLEDGEMENTS

The authors are extremely grateful to the organisations and individuals who assisted HSL by allowing us to film work tasks and who provided valuable time and information for the case studies to be developed. The HSL would also like to thank the many organisations and manufacturers of automated equipment who provided information.

Please note that the HSL/HSE do not endorse any specific manufacturer or product and where website links have been included they are to provide an illustration of the type of equipment and approximate cost of equipment that is available. All websites were current at the time of printing this report.
KEY MESSAGES

The key findings and main implications of the research are as follows.

- Limited relevant information is currently available on the use of automation/mechanisation as a control measure to reduce the risk of upper limb disorders. This report provides examples relevant to specific work activities; however, these may be adapted to suit other tasks. Discussions with manufacturers would allow individual organisations to consider how they could benefit from automation or mechanised systems and to develop bespoke equipment if necessary.

- This report aims to show a variety of automated and mechanised equipment and the benefits and limitations of using the devices based on ‘real-world’ case studies. However, for a number of reasons there are likely to be a number of useful devices that are not highlighted here. Primarily, the researchers’ were reliant on the willingness of individual companies to participate in the study, volunteering their time and providing HSL with information.

- Industry needs to carefully consider the use of mechanisation and how it is implemented to reduce the upper limb injury risk to workers. Workers will remain an important part of a production system but there are likely to be residual tasks that cannot be mechanised. For example, where workers are trying to keep pace with a machine or where there is limited scope to undertake a variety of tasks.

- Workers should always be consulted about any potential changes to a work system in the first instance, as they may have suggestions on how a task could be improved. This will also help to ensure worker buy-in.

- When changes to a work system have been implemented it is important to assess the risk again. While the risk may be eliminated or reduced for one task, it may be transferred to another process or task, or new risks may be introduced.
EXECUTIVE SUMMARY

OBJECTIVES

The aim of the research is to review current literature on mechanical handling aids and automated systems that reduce musculoskeletal injury risks for the upper limbs as well as commercially available products. The objectives of this research were to:

1. Undertake a literature review to identify if there is any guidance or information currently available in the UK and elsewhere (e.g. USA, Canada, Australia, New Zealand, Scandinavia) about reducing upper limb injury risk by mechanisation and automation;

2. Identify what mechanisation and automation products are commercially available to reduce the risks of musculoskeletal injuries for the upper limbs; and

3. Identify the benefits and limitations of using the equipment identified based on real-world examples where possible.

APPROACH

The method used for this study involved three key approaches.

1. Literature review. A literature review was performed by searching key scientific databases. The aim was to identify if, and where, automation or mechanisation have been used as a risk reduction measure for exposure to repetitive tasks that may lead to upper limb injury. The key search words used were: upper limb disorders (ULD); automation; mechanisation; risk reduction; upper limb; neck; shoulder disorders; work related; packaging; sorting; assembly; processing; cleaning; and picking. The search targeted information from a variety of industry sectors including agriculture, engineering, manufacturing, and woodworking/furniture production. The list of terms selected for searching was identified from searches of previous HSL/HSE reports and guidance.

2. Site visits. Eight visits were made where automated devices are used. A walk-through of the work environment was carried out to identify suitable risk reduction measures, and informal discussions took place with the relevant health and safety managers and device operators. The aim of the visits was to understand and record the practicalities of using the equipment, and the benefits and limitations or difficulties they have experienced when implementing any changes within the work system. Where possible, data on costs, return on investment, and productivity levels were recorded.

3. Internet searches. An internet search for products and manufacturers was undertaken using the stated key search terms. Also, the search sought to identify any relevant trade organisations and publications that have specific information on mechanical and automated devices; and if there were any relevant exhibitions that should be attended. Where suitable risk reduction measures were identified, organisations were approached by telephone or email for further information.
MAIN FINDINGS

• Findings from the literature review. In total, 27 papers were identified as relevant to the current project. Eighteen papers suggest implementing automation as a strategy to reduce the risk of ULD injury, or discussed the prevalence/incidence of ULD injuries within a particular industrial setting. However, these were of limited value; only nine contained sufficient detail to allow a thorough evaluation of where an intervention to reduce the risk of ULD injury was investigated or provided useful information about ULDs and mechanisation. The literature highlighted these key points.

  o The use of mechanisation and automation appears to be increasing, but people will remain an important part of a production system. Therefore careful consideration of the residual handling tasks, and interaction between the worker and the machine are of importance.

  o The introduction of automated systems may increase productivity and decrease the physical work demands. However, in some situations repetitive work tasks may actually increase as the task variety is reduced. For example, the workers are left with the residual tasks that cannot be automated. Automation may also result in workers having to work faster to keep pace with the mechanised system.

  o When changes to a work system have been implemented it is important to assess the risks again. While the risk may be eliminated or reduced for one task, it may be transferred to another process or task or new risks might be introduced.

  o Trialling a system prior to widespread implementation and getting user buy-in are important.

• Case studies. Fourteen case studies are presented, with the majority relevant in a variety of manufacturing settings. For most of the case studies it has been possible to provide a ‘before’ and ‘after’ scenario where the task was previously manually performed and has since been automated. The case studies illustrate how the following machines have been used in industry:

  o Advent calendar stacking (automated stacking machines);

  o Sealing boxes (automated box sealers);

  o Bagging flour (automated filling machines);

  o Packaging sausages (automated sleeving machines);

  o Paper collating (automated collating machines);

  o Sanding aircraft wings (mechanised device to support the sander when sanding);

  o Fish filleting (automated fish filleting machines);

  o Tying “rebar” (automated rebar tying devices);

  o Potato grading (automated grading machines);
o Carton filling (automated carton filling devices);

o Labelling (automated labelling devices);

o Bread making (automated loading/unloading machine);

o Biscuit production (automated biscuit cutting machine);

o Palletising containers (automated robot picking device).

CONCLUSIONS AND IMPLICATIONS

- The equipment shown in the case studies within this report could be used in a variety of situations. Although limited relevant information is currently available on the use of automation/mechanisation as a control measure to reduce the risk of upper limb disorders, this report identifies a variety of examples of equipment that could be used or adapted to suit the needs of individual organisations. This report aims to provide some guidance to health and safety professional on a range of equipment that is currently available. Discussions with manufacturers could help to develop bespoke solutions for organisations to reduce the risk of ULDs.

- Industry needs to carefully consider the use of mechanisation and automation. The use of mechanisation and automation appears to be increasing, and people will remain an important part of a production system. However, there are still likely to be residual tasks that cannot be mechanised. The introduction of automated systems may increase productivity and decrease the physical work demands. However, in some situations repetitive work tasks may actually increase as the task variety is reduced. Organisations need to carefully consider these tasks to ensure that the upper limb injury risk is as low as reasonably practicable. Workers should always be consulted about any potential changes to a work system in the first instance, as they may have suggestions on how a task could be improved. This will also help to ensure worker buy-in.

- Reassess the risk following implementation of automation or mechanisation. Where changes to a work system have been implemented, it is important to assess the risk again to ensure that new risks have not been introduced, or that the risk has not been transferred to another process or task. The introduction of automated/mechanised machinery does not necessarily have to be complicated or expensive, and often can have a relatively short payback period. Trialling a system prior to widespread implementation and getting user buy-in are of key importance.
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1. INTRODUCTION

The Health and Safety Executive (HSE) produced a document (INDG 398; [1]) that provides practical advice on mechanical aids that reduce the risk of heavy manual handling. However, there is little information on the mechanisation and automation available to reduce upper limb disorder risks that can arise with repetitive handling (i.e. handling light loads at least every few seconds). HSE guidance ‘Upper limb disorders in the workplace’ [2] suggests a hierarchical approach to risk reduction and asks ‘can machinery do the highly repetitive functions and leave more varied jobs for the workers?’ However, no further information on this important risk reduction measure is provided. As such, it is difficult for HSE and Health and Safety Laboratory (HSL) specialists to advise Inspectors and duty holders on whether mechanisation or automation is a reasonably practicable control option to reduce upper limb disorder risks.

The introduction of the ART tool [3] has provided inspectors and duty holders with a risk assessment tool where tasks that predominately use the upper limbs can be assessed. This is likely to lead to an increased knowledge and awareness of ULD risk factors. However, there is little guidance for inspectors and duty holders regarding reasonably practicable control measures where the tasks are performed manually and there is no mechanisation or automation in place. The aim of this document is to provide practical examples of risk control measures used in industry.

1.1 AIM

The aim of the research is to review current literature on mechanical handling aids and automated systems that reduce musculoskeletal injury risks for the upper limbs as well as commercially available products.

1.2 OBJECTIVES

The objectives of this research were to:

1. Undertake a literature review to identify if there is any guidance or information currently available in the UK and elsewhere (e.g. USA, Canada, Australia, New Zealand, Scandinavia) about reducing upper limb injury risk by mechanisation and automation;

2. Identify what mechanisation and automation products are commercially available to reduce the risks of musculoskeletal injuries for the upper limbs; and

3. Identify the benefits and limitations of using the equipment identified based on real-world examples where possible.
2. IMPLICATIONS

The key implications from this study are:

- **The equipment shown in the case studies within this report could be used in a variety of situations.** Although limited relevant information is currently available on the use of automation/mechanisation as a control measure to reduce the risk of upper limb disorders, this report identifies a variety of examples of equipment that could be used or adapted to suit the needs of individual organisations. This report aims to provide some guidance to organisations and Inspectors on a range of equipment that is currently available. Discussions with manufacturers could help to develop bespoke solutions for organisations to reduce the risk of ULDs.

- **Industry needs to carefully consider the use of mechanisation and automation.** The use of mechanisation and automation appears to be increasing, and people will remain an important part of a production system. However, there are still likely to be residual tasks that cannot be mechanised. The introduction of automated systems may increase productivity and decrease the physical work demands. However, in some situations repetitive work tasks may actually increase as the task variety is reduced. Organisations need to carefully consider these tasks to ensure that the upper limb injury risk is as low as reasonably practicable. Workers should always be consulted about any potential changes to a work system in the first instance, as they may have suggestions on how a task could be improved. This will also help to ensure worker buy-in.

- **Reassess the risk following implementation of automation or mechanisation.** Where changes to a work system have been implemented, it is important to assess the risk again to ensure that new risks have not been introduced, or that the risk has not been transferred to another process or task. The introduction of automated/mechanised machinery does not necessarily have to be complicated or expensive, and often can have a relatively short payback period. Trialling a system prior to widespread implementation and getting user buy-in are of key importance.
3. METHOD

3.1 LITERATURE REVIEW

3.1.1 Search Strategy

A literature review was performed to identify if, and where, automation or mechanisation have been used to reduce exposure to repetitive tasks that may lead to upper limb injury. Web of Science, Ergonomics Abstracts, Health and Safety Science Abstracts (HEALSafe), and OSH-ROM (HSELINE, CISDOC, NIOSHTIC, NIOSHTIC2, RILOSH, MHIDAS and MEDLINE) were searched for published, peer-reviewed studies, using the following key words:

- Upper Limb Disorders (ULD), automation, mechanisation, risk reduction, upper limb, neck, shoulder disorders, work related; and
- Packaging, sorting, assembly, processing, cleaning, picking.

Examples of how these were combined: ULD and packaging, automation and packaging, automation and sorting, mechanisation and ULD, etc.

The search covered information from a variety of industry sectors including agriculture, engineering, manufacturing, and woodworking/furniture production. The list of terms selected for searching was identified from searches of previous HSL/HSE reports and guidance (e.g. ‘Assessment of repetitive tasks of the upper limbs (the ART tool, [3])’, ‘HSG60 – Upper limb disorders in the workplace’, [2]; ‘HSG196 - Moving food and drink’, ‘Handling the news’, FIS23 Injuries and ill health caused by handling, Case studies with the Rubber Industry Advisory Committee (RUBIAC) on tyre handling, and the Textiles Industry Advisory Committee (TEXIAC).

3.1.2 Exclusions

Eighty-eight papers that made specific reference to the introduction of automation or mechanisation to reduce the risk of ULD were identified. From this, duplicates and papers that covered topics outside the scope of this report (e.g. visual display units (VDU), display screen equipment (DSE), or specific injury causes) were excluded from the review process leaving a total of 27 papers that were relevant to the current project including four non-English language papers (one French and three Italian) that were translated using HSE Language Services. Web searches using the Google scholar search engine and the key words were performed periodically to ensure that relevant current reports were not missed.

3.2 SITE VISITS AND DEVELOPMENT OF CASE STUDIES

Site visits to eight different companies were made. A walk-through of the work environment was carried out to identify suitable risk reduction measures for inclusion in this report as a case study. Informal discussions took place with the relevant health and safety managers and device operators to understand and record the practicalities of using the equipment and the benefits and limitations or difficulties they have experienced implementing any changes within the work system. Where possible, data on costs, return on investment, and productivity levels were recorded. During the site visits HSL Visual Presentation Services (VPS) recorded the risk reduction measures on photographs and video to illustrate how the devices work. Permission has been obtained from organisations and individuals, where photographed, to include images in this report.
The ART tool was used to assess the ULD risk workers are exposed to in the case studies presented in this report. The ART tool [3] provides guidance for health and safety practitioners, consultants, ergonomists, and large organisations to assess the risks associated with tasks that require the repetitive moving of the upper limbs, including the arms and hands. It helps in assessing some of the common risk factors in repetitive work that contribute to the development of ULDs. The ART tool uses a numerical score and a traffic light approach that identifies the high-risk elements of a task and indicates where risk reduction strategies should be focused. Risk factors are grouped into four stages: frequency and repetition of movements; force; awkward postures of the neck, back, arm, wrist and hand; and additional factors, including breaks and duration. The factors are presented on a flow chart (Appendix 1), which provides a step-by-step evaluation of the degree of risk associated with the assessed tasks. The tool is supported by an assessment guide, providing instructions to help individuals score repetitive tasks.

ART is best suited to tasks that involve actions of the upper limbs, that are repeated every few minutes or more frequently, and occur for at least 1-2 hours per day or shift; however, it is not suitable for display screen equipment (DSE) assessments. Repetitive tasks are typically found in assembly, production, processing, packaging, packing and sorting work, as well as work involving regular use of hand tools. For information on the ART tool and case study examples refer to: http://www.hse.gov.uk/MSD/uld/art/whatis.htm.

### 3.3 INTERNET SEARCHING FOR COMMERCIALY AVAILABLE PRODUCTS

An internet search for products and manufacturers was undertaken using ‘Google’ and inputting the key search terms. Also, the search sought to identify any relevant trade organisations and journals that had specific information on mechanical and automated devices; and if there are any relevant exhibitions that should be attended. Where suitable risk reduction measures were identified, organisations were approached by telephone or email for further information. A total of four manufacturers were contacted during the course of the project. Two calls resulted in site visits, while a further two provided information to include as a case study. Where pictures or photographs of equipment from company websites have been used, copyright permission has been obtained. The HSL/HSE do not endorse any specific manufacturer or product and where website links have been included they are to provide an illustration of the type of equipment that is available. All websites were current at the time of printing this report.
4. RISK FACTORS FOR UPPER LIMB DISORDERS

It is generally accepted that upper limb disorders are cumulative in nature, in that injuries may develop due to repeated exposure to certain risk factors. Furthermore, there is an increased risk of injury when there are a number of risk factors acting in combination. However, a single risk factor acting alone can create an unacceptable risk of injury if it is sufficiently great in magnitude, frequency, or duration. Risk factors that modify the development and extent of ULD are summarised in the following sections.

4.1 FREQUENCY AND REPETITION OF MOVEMENTS

Work is repetitive when it requires the same muscle groups to be used over and over again during the working day, or when it requires frequent movements to be performed for prolonged periods. Rapid or prolonged repetition may not allow sufficient time for recovery. This can cause muscle fatigue due to depletion of energy and a build up of metabolic waste materials. Repeated loading of soft tissues is also associated with inflammation, degeneration and microscopic changes.

4.2 FORCE

Use of excessive force can lead to fatigue and, if sustained, to injury, either through a single-event strain injury or through the cumulative effect of the repeated use of such force. Force can be applied through the muscles, tendons, and joints of the upper limb and can occur as a result of:

- Handling heavy objects when performing tasks;
- Fast movement or excessive force, generated to be transmitted to an external load, such as trying to undo a stiff bolt;
- Local compression and stress from items that come into contact with parts of the upper limb, such as the handle of a pair of pliers digging into the palm of the hand. This can also cause direct pressure on the nerves and/or blood vessels and increase the risk of discomfort and injury;
- Impact or shock, such as when hammering or using the hand as a tool;
- The need to grip materials, products or tools is a potential risk factor if excessive force is used; and
- Vibrating tools or equipment, as operators are likely to increase the amount of force required to grip the vibrating tool.

The ability to apply a force will largely depend on the posture the hand is held in (e.g. the closer to neutral the more force can be produced) and, the type of grip the worker uses. A power grip where the handle is held in the palm and gripped with the fingers and thumb is preferred to a pinch, or wide finger grip. A pinch grip and wide finger grip are less efficient at generating force as fewer muscles are activated and therefore less force can be produced. The amount of force required to grip is also influenced by the properties of the object. For example:

- Soft handles can improve grip, meaning lower gripping forces are required to exert a given pushing/pulling or turning force. (E.g. a screwdriver handle with a flexible grip requires less force when being used than one with a hard handle;
• The size of the object (e.g. pliers with a handle span that is too wide or too narrow will be less efficient in utilising the force generated by the hand).

4.3 WORKING POSTURE

Working postures can increase the risk of injury when they are awkward and/or held for prolonged periods in a static or fixed position. It is important to understand the concept of a ‘neutral position’. When the body or a joint is in a ‘neutral position’ it is positioned approximately in the central region of its range of joint motion. For example, the trunk and head are upright, the arms are by the side of the body, forearms are beside the body, or at a right angle to the upper arm, and the hand is in the handshake position. This is opposed to awkward postures where a part of the body is used well beyond its neutral position. For example, when employees are performing overhead work, their shoulders and arms are far from the neutral position. When awkward postures are adopted, additional muscular effort is needed to maintain body positions, as muscles are less efficient at the extremes of the joint range. Resulting friction and compression of soft tissue structures can also lead to injury.

Static postures occur when a part of the body is held in a particular position for extended periods of time without the soft tissues being allowed to relax. When holding a box, for example, it is likely that the hands and arms are in a static posture. Static loading restricts blood flow to the muscles and tendons resulting in less opportunity for recovery and metabolic waste removal. Muscles held in static postures in a non-neutral position fatigue very quickly.

4.4 DURATION OF EXPOSURE

The duration of exposure is an important concept in assessing the level of risk. Duration refers to the amount of time that a task is performed. It includes the number of hours that the task is undertaken in each shift (including the amount of time that the task is performed without a break) and number of working days the task is performed (e.g. four hours per day, five days per week).

It is generally accepted that many types of ULD are cumulative in nature. Therefore, when the duration of a person’s exposure is increased, the risk of injury is increased. This is because there may be insufficient time for recovery when parts of the body undertake work for periods without rest. Consequently, the amount of time available for the body to recover from a specific task or tasks is important. Short exposures are unlikely to create a significant risk of injury, except where the task is exceptionally demanding and/or the worker has not been allowed to build up to its demands over a period of time. This can occur after a prolonged absence from work (e.g. returning to work following a holiday) or with an increase in work pace.

4.5 WORKING ENVIRONMENT

Working environment considers the influence of factors within the physical environment that can increase the risk of ULD, such as vibration, cold, and lighting. These factors may alter how a task is performed, for example:

• Vibration. Hand-arm vibration results from the use of hand-held power tools and equipment, as well as the use of fixed machinery such as bench grinders where the worker holds the work piece. Vibration can increase the risk of ULD and these types of injuries are generally known as hand arm vibration syndrome (HAVS) that may result in a loss of sense of touch or temperature, painful joints and loss of grip strength. ART does not specifically cover the assessment of hand-arm vibration, as this is addressed as a separate health topic (for further information see http://www.hse.gov.uk/vibration/).
Cold. Working in cold temperatures, handling cold products, or having cold air blowing on parts of the body can place additional demands on the body. Exposure to cold can result in decreased blood flow to the hands and upper limbs, decreased sensation and dexterity, decreased maximum grip strength and increased muscle activity (which is part of the body’s natural response to being cold). Exposure to cold may also require the use of personal protective equipment such as thick gloves, which can make handling more difficult, and compound the risk by requiring additional force to grip items.

Lighting. The visual demands of the task are an important consideration, since a worker’s posture can be largely dictated by what they need to see. Dim light, shadow, glare or flickering light can encourage workers to adopt a bent neck and back, and poor shoulder postures in order to see their work.

4.6 INDIVIDUAL FACTORS

All individuals are different and some people will be predisposed to develop an ULD, while others will not. Some individual factors that may increase the risk of developing ULD symptoms include:

- Differences in competence and skills (e.g. new workers may need time to acquire work skills and pace of work);
- Anthropometric differences (e.g. height, weight, and reach), which can result in awkward postures, particularly at shared/standardised workstations;
- Age and health status, including a prior history of ULD symptoms;
- Individual attitudes which may affect compliance with safe working practices;
- Vulnerable groups, such as new and expectant mothers; and
- Individual attitudes or characteristics that may affect compliance with safe working practices, or the reporting of ULD symptoms.

4.7 PSYCHOSOCIAL FACTORS

A worker’s psychological response to work and workplace conditions has an important influence on health and the reporting of symptoms. Psychosocial factors include the design, organisation and management of work, the social context in which work takes place, and the impact of specific job content. Some examples of psychosocial factors that increase the risk of ULD include:

- Workers having little control over their work and work methods (including shift patterns);
- Workers not being involved in making decisions that affect them;
- Work is machine or system paced (and not monitored appropriately);
- Work is monotonous, and/or workers are not able to make full use of their skills;
- Work demands are perceived to be excessive;
- Work systems limit opportunities for social interaction;
- Payment and incentive systems encourage working too quickly or skipping breaks; and
High levels of effort are not balanced by sufficient reward (resources, status, self-esteem, remuneration).

Many of the effects of psychosocial factors occur via stress-related processes, which include direct biochemical and physiological changes. Also included are instances where individuals try to cope with stressful demands with behaviours that, in the long term, may be detrimental to health. An example is where an individual, because of high workload or deadlines, foregoes the rest breaks to which they are entitled.

4.8 RISK REDUCTION

HSE guidance ‘Upper limb disorders in the workplace’ [2] suggests a hierarchical approach to risk reduction where priority is given to elimination of risk at source. Where reasonably practicable the hazard should be eliminated by redesign of the work task, substitution or replacement of tools or components, or through automation of the task. In some cases it may be possible to isolate the risks at source by engineering controls or protective measures (e.g. by shielding the worker from draughts or by preventing exposure to vibration). Where these are not viable, the lowest order in the hierarchy of controls is to minimise risk by designing suitable systems of work, using PPE if appropriate, and to provide training.

The general principle of risk reduction, in terms of ULDs, is to reduce the number of repetitive movements and the rate at which they are made, especially where these are combined with applying force and/or awkward postures. In practice, control measures range from mechanised or partially mechanised operations [4] to programmed rest breaks. Westgaard and Winkel [5] in a review of effective ergonomic interventions for improved musculoskeletal health classified interventions as:

- **Mechanical exposure interventions.** Reducing worker exposure to risk factors such as excessive repetition, high force and awkward posture;

- **Production system interventions.** Changes to the production system and/or the company organisational culture often through a participatory ergonomics programme; and

- **Modifier interventions.** Workers are put in a better position to address existing job demands through health education, exercise, and other types of training.
5. FINDINGS FROM THE LITERATURE REVIEW

5.1 SUMMARY OF RELEVANT LITERATURE

The focus of the literature review was to identify if, and where, mechanisation and automation have been implemented in industrial tasks to reduce the risk of upper limb injury. The aim was also to identify if there is any guidance currently available in the United Kingdom and other English published literature and European sources on mechanisation and automation to reduce the risk of upper limb injuries.

In total, 27 papers were identified as relevant to the current project. Eighteen papers suggest implementing automation as a strategy to reduce the risk of ULD injury, or discuss the prevalence/incidence of ULD injuries within a particular industrial setting (e.g. [6-14]) However these were of limited value; only nine were found to contain sufficient detail to allow a thorough evaluation where an intervention to reduce the risk of ULD injury was investigated or provided useful information about ULDs and mechanisation. These studies are summarised in Table 1 and act as individual case studies where mechanical devices have been introduced or a comparison was made between mechanical devices and manual tasks.

5.2 POINTS FOR CONSIDERATION WHEN IMPLEMENTING CHANGES TO WORK SYSTEMS

Westgaard and Winkel [5] suggest that the lack of success of ergonomic interventions is probably due to the shortage of knowledge concerning ergonomic consequences of changes in production systems. They also reported how a person interacts with a production system determines the potential risk of injury. Bao et al [15] suggest that even though organisations recognise that automation in many cases could reduce or eliminate some high risk tasks, there may be a high financial cost. Organisations tend to introduce automation to primarily solve production problems or increase output, rather than to reduce the risk of injury to their workforce. As a result little thought may have been put in to the nature of the residual tasks that individuals will have to perform. Tasks such as filling machines and retrieving finished products off conveyor lines can often be repetitive and of high frequency which can present a risk to individuals developing an ULD. Therefore, despite increased mechanisation, people are still an essential part of a production system.

When introducing mechanisation/automation in the manufacturing process, all effects on the physical workload should be taken into consideration, in addition to the effect on productivity. All tasks should be designed so they can be undertaken without creating a risk of ULD. However, there is no scientifically valid screening test that can predict the future development of ULD in an individual. Placement procedures should be taken into account during risk assessment, identifying the job requirements and the individual differences. Chaffin [16] recommended that ergonomic issues should be addressed early in the system design. Therefore the tasks people will have to perform are considered at the start of the design process to enable any system changes to be made relatively easily.

To be able to achieve true variation, the work tasks involved must create different physical exposure levels. In addition, the changes between work tasks must occur with sufficient frequency during the workday.

HSE’s approach to implementing solutions to reduce the risk of ULDs is outlined in HSG60 [2]. Risks can be removed or reduced through systematic attention to some or all of the risk factors mentioned previously. Good management is the key to analysing the problems and
Efforts should be prioritised, and precedence given to tackling serious risks affecting a number of employees rather than an isolated complaint of minor discomfort;

- Great benefit often results from simple and low cost interventions (e.g. changes in working height) which are generally more practical and easier to implement;
- Employees can be especially good at devising effective and practical improvement measures;
- Consider a number of possible solutions, preferably trying them out on a small scale before deciding on one to implement;
- Check that any changes do not create new health and safety risks elsewhere;
- Successful implementation often requires the involvement of all employees from the top level downwards. Even sound ergonomic solutions may not be successful if they are imposed. Involving workers in problem solving and the implementation processes gives an enhanced sense of ownership of the solutions and may create a greater commitment to their effective implementation;
- In large, geographically-spread organisations, incorporate short-term local initiatives into the company’s overall health and safety strategy;
- Refer to case studies from other sources, (e.g. from trade associations or the internet), for ideas concerning best practice solutions;
- When considering workstation design and systems of work, do not forget the importance of the general work environment such as the condition and slip resistance of floors, workplace temperature, lighting, etc;
- Monitor the situation to make sure solutions are still effective at a later date and keep abreast of new technological developments. The solutions implemented may be superseded by better ideas in years to come.
- In many circumstances workers have to interact with mechanised systems undertaking residual tasks that could not be mechanised or automated. Careful consideration of these tasks and the work pace should be given particularly to new employees, young workers, and those returning to work from a holiday, sickness or injury and may need to be introduced to a slower rate of production than the existing workforce. This can then be followed by a gradual increase in pace. Adopting a slower pace would also be applicable to temporary workers who are unlikely to be familiar with the work task and may not be able to cope with ‘normal’ working speeds. This works best, for example, by only working for a limited time per day at production speed, increasing as appropriate. Introducing newcomers at a slower pace enables them to develop good work practices before having to concentrate on working fast, and helps them to assimilate training more effectively. Ideally, early training should be done ‘off-line’.
This study examined the consequences of technical and organisational change in a case study at a parquet flooring production plant. A comparison between manual, semi-automated and fully automated parquet flooring production lines and the tasks undertaken by workers was performed.

- Tasks on the manual and semi-automated lines were similar in terms of physical workload.
- There was more opportunity for muscle recovery on the semi-automatic line compared to the manual line, but head and upper arm postures were more restricted on the semi-automatic line. The automated line showed the highest possibility for rest.
- The work tasks changed to a more supervisory function on the automated line.
- New work tasks on the automated line were performed at irregular intervals with frequent changes according to the demands of the manufacturing process.
- The supervisory tasks showed muscular loads that are 2-3 times lower than tasks on the manual and semi-automatic lines.

**Conclusion:** Comparing the manual, semi-automated and fully automated systems shows that an increase in productivity can be achieved with a decrease in physical work demands placed on individuals. However, the tasks changed substantially and therefore new risks factors may be introduced that need to be assessed.

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Balogh, et al</strong> [17]</td>
<td>Parquet flooring production</td>
</tr>
<tr>
<td></td>
<td>This study examined the consequences of technical and organisational change in a case study at a parquet flooring production plant. A comparison between manual, semi-automated and fully automated parquet flooring production lines and the tasks undertaken by workers was performed.</td>
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<td><strong>Conclusion:</strong> Comparing the manual, semi-automated and fully automated systems shows that an increase in productivity can be achieved with a decrease in physical work demands placed on individuals. However, the tasks changed substantially and therefore new risks factors may be introduced that need to be assessed.</td>
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</tbody>
</table>
### Table 1 continued  Summary of case studies identified in the literature

<table>
<thead>
<tr>
<th>Reference</th>
<th>Intervention</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| Bao, et al [15] | Handling timber within a saw mill                                           | • The ‘machine bearers’ task varied at the four sites:  
|                 |                                                                               |   o Site 1 - Required manual manipulation of the boards.  
|                 |                                                                               |   o Site 2 - Work practices meant that heavier boards did not need to be manually manipulated, but the task had been shifted further down the production line. Therefore the risk had been transferred.  
|                 |                                                                               |   o Site 3 - Heavy boards did not need to be turned as tilting the saw modified the task and therefore the MSD risk was eliminated.  
|                 |                                                                               |   o Site 4 - Production was fully automated. The worker was only required to monitor the system and therefore the physical exposure for MSD was eliminated.  
|                 |                                                                               | • Conclusion: Changing the work practices or fully automating a system may reduce or eliminate the need for individuals to perform handling tasks, thereby reducing the risk of physical injury. The importance of assessing the entire work system is highlighted to ensure a change in the process does not introduce or transfer the risk to another worker further down the production line (as occurred in Sawmill 2). |
### Table 1 continued Summary of case studies identified in the literature

<table>
<thead>
<tr>
<th>Reference</th>
<th>Activity</th>
<th>Description</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| Coury, et al [18]  | Packing pencils   | This study compared the repetition of wrist movements and force involved in packing pencils in manual, semi-automated and fully automated operations. | - Highly repetitive tasks were identified in all packaging operations associated with the three levels of production automation.  
- The forces required to pack the pencils when comparing the three operations were not significantly different.  
- The highest frequencies of movement were observed in the semi-automated operations, followed by manual and automated workings.  
- The average duration of the work cycle was 8 seconds in the manual operation, 1 second in the semi-automated operation and 2 seconds in the automated operation.  
- **Conclusion**: The findings indicate that partial automation does not necessarily decrease or eliminate repetitive tasks performed by individuals. Therefore a risk assessment should be completed following the implementation of any new work system to ensure new risk factors have not been introduced. |
<table>
<thead>
<tr>
<th>Reference</th>
<th>Process</th>
<th>Intervention</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| Estil and MacDonald [19]        | Washing machine production – fitting the bellows gasket and tub          | This study examined the effect of mechanised operations on workers exposure to physical stressors at a household laundry assembly plant. An automatic bellows machine was introduced that required the worker to load the tub and bellows gasket into a machine, press the activation buttons to automatically fit the bellows into the tub, and then unload the assembled product. This was compared to the bellows being installed manually. | • Cycle time reduced by more than a third and as a result the production volume increased.  
• The automation of the assembly task reduced the number of physical stressors associated with the manual operation:  
  o The number of pinch grips per cycle;  
  o Peak back flexion, twisting and lateral deviation;  
  o Peak neck flexion and lateral deviation (for most workers observed);  
  o The number of workers who experienced task specific pain in their fingers.  
• The automated assembly system reduced workers ratings of physical exertion and they could keep up with production demands more often.  
• Workers were still required to manually install some of the bellows to keep up with the overall production demands (1 manual installation for every 8 mechanical installations).  
• **Conclusion:** The automation of the assembly process had a positive effect on reducing the risk of ULD, however, there still may be issues with keeping pace with the machine and some manual installation tasks are still required. |
**Table 1 continued** Summary of case studies identified in the literature

<table>
<thead>
<tr>
<th>Reference</th>
<th>Outcomes</th>
</tr>
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<tbody>
<tr>
<td>Fatallah [20]</td>
<td>A variety of agricultural tasks</td>
</tr>
</tbody>
</table>
| | This paper presents an overview of the extent of MSDs in agriculture, and a historical perspective on how ergonomics has been used to reduce the adverse health effects of labour-intensive agricultural tasks.
| | In particular it includes a summary of exposure to physical risk factors within various classes of crops, along with engineering controls for reducing MSD. Specific interventions were identified where the MSD risk has been reduced: |
| | • Automated tomato harvester; |
| | • Automatic rice threshers; and |
| | • Pneumatic power cutters. |
| | This paper also identifies other potential mechanised or automated technologies that may reduce the labour demands on workers such as the use of global positioning systems (GPS), and robots for weed control. |
| | • Tomato harvester: provided a dramatic increase in harvesting capabilities, but introduced a new set of risks to workers (e.g. high exposure to whole-body vibration, harvesting dust, and engine exhaust fumes). |
| | • Automatic rice threshers have resulted in major increases in productivity and reductions in labour by eliminating manual threshing, sifting and winnowing of rice paddy, wheat and other grains. |
| | • Bench-based pneumatic power cutters eliminate the need for manual cutting when preparing plants for propagation of future nursery crops; a task that exposes workers to severe risk of hand/wrist injury. |
| | • **Conclusion:** Some of these ergonomic solutions can easily be implemented into many agricultural situations, and many are relatively inexpensive. The greatest barrier to implement such solutions is the awareness of the employer or the worker that a solution exists. This emphasises the need for improvements in communicating and educating the affected workforce about ergonomics issues and the existence of, and accessibility to these solutions. |
| | • In addition to the development of technology the worker is an integral contributor to all aspects of developing and implementing an intervention. Further, consideration of the psychosocial and socio-cultural aspects of the work environment is crucial when effectively implementing interventions. |
### Table 1 continued Summary of case studies identified in the literature

<table>
<thead>
<tr>
<th>Reference</th>
<th>Intervention</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juul-Kristensen et al [21]</td>
<td>Chicken de-boning</td>
<td>This study compared the physical workload (force, posture, repetitive hand movements) of manual de-boning with mechanical de-boning following the introduction of a mechanised system. The mechanical de-boning system cuts the meat mechanically along the chest bone, leaving the de-boners to manually pull off the meat.</td>
</tr>
</tbody>
</table>

- The introduction of mechanical de-boning technology had only marginal effects on reducing the risk factors associated with ULD.
- When comparing the physical workload differences during manual and mechanical de-boning the differences in level of force, posture, repetition and ‘rest’ of the hand were very small and almost negligible.
- The force demands for both manual and mechanical de-boning were high, with high levels of muscular activity required.
- Mechanical de-boning did improve extreme postures of the hand compared to manual de-boning.
- **Conclusion:** Apart from an improvement in wrist posture with the introduction of the mechanised de-boning system, very little reduction in ULD risk factors were found. This highlights the importance of trialling a system prior to widespread implementation and undertaking detailed assessed to ensure risk factors have been reduced, or to highlight where new risk factors have been introduced.
**Table 1 continued** Summary of case studies identified in the literature

<table>
<thead>
<tr>
<th>Neumann et al [22]</th>
<th>Micro chip production</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>This study evaluated the impact of partial automation strategies on the productivity and biomechanical / ergonomic stressors in an electronics company that produce AC / DC converters for mobile phone transmission stations. A product cart, a wave soldering machine, in-circuit testing and automatic circuit board cutting machines were replaced by a robot assembly station and line-based conveyor system.</td>
<td>The new line system had 51% higher production volumes and 21% less labour input per product than the old batch cart system.</td>
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<td>Automation reduced transport labour by 63% and partial automation of assembly operations decreased the total amount of repetitive assembly work by 34%.</td>
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<tr>
<td>The introduction of the automated system lead to a change in the manual work resulting in an increase in time spent monitoring and feeding the assembly machines.</td>
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<tr>
<td>Where tasks could not be automated there was a significant increase in the repetitive action of the upper limbs.</td>
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<tr>
<td>Introducing a second elevated row of storage bins at the workstations increased the physical load placed on the shoulders.</td>
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<tr>
<td><strong>Conclusion:</strong> Production levels increased and there was a reduction in repetitive tasks where the operation was fully automated. However, where the tasks could not be automated an increase in repetitive actions of the upper limbs was observed to keep pace with the increase in production. This highlights the importance of assessing the work system when changes occur to identify any new risk factors that may have been introduced.</td>
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</tbody>
</table>
### Table 1 continued  Summary of case studies identified in the literature

<table>
<thead>
<tr>
<th>Reference</th>
<th>Process</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulin and Keyserling [4]</td>
<td>Automotive parts distribution</td>
<td>This study evaluated the impact of ergonomics interventions for manual materials handling operations on a network of parts distribution centres. Several solutions to reduce the manual handling burden on workers were introduced, including; self-elevating vehicle, lift and tilt pallet jacks, and telescopic conveyors.</td>
</tr>
</tbody>
</table>

- Overall, the interventions provided a reduction in exposure to MSD related risk factors. For example:
  - Self-elevating vehicle - ladder climbing, pushing carts, and shoulder elevation were eliminated or reduced, e.g. the amount of time the shoulder was in a non-neutral posture was reduced to 12%, about half of the duration when using the ladder cart.
  - Lift and tilt pallet jacks - reductions in biomechanical stresses affecting the lower back came at the cost of increases in stresses affecting the shoulders in order to reach higher vertical locations when the product was on the pallet jack.
  - Telescopic conveyors - less shoulder elevation was required to lift totes from the new conveyor. 90% of males had the shoulder strength capability to lift totes up to 18.2kg and 75% of females had the shoulder strength capability to lift totes up to 15.9kg.

- **Conclusion:** Highlights issues concerning the design and implementation of ergonomic interventions. Any interventions must be developed within the framework of the entire manufacturing system where production demands, safety concerns, work climate and other task demands must be considered.
<table>
<thead>
<tr>
<th>Reference</th>
<th>Process</th>
<th>Intervention</th>
<th>Outcomes</th>
</tr>
</thead>
</table>
| Vi [23]   | Tying steel rebar at ground level on construction sites | This study evaluated the potential reduction in risk of MSD injuries to workers when using an automatic rebar tying tool. A rebar tying tool is a battery-powered tool that is placed around the intersecting segments of rebar rods; the tool automatically feeds the wire around the bars, twists it and cuts it. It therefore eliminates the need to manually tie the rebar using pliers. | • Eliminates the need for manual tying at ground level on horizontal rebar but the tool cannot be used for vertical rebar ties.  
• Reduced repetition of hand/wrist twisting and bending.  
• Decreased exposure to awkward forward bent postures of the trunk and decreased muscular exertion.  
• Tying time was significantly reduced by about 50%.  
• Workers preferred using the tool and found that there was significantly less discomfort in the hands, arms and back compared to manual tying but reported that pliers would still remain their key tool.  
• **Conclusion:** The rebar tying tool improves posture and decreases the risk of ULD injury but may only be able to be used in certain situations (e.g. when tying at ground level). While workers could see the benefits of using the device there may be some reluctance to implement its use as they may be resistant to changing their traditional work method. This highlights the importance of having worker buy-in when trying to implement any change to a work system. |
5.3 CONCLUSIONS

The case studies reviewed highlight several key factors:

- The introduction of automated systems may increase productivity and decrease the physical work demands. However, in some situations repetitive work tasks may increase as the task variety is reduced. For example, workers are left with the residual tasks that cannot be automated easily. Automation may also result in workers having to work faster to keep pace with the mechanised system.

- The literature reviewed suggests that the use of mechanisation and automation appears to be increasing, but people will remain an important part of a production system. Careful consideration of the residual tasks and the interactions between the worker and the machines is important to ensure that the remaining risk for MSD/ULD injuries is reduced as far as is reasonably practicable.

- When changes to a work system are proposed it is important to assess the risk arising from the new arrangements. While some risk factors may be eliminated or reduced for one task, risks may be transferred to another process or task.

- Trialling a system prior to widespread implementation will help ensure that a workable solution is chosen, and getting user buy-in is of key importance in successful interventions.
Table 2 summarises the level of upper limb injury risk associated with the workplace operations that have been assessed in this report. Each entry outlines:

- The work processes observed;
- The key risk factors associated with upper limb injury assessed using the ART tool;
- The risk reduction measures introduced, including both positive and negative consequences and experiences; and
- An evaluation of the impact of these measures on ULD risk using the ART tool where applicable.

Full case studies are included in Appendix 2.
### Table 2 Summary of upper limb injury risk associated with the workplace operations assessed in this report using the ART tool

<table>
<thead>
<tr>
<th>Task</th>
<th>Task characteristics and key risk factors</th>
<th>Additional Factors/Information</th>
</tr>
</thead>
</table>
| Advent calendar stacking    | - Workers are required to sort, stack, and package advent calendars from a conveyor system into boxes.  
- Overall this task presents a low to moderate level of ULD risk but will depend on the duration of time spent performing this task (e.g. less than 2 hours is low risk and between 4-8 hours is moderate risk).  
- The key risk factors are:  
  o Very frequent arm movements that are almost continuous with similar motion pattern of the arms and hands.  
  o The sideways twisted posture of the back for more than 50% of the time. | Productivity increased as the time taken to pack boxes is decreased. Additional space and the elimination of the stacking task meant that workers were more able to keep up with production using the stacking station than when manually stacking calendars. |
| Sealing boxes               | - Flat pack boxes need to be erected by workers by taping the bottom closed and then the top when full.  
- The manual task presents a low to moderate level of ULD injury risk depending on the duration of time spent performing this task.  
- The key risk factors are:  
  o Frequent arm movements with some pauses and repetitive motion patterns while applying a moderate force for part of the time.  
  o Forward bent neck posture. | The worker still needs to place the empty carton onto and then through the sealing machine. |
| Bagging flour               | - 10kg bags of flour need to be manually selected and held in position on the bagging carousel during filling.  
- Workers perform very frequent arm movements with similar motion patterns of the arms and hands while their neck and back is bent or twisted and presents a moderate risk of upper limb injury. | Introduced an automatic bag presenter to reduce the manual bagging of flour (cannot be used for ≤10kg bags). |
<table>
<thead>
<tr>
<th>Task</th>
<th>Risk</th>
<th>Additional Factors/Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Packaging sausages</strong> (Case Study 4)</td>
<td>Moderate - High</td>
<td>An automatic pre-glued sleever was introduced that automatically places the cardboard sleeve over the packs of sausages, eliminating the manual sleeving task.</td>
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<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td><strong>Paper collating</strong> (Case Study 5)</td>
<td>High</td>
<td>Introduction of an air suction automated feed collator eliminated the need to manually collate papers.</td>
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<tr>
<td></td>
<td></td>
<td>Low</td>
</tr>
</tbody>
</table>
### Table 2 continued Summary of upper limb injury risk associated with the workplace operations assessed in this report using the ART tool

<table>
<thead>
<tr>
<th>Task Characteristics and Key Risk Factors</th>
<th>Additional Factors/Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sanding aircraft wings (Case Study 6)</strong> High</td>
<td>In this case study while the risk of upper limb injury is still high (e.g. ART score of 42 reduced to 27), the device does not help to reduce the level of repetition and workers still have to work with their hands above their heads with their necks bent. In general, manufacturers report that productivity can increase by about 50%, with a significant reduction in the force applied. The device can help to reduce hand arm vibration and accommodate ageing workers.</td>
</tr>
<tr>
<td>• Sanding is a regular part of the preparation for aircraft painting and refurbishment and the task requires individuals to work with their arms above their head with their neck bent backwards during the sanding process, for the majority of their work day.</td>
<td></td>
</tr>
<tr>
<td>• This task presents a high risk of upper limb injury and the key risk factors are:</td>
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<tr>
<td>o Very frequent arm movements that are almost continuous with similar motion patterns of the arms and hands.</td>
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<tr>
<td>o The application of a moderate amount of force for long periods of time, combined with the worker being exposed to vibration from the sander.</td>
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<tr>
<td>o The neck and back are twisted for more than 50% of the time and the arms are held above the head when using the sander.</td>
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<tr>
<td>• Introduction of a mechanised arm assisted device that bears the weight of the sanding tool.</td>
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<tr>
<td><strong>Fish filleting (Case Study 7)</strong> High</td>
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<tr>
<td>• Manual fish filleting requires workers to perform highly repetitive actions of the upper limbs when gripping and filleting the fish in a chilled environment.</td>
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</tr>
<tr>
<td>• The task presents a high risk of upper limb injury risk and the key risk factors are:</td>
<td></td>
</tr>
<tr>
<td>o Very frequent arm movements that are almost continuous with similar motion patterns of the arms and hands.</td>
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<tr>
<td>o A moderate to light force was applied for periods of time during the filleting task.</td>
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<tr>
<td>o The neck and back are held in awkward postures and the wrists operate in deviated postures.</td>
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</tr>
<tr>
<td>• Installation of a laser fish-filleting machine means that there is a reduction in the number of fish that need to be manually filleted.</td>
<td>An increase in production was observed but workers need to place fish onto the conveyor/chute and retrieve them from once filleted.</td>
</tr>
</tbody>
</table>
### Table 2 continued  Summary of upper limb injury risk associated with the workplace operations assessed in this report using the ART tool

<table>
<thead>
<tr>
<th>Task Characteristics and Key Risk Factors</th>
<th>Risk Reduction Measures</th>
<th>Additional Factors/Information</th>
</tr>
</thead>
</table>
| **Tying rebar**  
*Case Study 8*  
Moderate |  
- Rebar is a steel bar that is used in reinforced concrete structures. Workers need to ‘tie’ rebar together using wire and pliers before concrete can be poured.  
- This task presents a moderate level of upper limb injury risk to workers, and the key risk factors are:  
  - Very frequent arm movements that are almost continuous and occur over the majority of the workday.  
  - Highly repetitive twisting actions of the wrist and forearm with gripping and a low level of force applied to the pliers (e.g. when cutting the wire).  
  - Sideways twisted posture of the back for more than 50% of the time.  
- A variety of automated rebar tying machines are available but these have not been observed in use by HSL. |  
- Devices can reportedly improve posture and reduce the repetitive use of the upper limbs when tying rebar. A full assessment should be completed of any devices to indicate if any risk factors have been introduced. |
| **Potato grading**  
*Case Study 9*  
High |  
- Manual potato grading requires workers to inspect and select poor quality potatoes off a conveyor. This means that workers are performing very frequent arm movements with similar motion patterns of the arms and hands over the 8-hour workday.  
- This task presents a high risk of upper limb injury risk; the key risk factors are:  
  - Very frequent arm movements with the arms raised away from the body for more than half the time.  
  - The head/neck and back is bent or twisted.  
  - The hand/wrist are bent or deviated part of the time.  
  - Workers maintain a static standing posture for the majority of the shift.  
- Optical grading and sorting machines. |  
- Increase in the accuracy of correctly graded and sized potatoes, in comparison to manual grading. Cost savings can be made through a reduction in the number of staff required to operate the grading and sorting line. However, the majority of potatoes are still hand-checked for damage and rot that the optical sorter may have missed. Additional training may be required. |
Table 2 continued  Summary of upper limb injury risk associated with the workplace operations assessed in this report using the ART tool

<table>
<thead>
<tr>
<th>Task</th>
<th>Upper limb injury risk (Before)</th>
<th>Task characteristics and key risk factors</th>
<th>Risk reduction measures</th>
<th>Additional Factors/Information</th>
</tr>
</thead>
</table>
| Carton filling     | Moderate - High                 | Workers slide sachets from one conveyor into empty packets/cartons on a second conveyor as part of a packaging task. The upper limb injury risk level is moderate to high depending on the length of time spent performing the task. The key risk factors are:  
  o Very frequent arm movements with similar motion patterns of the arms and hands.  
  o Forward bent posture of the neck for more than 50% of the time.  
  o Deviated wrist postures for more than half the time. |  
  An automatic cartoner could be used for this task but was not observed. Information about other applications of automatic cartoners’ are provided in this case study. | Low  
  Cartoners’ can automatically fill packets thereby reducing the risk from ULDs (e.g. eliminate repetitive arm moments). They are fast, easy to use, and relatively inexpensive. However, the finished product still needs to be manually packed in boxes and palletised which is still repetitive and labour intensive. |
| Labelling          | High                            | Manual labelling tasks require workers to peel off labels and apply them to a product. This case study requires workers to lift a bottle off a conveyor, place the label on the bottleneck and replace the bottle onto the conveyor.  
  This task presents a high injury risk of ULD; the key risk factors are:  
  o Repetitive and similar motion patterns of the arms are performed for the majority of the time using a pinch grip.  
  o The head and neck are bent for more than half the time and the shoulder and arms are held away from the body.  
  o There is no job rotation and workers often find it difficult to keep up with production demands. |  
  A number of automated labelling machines are available that can apply labels to a wide variety of products, however to our knowledge these have not been applied to the task described here. | Low  
  Eliminates the need to manually label items, reducing injury risk. The use of automatic labelling applications can reduce production bottlenecks as the machine keeps pace with production demands. Facilitates accurate product labelling i.e. batch numbering, serial number, and use by dates, etc. |
Table 2 continued Summary of upper limb injury risk associated with the workplace operations assessed in this report using the ART tool

<table>
<thead>
<tr>
<th>Task</th>
<th>Risk level</th>
<th>Task characteristics and key risk factors</th>
<th>Risk reduction measures</th>
<th>Additional Factors/Information</th>
</tr>
</thead>
</table>
| Bread making (Case Study 12) | Moderate   | • Workers are required to load and unload a reel oven with trays of baked bread.  
• This task presents a moderate level of upper limb injury risk; the key risk factors are:  
  o Repetitive arm movements with similar motion patterns of the arms and hands while applying a pinch grip to hold the trays.  
  o Awkward postures of the head/neck and back.  
  
  
Introduction of a robot-on-a-reel oven that eliminates the manual loading and unloading tasks.  
Low  
Reduction in ULD risk as manual loading and unloading of the oven were eliminated due to automation. The capacity of the reel oven was increased by 80%, with an associated energy saving of around 50%. However, several problems arose that had not been accounted for during the implementation phase, which meant that over time the robot could have difficulties in picking up the trays, ultimately leading to its removal. |
| Biscuit production (Case Study 13) | Moderate   | • Workers repetitively use cutters to manually cut shapes into dough and place them on baking trays.  
• This task presents a moderate level of upper limb injury risk; the key risk factors are:  
  o Very frequent arm movements with similar motion patterns of the arms and hands.  
  o Head/neck and back postures that are bent or twisted.  
  o The cutting tool is struck against the hand more than ten times per minute.  
  
  
Introduction of an automatic cookie-cutting machine that eliminates the need for manual cutting.  
Low  
The frequent and repetitive arm movements associated with manual cookie cutting have been eliminated. Production has increased as the cookies can be cut at a higher rate compared to when they are manually cut. |
### Table 2 continued Summary of upper limb injury risk associated with the workplace operations assessed in this report using the ART tool

<table>
<thead>
<tr>
<th>Additional Factors/Information</th>
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<tbody>
<tr>
<td>Introduction of an industrial robotic arm that eliminates the need for manual palletising.</td>
</tr>
</tbody>
</table>

**Palletising containers** *(Case Study 14)*  
**High**  
- Products are frequently manually handled from conveyors and placed onto pallets. This case study refers to the palletising of grout and adhesives.  
- This task presents a high level of upper limb injury risk; the key risk factors are:  
  - Very frequent arm movements associated with the picking and placing of buckets of grout with the arms held away from the body when placing the grout onto the pallet.  
  - Sideways twisted posture of the back for more than half the time.  
  - Pinch or wide finger grip for more than half the time when picking and placing buckets.  
  - The pace of work is dictated by the production rate.  

**Low**  
- Repetitive handling of 1-5kg loads are eliminated and therefore so too is the ULD risk. However, two new tasks are introduced where: workers have to manually load a conveyor with empty buckets, which are automatically filled, and then place lids on top of the buckets by hand as lids are difficult to automate due to machine and lid/bucket tolerances.
7. APPENDICES

Appendix 1: ART Flowchart;

Appendix 2: Individual case studies.
APPENDIX 1 ART FLOWCHART

Stage A: Frequency/Repetition
- In frequent (e.g., some intermittent movement)
- Frequent (e.g., regular movement with some pauses)
- Very frequent (e.g., almost continuous movement)

Stage B: Arm Movements
- Arm repetitions

Stage C: Awkward Postures
- Almost neutral
- Bent or twisted part of the time
- Bent or twisted more than half of the time

Stage D: Force
- See grid on page 9 of the assessment guide
- Elbow close to the body or the arm is supported
- Elbow raised away from the body or part of the time
- Elbow raised away from the body more than half of the time

Stage E: Arm Posture
- Almost neutral/straight
- Bent or twisted part of the time
- Bent or twisted more than half of the time

Stage F: Wrist Posture
- Power grip or no awkward grip
- Pinch or side finger grip for more than half of the time
- Pinch or side finger grip for part of the time

Stage G: Hand/Finger Grip

Stage H: Duration
- Less than 2 hours
- 2 to less than 4 hours
- 4 to 8 hours
- More than 8 hours

Stage I: Other Factors
- No factors present
- 1 factor present
- 2 or more factors present

Stage J: Additional Factors
- Task score
- Exposure score

Stage K: Exposure Score

Stage L: Task Score

Stage M: Duration

Stage N: Exposure Score

Stage O: Frequency Score

Stage P: Force Score

Stage Q: Posture Score

Stage R: Additional Factors Score

Left hand

Right hand

30
APPENDIX 2 CASE STUDIES

Case studies are provided in the following sections where automation or mechanisation have been shown to reduce the risk of upper limb injuries to workers.

1. **Case Study 1: Advent calendar stacking.** Compares a manual stacking task of advent calendars off the production line with an automated stacking machine.

2. **Case Study 2: Sealing boxes.** Compares a production line task where boxes are manually sealed with an automated box-sealing device.

3. **Case Study 3: Bagging flour.** Compares manual tasks when interacting with machinery to fill bags of flour with more automated systems.

4. **Case Study 4: Packaging sausages.** Compares manual packing of sausages with an automated machine.

5. **Case Study 5: Paper collating.** Compares a manual paper-collating task with an automated paper-collating machine.

6. **Case Study 6: Sanding aircraft wings.** Compares manual sanding of aircraft wings with a sanding operation using a robotic arm that takes the weight of the sanding equipment.

7. **Case Study 7: Fish filleting.** Compares a manual fish-filleting task with an automated laser fish-filleting machine.

8. **Case Study 8: Tying rebar.** Compares manual rebar tying using pliers with mechanised rebar tying equipment.

9. **Case Study 9: Potato grading.** Compares manual potato grading with an automated grading machine.

10. **Case Study 10: Carton filling.** Compares manually inserting sachets into cartons with an automated carton-filling machine.

11. **Case Study 11: Labelling.** Provides an example of different labelling machines.

12. **Case Study 12: Bread making.** Compares manual loading and unloading of ovens with an automated system.

13. **Case Study 13: Biscuit production.** Compares manually cutting biscuit dough with an automated biscuit cutter.

14. **Case Study 14: Palletising containers.** Provides an example of an automated robotic arm that handles loads off a conveyor and onto a pallet.
CASE STUDY 1: ADVENT CALENDAR STACKING

THE PROBLEM: MANUAL STACKING
Advent calendars are produced over a six-month period and require individuals to sort, stack, and package them from a conveyor system. The calendar-stacking task presents a low to medium level of upper limb injury risk to workers depending on the duration of time spent performing this task.

TASK DESCRIPTION AND DETAILS
This task requires the worker to:
- Collect individual advent calendars as they exit the wrapping machine via a conveyor belt. The calendars are collated in stacks of 10-15 ready for packing in boxes for distribution;
- Two more workers then take the stacked calendars and place them in boxes, which they make up;
- Advent calendars weigh 60g each and the worker stacks 40 calendars per minute, requiring little force;
- The shift pattern is 06:00-14:00, 14:00-22:00, or 22:00-06:00, with three 15 minute breaks throughout the shift;
- Workers carry out this task daily and rotate to other tasks throughout their shift, working no longer than 2 hours on any particular task.

ULD RISK FACTORS AND ART ASSESSMENT
A medium level of upper limb injury risk to workers was assessed using the ART tool; the findings are presented in Table A1. The key areas of concern when stacking advent calendars are:
- Very frequent arm movements that are almost continuous;
- Similar motion pattern of the arms and hands that are repeated more than 20 times per minute; and
- The sideways twisted posture of the back for more than 50% of the time.
**Table A1** Summary of upper limb injury risk using the ART tool when manually stacking advent calendars

<table>
<thead>
<tr>
<th></th>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td></td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td></td>
<td>R6</td>
</tr>
<tr>
<td>B Force</td>
<td></td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td></td>
<td>A2</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td></td>
<td>A2</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td></td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td></td>
<td>G0</td>
</tr>
<tr>
<td><strong>Task score</strong></td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Exposure score</strong></td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Low*: consider individual circumstances</td>
<td>Low*: consider individual circumstances</td>
</tr>
</tbody>
</table>

* If the task were undertaken for between 4-8 hours then it would represent a medium level of upper limb injury risk.

**POSSIBLE SOLUTION: AUTOMATIC STACKING STATION**

An automatic stacking station was introduced in an attempt to reduce the level of risk that operators on the advent calendar production line are exposed to. Photographs 2-4 show the stacking station and the steps involved during the automated process. The machine automatically stacks 10 calendars together and therefore the worker is performing fewer repetitive actions of the upper limbs to collect them from the machine.

Advent calendars are delivered to the stacking station via conveyor. Workers collect stacked calendars from the machine.

**Photograph 2** Conveyor system transporting calendars to stacking station
A worker places a box onto the stacking machine  

Stacked calendars are collected from the machine  

Stacks of calendars are placed into boxes

Photograph 3 Automatic stacking station

Once the calendars are collected from the machine and placed into boxes they are fed through the box-sealing machine shown in Case Study 2.

Details

- The initial cost of the stacking station was £29,000, with a payback period of less than one year. Cost savings were made through a reduction in the number of staff (from three operators to one operator) required to operate the advent calendar line (staff have been moved to other production lines).

- The station is capable of stacking 36 units per minute and currently processes 10,000,000 calendars per season (calendars are produced for six months of the year).

- The stacking station is an off the shelf product that complements the company’s existing equipment, and maintenance is minimal.

- The stacker contains a small number of basic moving parts and the company have an on-site team of engineers who fix problems as and when they arise.

- The introduction of the stacking machine allowed for a conveyor belt to be removed from the end of the production line. This smaller footprint allowed more circulation space for other lines on the production floor as the process is slightly shorter. The space saved also allows the operator to use a box-sealing machine (Case Study 2), which in previous years could not be used because the space was needed to accommodate the staff required to keep pace with production.

Benefits

- The introduction of the advent calendar-stacking machine has served to reduce the demands placed on the operator during the stacking task.

- The frequency and repetition of arm movements and back posture have been improved and is highlighted by the ART assessment shown in Table A2.

- The number of operators working to pack the advent calendars for transportation has reduced, but this may have increased the individual’s workload, as they are required to fill boxes at a faster rate. However, the calendars exit into a buffer area that allows for several stacks to build up giving the operator time to perform other tasks (e.g. changing pallets), as and when required. This provides the operator with a series of micro-breaks throughout the course of the workday. These additional tasks use different muscle groups to those used in the packing of advent calendars.
### Table A2 Summary of upper limb injury risk using the ART tool using the advent calendar stacking station

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>A3</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>G0</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>A1</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>G0</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>G0</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>A1</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A2</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
</tr>
<tr>
<td><strong>Task score</strong></td>
<td>8</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Exposure score</strong></td>
<td>4</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Low: Consider individual circumstances</td>
</tr>
</tbody>
</table>
CASE STUDY 2: SEALING BOXES

THE PROBLEM: SEALING BOXES MANUALLY

The final stage of advent calendar production requires workers to pack the completed products into larger boxes where they are sealed using a box-sealing machine. This task requires repetitive use of the upper limbs and presents a low to medium risk of upper limb injury depending on the duration of time operators spend at this workstation.

TASK DESCRIPTION AND DETAILS

This task requires the worker to:

- Pick up the flat sheets of cardboard and manually erect the boxes by taping the bottom closed;
- Fill the boxes with the advent calendars and tape the top shut;
- Make frequent and repetitive use of the upper limbs requiring a light to moderate level of force;
- The shift patterns are 06:00-14:00, 14:00-22:00, or 22:00-06:00, with three 15 minute breaks throughout the shift; and
- Carry out this task daily and rotate to other tasks throughout their shift, working no longer than 2 hours on any particular task.

HSL did not have any photographs of the manual box-sealing task for the advent calendar line, but did observe this task by operators working on the gingerbread packing line (Photograph 4a-d).

HSL did not have any photographs of the manual box-sealing task for the advent calendar line, but did observe this task by operators working on the gingerbread packing line (Photograph 4a-d).
ULD RISK FACTORS AND ART ASSESSMENT

Under the circumstances described in this case study the box sealing task presents a low to medium level of upper limb injury risk to workers (Table A3). The organisation has mitigated some of the risk by using job rotation to reduce exposure so that operators spend less than 2 hours on the task. If the task were performed for more than 2 hours, workers would be exposed to a medium level of upper limb injury risk. The key areas of concern when manually sealing boxes are:

- Frequent arm movements with some pauses and similar motion patterns;
- Neck posture that is bent or twisted for more than half the time; and
- Applying a moderate force for a part of the time.

Table A3 Summary of upper limb injury risk using the ART tool to manually seal boxes

<table>
<thead>
<tr>
<th></th>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>A3</td>
<td></td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>A3</td>
<td></td>
</tr>
<tr>
<td>B Force</td>
<td>A2</td>
<td></td>
</tr>
<tr>
<td>C1 Head/posture</td>
<td>R2</td>
<td></td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>A2</td>
<td></td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>C5 Hand/finger</td>
<td>G0</td>
<td></td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A2</td>
<td></td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
<td></td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
<td></td>
</tr>
<tr>
<td>Task score</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Duration multiplier</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Exposure score</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Low*: consider individual circumstances</td>
<td>Low*: consider individual circumstances</td>
</tr>
</tbody>
</table>

* A medium score would be seen if the task was performed for more than 2 hours.

POSSIBLE SOLUTION: AUTOMATIC BOX SEALER

An automatic stacking station (Case Study 1) was introduced in an attempt to reduce the level of risk that operators on the advent calendar production line were exposed to. An automatic box sealer was also introduced. This machine eliminates the need for operators to manually seal boxes, however, they are still required to perform some functions and interact with the machine. Firstly, the operator opens out the flat pack box and places the bottom flaps into the box sealer. The box is then manually filled with the stacks of advent calendars and then the boxes are pushed through the box-sealing machine (Photograph 5a&b). Runners on the machine fold both the top and bottom flaps down and applies tape to both ends as the box passes through the
machine. The sealed box then passes along the conveyor where they are stacked on to a pallet (Photograph 6a&b).

**Details**

- The box sealing machine is an off the shelf product that complements the company’s existing equipment.
- The box-sealing machine has a limited number of parts and maintenance is minimal.
- Operators must ensure the tape dispenser is kept full.

**Photograph 5** Box sealing machine automatically sealing boxes

**Collecting box from the sealing machine**

**Photograph 6** Operator using the box sealing machine to seal full boxes

**Benefits**

- Quick and efficient to seal boxes with reduced repetitive actions of the upper limbs.
- Machines can be used for fixed or random sized boxes.
- Easy to adjust to allow for quick changes between box sizes.
CASE STUDY 3: BAGGING FLOUR

THE PROBLEM: MANUAL BAGGING

The two main elements of bagging flour are the bagging scales and the bagging carousel. The bagging scale allows the accurate weighing of flour while the bagging carousel is used to pack open-mouth bags ranging between 10kg and 50kg, at a rate of approximately 18 bags per minute. The line is designed for a minimum of two operators working in either production: bag filling, sealing, stitching and metal checking; and packing, monitoring the automatic pallet stacker and pallet wrapper, and operating the forklift to move pallets.

The process of bagging flour is largely automated, however the automatic bag presenter cannot handle the smaller sized 10kg bags. Incorrect placement on the carousel can cause spillages, waste and production delays and therefore the bags must be presented to the bagging carousel manually, which presents a medium level of upper limb injury risk to workers.

TASK DESCRIPTION AND DETAILS

- When manually placing the smaller 10kg bags on the carousel the worker has to:
  - Pick and place the flour bag on the hopper, holding it in the correct location for the carousel’s automatic arms to secure the opening of the bag prior to filling;
  - 10kg bags are filled at approximately 300 per hour (about 5 per minute);
  - The work is machine-paced, although workers did not report difficulties keeping pace with the machine;
  - The work system means that operators should only spend three hours manually packing per day. Operators regularly switch between manual and automatic bag filling; and
  - The work is performed over three shifts, 5 days a week (06:30-14:00, 14:00-21:30 and 21:30-05:00).

Selecting individual 10kg bags to load into the bagging carousel  
Filling the bagging carousel with individual 10kg bags

 Photograph 7 Manually presenting flour bags on the bagging carousel
ULD RISK FACTORS AND ART ASSESSMENT

A medium level of upper limb injury risk to workers when undertaking the manual flour-bagging task was assessed using the ART tool and the risks are shown in Table A4. The key areas of concern for upper injury when manually presenting the flour bags are:

- Very frequent arm movements that are almost continuous;
- Similar motion pattern of the arms and hands that is repeated up to 20 times per minute; and
- The bending and twisting of the neck and back for part of the time.

Table A4 Summary of upper limb injury risk using the ART tool when manually bagging flour

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>A3</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>A1</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>A2</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>G0</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>G0</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A4</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
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<tr>
<td><strong>Task score</strong></td>
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</tr>
<tr>
<td><strong>D4 Duration multiplier</strong></td>
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<tr>
<td><strong>Exposure score</strong></td>
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</tr>
<tr>
<td>Estimated exposure level</td>
<td>Medium: further investigation required</td>
</tr>
</tbody>
</table>

POSSIBLE SOLUTION: AUTOMATIC BAG PRESENTER

Details

- Photograph 8a&b show the automatic bag presenter used when filling 16-25kg bags. Bags are currently filled at 400-450 per hour. The machine automatically selects each individual bag (Photograph 8a); it is automatically opened (Photograph 8b) where it is ready to be filled.
Once each bag is automatically filled with flour, the open-mouth bags pass along the production line where they are automatically closed (Photograph 9a) and then sealed (Photograph 9b) at the bag closing station. The machine can handle bagged weights ranging from 10-50kg and empty bag widths of 400-620mm. The system is capable of sealing up to 14 bags per minute.

When using the automatic bag presenter, the main task of the worker is to ensure that the machine hopper is loaded with enough bags. Otherwise, they perform a supervisory role overseeing production (bag filling, sealing, stitching and metal checking), and problem solving as and when issues arise.

Maintenance is minimal and an onsite maintenance team can fix problems when they arise.

The machine observed during the site visit is 30 years old and is refurbished on a regular basis with the bearings being replaced every six months. During this time production ceases for a full 24 hour period. The organisation were quoted £1.2 million to replace the line including the scale, carousel, bag closing station, the automatic bag presenter, conveyors and the robotic palletising and pallet wrapping machines. There may be opportunities to purchase second-hand equipment.

No cost-benefit analysis has been performed due to the age of the equipment, however there is an increase in production associated with using the automatic bagging machine compared to manual bagging.

There were no specific injuries reported, but there were complaints about having to manually pack the bags. Many of the complaints were associated with having to job rotate as the majority of workers have a preference for production or packing.
• The company has invested in a series of automated systems so that the workers do not have to keep pace with the increase in production.

• Photograph 10a-d and Photograph 11a&b show the process after the bags have been filled and sealed. The sealed bags are transported by conveyor to the packaging area (Photograph 10a) where a robotic palletising machine stacks the flour (Photograph 10b&c). Finished pallets are transported by forklift from the conveyor (Photograph 10d) to a pallet-wrapping machine and then into the storage racking until they are required for dispatch (Photograph 11a&b). Risks associated with heavier manual handling tasks are also reduced.

**Benefits**

• Reduction in frequent and repetitive use of the upper limbs compared to when manually presenting 10kg flour bags.

• Increase in production levels.

• Reduced manual handling of full sacks off the conveyor by using the robotic palletising and wrapping machines.
CASE STUDY 4: PACKAGING SAUSAGES

THE PROBLEM: MANUAL PACKING

Workers have to repetitively pick packaged sausages off a conveyor and slide a cardboard sleeve over them. While this task is repetitive, job rotation means that the exposure to the task and subsequent level of ULD risk is low. However, job rotation has occurred as a result of previous complaints of upper limb injuries. A medium-high level of ULD risk would be expected if workers undertook this task for the duration of their workday and that might be the case in other factories.

TASK DESCRIPTION AND DETAILS

- The worker opens a cardboard sleeve with their right hand and slides the packaged sausages into position (collected as they exit the shrink-wrapping machine via conveyor belt) with their left hand (Photograph 12a&b). The completed pack is then placed back on to the conveyor with their right hand where it is packaged by another worker further down the line (Photograph 12c);
- The packs of sausages weigh 454g each and there is little force required during the sleeving process;
- The worker sleeves an average of 30 packs per minute (PPM) and sometimes find it difficult to keep up with the work;
- Workers carry out this task daily while rotating to other tasks at regular intervals throughout their shift (approximately every 30 minutes to 2 hrs); and
- The shift pattern is 06:00-14:00, or 14:00-22:00, with three 15 minute breaks throughout the day.

Photograph 12 Manual application of cardboard sleeves
ULD RISK FACTORS AND ART ASSESSMENT

Under the circumstances described in this case study, the sausage-sleevi ng task presents a low level of upper limb injury risk to workers. However, the main reason that the task was assessed as low risk is the duration multiplier as the organisation had implemented administrative controls by imposing a two-hour maximum limit on the manual sleeving task. If this task is performed for more than 2 hours or over the duration of the workday then workers may be exposed to a medium-high level of ULD risk. The ART assessment is shown in Table A5 and the key areas of concern when manually sleeving packs of sausages are:

- Very frequent arm movements that are almost continuous;
- Similar motion pattern of the arms and hands that is repeated more than 20 times per minute;
- The worker’s head/neck is bent sideways and down for more than half the time;
- The wrists are bent for more than half the time while gripping and positioning the cardboard sleeve; and
- The right hand spans and grips the cardboard sleeve for more than half the cycle time.

Table A5 Summary of upper limb injury risk using the ART tool when manually packing sausages

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>R6</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>G0</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>A2</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>R2</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>R2</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A2</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>A1</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
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<tr>
<td><strong>Task score</strong></td>
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<tr>
<td><strong>Exposure score</strong></td>
<td>11.5</td>
</tr>
<tr>
<td><strong>Estimated exposure level</strong></td>
<td>Low-High*: Further investigation required</td>
</tr>
</tbody>
</table>

* A medium to high score would be seen if the task was performed for more than 2 hours.
POSSIBLE SOLUTION: AUTOMATED SAUSAGE PACKING/SLEEVING MACHINE

A fully automatic ‘pre-glued sleever’ was introduced in an attempt to reduce the level of risk that operators on the sausage packing line were exposed to. The machine is an automatic means of placing a pre-glued cardboard sleeve over a product that is in a semi rigid plastic tray. Photograph 13a-d shows the process where a label is automatically placed on the shrink-wrapped sausages (a), the sausages pass through the automatic sleeving machine (b) before being packed into boxes and then automatically sealed (c). Photograph 13d shows where the cardboard sleeves need to be inserted into the hopper/magazine.

Details

- The initial cost of the machine ranges between £60,000 and £80,000, depending on the machine specification.
- The parts can be changed to enable the machine to be modified to suit a number of different product tray dimensions, but the range of parts available adds to both the cost and complexity of the operation. Changeovers are relatively quick and easy, but the more product changes required, the greater the potential for the operation to become difficult and time consuming. However, over time operators and engineers will become familiar with the machines so downtime and speed of changeover should improve.
- In general, maintenance issues are minimal as the company undertakes a basic weekly/monthly preventative maintenance programme to manage the moving parts (greasing, oiling etc).
- Productivity has increased with the automated sleeving device. A high specification design can handle up to 100 PPM, but maintaining this at a constant rate can be problematic. The machines observed peak at around 80 PPM and average approximately 60 PPM. In comparison, an operator can typically produce an average of 30 PPM. Manually dextrous operators may reach speeds of up to 60 PPM, but can only sustain this for short periods of time. The production rate has doubled as a consequence of introducing the automatic sleever.
- When using the automatic sleever the main task of the worker is to oversee the operation of the machine, ensuring that the sleeve magazine is kept topped up and that the packs enter and exit the machine in an appropriate manner. As output increases, an additional person is required to assist further down the production line to cope with the demands placed on operators packing the completed product. The introduction of the extra worker ensured that there were no additional pressures placed on existing staff that could lead to an increase in the reporting of ULD injuries. Taking these factors into account, payback on a single automatic sleeving machine is approximately 20 months.
- How the sleeve behaves is crucial to the success of the machines efficiency, and is directly associated with its design and the material from which it is made. Therefore it is essential to involve the cardboard sleeve supplier in the development of the cardboard sleeve to be used with the sleeving machine.
- Where possible, a machine should be dedicated to a single tray size to avoid product changeovers and machine maintenance should be performed regularly.
- It is unlikely the machine will be up and running at full speed within 24 hours of commissioning as it takes time to perfect the sleeving process. Assuming only a 50% output for the first month or so is recommended.
Automatic label applicator places label on sausage shrink-wrap

Sausages pass through the automatic card board sleever

Box sealing machine

Cardboard sleeve magazine and machine

Cardboard sleeves on hopper

Photograph 13 Automatic application of cardboard sleeves

Benefits

• Increase in productivity.
• Reduction in ULD risk due to automation.
• Cost-effective solution, with machinery paying itself back in approximately 20 months.
• Can be modified to use on a variety of product tray dimensions but may take time to undertake the changeover of parts.

An auto-leveller device was also observed at the beginning of this process where the trays of sausages are loaded onto the end of the packaging conveyor (Photograph 14a&b). It rises automatically when a tray is lifted off and ensures the trays are always level with the conveyor.

Auto-leveller raises the height of the sausages to the conveyor height

Photograph 14 Auto-leveller at the end of the conveyor
CASE STUDY 5: PAPER COLLATING

THE PROBLEM: MANUAL COLLATING

Individuals are required to collate document pages. The task requires highly repetitive use of the upper limbs with the neck bent forward for more than half the time of the collating process. Workers are exposed to a high level of upper limb injury risk when manually collating papers.

TASK DESCRIPTION AND DETAILS

This task requires the worker to:

- Collate pages together into a document, which will eventually be bound together. In this instance there were 14 pages in each document and about 5 documents are made per minute;
- A low level of force is required to undertake this task;
- The work shift is from 07:45-16:30 with a 15 minute break at 09:45 and a lunch break between 12:00-12:45;
- The worker sets their own pace and does not find it difficult to keep up with the work;
- The work is carried out in a well-lit environment, and there are no other factors reported; and
- There is little or no task rotation.

ULD RISK FACTORS AND ART ASSESSMENT

Under the circumstances described in this case study the paper-collating task presents a high level of upper limb injury risk to workers. A video of the manual collating task is available at: http://www.hse.gov.uk/msd/uld/art/papers.htm. Table A6 presents the ART assessment of risk of upper limb injury that operators are exposed to. The key areas of concern when manually collating paper are:

- There is almost continuous arm movement with 14 similar motion patterns of the arms and hands within a cycle time of about 12 seconds;
- The worker’s head/neck is bent for more than half the time when looking down at the papers;
- The back is twisted sideways for more than half the time when walking in either direction;

Photograph 15 Postures observed during the manual collating task
The left wrist extends back for part of the time when picking papers and the right wrist is flexed forward for a part of the time when holding the papers; 

The right hand holds the papers in a pinch grip for more than half the time; and 

The worker performs the task for 8 hours per day and may work longer than 3 hours on this task before having a break.

Table A6 Summary of upper limb injury risk using the ART tool when manually collating paper documents

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>R6</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>R2</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>G0</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>A1</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>G0</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>R6</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
</tr>
<tr>
<td>Task score</td>
<td>23</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>1</td>
</tr>
<tr>
<td>Exposure score</td>
<td>23</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>High: further investigation required urgently</td>
</tr>
<tr>
<td></td>
<td>High: further investigation required urgently</td>
</tr>
</tbody>
</table>

POSSIBLE SOLUTION: AIR SUCTION FEED COLLATOR

An air suction feed collator was introduced in an attempt to reduce the level of risk that operators are exposed to when collating papers manually.

Details

- The machines are provided ‘built to order’ and a number of basic models are available, which can be adapted to fit a variety of sheet sizes, number of feeders, etc, and can be combined with other binding machines including stitch, fold, trimmers and in-line film wrapping machines.

- Under normal operating conditions, the machine requires minimal adjustment. A set of adjustable clamps is used to define the size of the in-tray and the machine can be adjusted to fit a variety of paper sizes and product weights (20-1000g).

- The collator is capable of performing 3000 collations per hour (CPH) and has auto-calibrating electronic double and miss detectors that identify incorrect collations as and
when they occur. The machine stops production and alerts the operator as to where the missed/duplicated page has occurred.

- The use of the auto-collator introduces new tasks for the operator:
  - Supervisory role: Operators need to make sure that the pages are loaded into the feeding stations in the right order and in sufficient number to complete the production run with the minimal number of stoppages. During the run the operator fulfils a supervisory control function where their only involvement is to reset the collator when the double/miss detectors signal a fault.
  - Feeding: Bundles of papers are fed into the machine at various positions and the collated or assembled booklets are removed from the other end. The principal action during this process is the gripping of various widths of paper.
  - Knocking-up: Air is introduced between the various sheets of paper by vigorously bending the sheets up and down. During this process the operative has to firmly grip each edge of the paper bundles to allow the process to be undertaken.

![Photograph 16 Air suction paper collator](image16)

![Photograph 17 Air suction paper collator](image17)

**Benefits**

- The frequency and repetition of arm movements and back posture have been improved by the introduction of the auto-collator. However it has introduced new tasks when setting-up the auto-collator that may expose the worker to ULD risk factors which would need to be assessed.
- The most significant reduction is in the amount of time spent performing the task; the machine takes around 30 minutes for a full production run, which lasts around three hours. This means that a worker may spend around one hour over the course of the total shift undertaking the ‘knocking-up’ task.
• Despite the reduction in physical demand afforded by the auto-collator, several key areas of concern remain. For example:
  o The left wrist is bent for part of the time when picking papers and the right wrist is flexed forward for a part of the time while holding the papers.
  o Both hands are used to hold the papers in a pinch grip for more than half the time. Operators may therefore suffer problems associated with continuous gripping, lifting and fanning widths of paper, when using automated collators.

• The auto-collator also has a ‘jogger’ function (Photograph 18a&b) whereby the paper is gently vibrated to align page edges for efficient document gathering, folding, and binding. It also removes paper dust and static generated on printed/copied papers. In order to distinguish each set from the next, the criss-cross jogger rotates through 15° on completion of each set, producing an offset stack of individual sets.

• To manually complete the ‘jogging’ task workers would need to fan the paper before jogging, requiring them to grab and lift the paper from opposite ends, bend the edges and lift them in towards each other, while tightly holding the edges of the bent stack and then straighten it out, releasing the edges of the stack to let the sheets straighten out. Workers would have to repeat this procedure two or three times per stack to loosen all the sheets. This would be a highly repetitive and physically demanding task similar in nature to the ‘knocking-up’ task. However, introducing the criss-cross paper jogger, the overall level of risk that the worker is exposed to is reduced. An example of manually ‘jogging’ paper is presented on the HSE website at: http://www.hse.gov.uk/msd/uld/art/jogging.htm.

The ART assessment (shown in Table A7) when setting-up the auto-collator is considered to be low risk. The assessment shows that the level of upper limb injury risk is reduced compared to the manual collating task that is considered to present a high risk to individuals (Table A6).
### Table A7 Summary of upper limb injury risk when using the ART tool when setting up the auto-collator

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>A3</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>A3</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>G0</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>A2</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>R2</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>A1</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>G0</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
</tr>
<tr>
<td><strong>Task score</strong></td>
<td>13</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Exposure score</strong></td>
<td>6.5</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Low: Consider individual circumstances</td>
</tr>
</tbody>
</table>
CASE STUDY 6: SANDING AIRCRAFT WINGS

THE PROBLEM: MANUAL SANDING OF AIRCRAFT WINGS

Sanding is a regular part of the preparation for aircraft painting and refurbishment. Airlines and aircraft manufacturers generally have dedicated teams that perform sanding in their aircraft refurbishment and paint facilities. Traditionally, this area has been one of the most labour intensive operations during the final paint and refurbishment process and has been identified as a major production bottleneck. The task requires individuals to work with their arm(s) above their head with their neck bent backwards and trunk extended during the sanding process for the majority of their workday and presents a high level of ULD injury risk.

TASK DESCRIPTION AND DETAILS

- The bulk of sanding is typically performed using small handheld orbital palm sanders due to their ability to navigate tight spaces and provide a high quality surface finish;
- Large surface areas are involved which require overhead use of tools and awkward reach angles;
- A considerable amount of force needs to be applied for long periods of time, combined with the worker having to withstand vibration from the sander; and
- This task is performed for the majority of the workday.

ULD RISK FACTORS AND ART ASSESSMENT

Under the circumstances described in this case study the manual sanding task presents a high level of upper limb injury risk to workers. The ART assessment shown in Table A8 highlights the risk of upper limb injury that operators are exposed to when performing the manual sanding task. However, this task was not observed by HSL and the assessment is based on information provided by the manufacturer. The key areas of concern are:

- Very frequent arm movements that are almost continuous and occur over the majority of the workday;
- Similar motion pattern of the arms and hands that is repeated more than 20 times per minute while applying a strong level of force over the majority of the working day;
- Bent or twisted head/neck and back postures more than half the time with the arm(s) held above the head; and
- Exposure to hand arm vibration (HAV) from the sanding tool.

1 Note: This task is based on an internet case study and was not observed by HSL researchers.
Table A8 Summary of upper limb injury risk using the ART tool when manually sanding aircraft wings

<table>
<thead>
<tr>
<th></th>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Arm movements</td>
<td>G0</td>
</tr>
<tr>
<td>A2</td>
<td>Repetition</td>
<td>G0</td>
</tr>
<tr>
<td>B</td>
<td>Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1</td>
<td>Head/neck posture</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>Back posture</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>Arm posture</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>Wrist posture</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>Hand/finger grip</td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>Breaks</td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>Work pace</td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>Other factors</td>
<td></td>
</tr>
<tr>
<td>Task score</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>D4</td>
<td>Duration multiplier</td>
<td>1</td>
</tr>
<tr>
<td>Exposure score</td>
<td></td>
<td>11</td>
</tr>
</tbody>
</table>

Estimated exposure level

- Low*: Consider individual circumstances
- High: further investigation required urgently

* The worker is likely to use both arms when sanding so the risk level may actually be higher than reported here.

POSSIBLE SOLUTION: THE ZERO G® EXOSKELETON ARM

Details

HSL researchers did observe the robotic arm in use at the UK supplier’s facility but it has not been observed in an occupational setting. Therefore there may be some limitations of using these devices that HSL are not aware of. The Zero G® is manufactured in the United States of America (USA) and a UK company has the distribution rights. The arm is a patented technology that allows tools, parts, and other payloads to be manoeuvred as the loads would normally be supported but the worker still has a full range of motion (Photograph 20).

- Two patented devices are used to:
  - Adjust a spring to provide constant lift in an articulated arm that matches the motion of a human; and
  - Give any payload (such as a tool) complete angular freedom in all axis. Because freedom of motion is maintained, workers can maintain the muscle memory and skills that were developed when learning to use the tool. The result is that the worker can do a task with the same freedom of motion that they did before, but without needing to support the weight of the tool.

- There are two Zero G® systems available: The Zero G2® is suitable for payloads/tools weighing between 0.1kg and 4.5kg and the Zero G4®, suitable for
payloads/tools weighing between 4.5kg to 16kg. List price is approximately £5,000 and £9,000 respectively. Heavier payloads can be accommodated with a single link which in general allows for an additional 2kg to 6kg respectively.

- Maintenance of the Zero G® is minimal; the manufacturer recommends a weekly routine maintenance programme with a six-month check of all moving parts.
- Mounting systems can provide additional reach and a fully mobile cart is also available to cover large work areas.
- Cabling such as pneumatic air lines, power cords, hydraulic hose or sensor wiring can be routed along the length of the system, which can include protective covers suitable for paint shops and refurbishment facilities to prevent corrosion and it also shields any pinch points.
- Factors that need to be considered prior to implementation:
  - What is the tool, part or object to be manipulated;
  - Where is the centre of mass on the item to be held;
  - Understand the orientation of the item that will be required to reach the work area (note any required areas for gripping the object);
  - Identify potential mounting locations;
  - Look at required work range (all areas where tool will be used); and
  - Make a note of any obstructions to reaching required areas.

The Zero G® was installed onto the aircraft wing sanding line to improve throughput in the area while also allowing users full range of movement needed to perform the task to the customer’s stringent quality standards. Photograph 21a-c shows operators using the device to sand aircraft wings. Photograph 21a&b show the worker standing while Photograph 21c shows the worker using a height adjustable chair to make it easier to access the lower parts of the wing.

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2 Images used with permission from: http://www.equipoisinc.com/
Table A9 shows the level of upper limb injury risk using the ART tool when using the Zero G® to sand aircraft wings. While the score for the right arm has reduced from 42 to 27, this still presents a high risk of upper limb injury (for both arms). This is largely because the arm movements and level of repetition are unlikely to have changed much and the body postures remain very similar (e.g. some twisting or bending of the back and neck) and working with the hands above shoulder height. The greatest reduction in the score is observed in the level of force that the workers have to apply. Using the device supports the weight of the sander and therefore the level of risk is reduced. However, the task still presents a high level of ULD risk to workers that should be considered further.

**Table A9** Summary of upper limb injury risk using the ART tool when sanding aircraft wings using the Zero G®

<table>
<thead>
<tr>
<th></th>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td></td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td></td>
<td>R6</td>
</tr>
<tr>
<td>B Force</td>
<td></td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td></td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td></td>
<td>R4</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td></td>
<td>G0</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td></td>
<td>R6</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td></td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td><strong>Task score</strong></td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Exposure score</strong></td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>High: further investigation required urgently</td>
<td>High: further investigation required urgently</td>
</tr>
</tbody>
</table>
Benefits

- The Zero G® eliminates the need to suspend tools from overhead wires as they can be mounted on portable gantries or carts and can also be fixed in position to linear rails.

- The amount of force required is greatly reduced as it eliminates the weight of the sander and also makes the task more efficient while still providing the user the complete freedom of motion required to do the job. It also allows for an improved degree of precision as fine motor skills can be used while in a compromised position as the tool weight is supported.

- Upward pressure can be created by adjusting the lift force of the springs thus allowing the worker to support the weight of their arms while simply guiding the sander along the surface.

- Tool vibration is minimised as grip force is reduced since the operator does not need to support the weight. This improves vascular delivery of blood to the hands. It may also be possible to attach an adjustable arm to the gimbal to improve the posture of the operator. This would allow the operative to work in a posture that is closer to neutral, in that their hands would not be above shoulder height for much of the task.

- Productivity improvements of up to 50% were observed, as users were able to sand a larger surface area faster than they could otherwise.

- Reduces operator fatigue and the potential for strain injury while accommodating an ageing workforce.

- The payback period was calculated at less than six months and it can help reduce the costs of accidental damage to the tools, as they cannot be accidentally dropped.

- Other reported uses include, grinding, welding and forming, sanding and buffing, drilling and cutting, riveting and torque tools with examples shown in Photograph 22a-c.

Photograph 22 Other applications where the Zero G® has been used

Grinding on the hull of a ship

Grinding engineering parts

Supporting a torque tool during car manufacture
CASE STUDY 7: FISH FILLETING

THE PROBLEM: MANUAL FISH FILLETING

Manual fish filleting is a highly skilled task. Workers are required to perform highly repetitive actions of the upper limbs while bending their neck forward to clearly view what they are filleting. This task presents a high level of risk of upper limb injury to individuals.

TASK DESCRIPTION AND DETAILS

The key work tasks involved in filleting are:

- Select the fish from the bin for filleting;
- Fillet the fish;
- Place the filleted fish onto the conveyor; and
- Undertake additional tasks such as cleaning out and changing the bins, and sharpening their knives.

ULD RISK FACTORS AND ART ASSESSMENT

Under the circumstances described in this case study the fish-filleting task presents a high level of upper limb injury risk to individuals. Table A10 presents the ART assessment of risk of upper limb injury that filleters are exposed to. The key areas of concern when manually filleting fish are:

- Very frequent arm movements that are almost continuous, particularly for the knife hand;
- Similar motion pattern of the arms and hands that is repeated more than 20 times per minute;
- The sideways twisted posture of the back for more than 50% of the time;
- Moderate to light force was applied for around 65-75% of the cycle time when using the knife. Light force was applied for about 80-95% of the time to stabilise the fish during filleting;
- The neck is bent more than half the time when working at the filleting workstation;
- Both arms are raised with the elbow away from the body, at chest height and unsupported for part of the time;
- The wrist of the knife hand spends a significant amount of the time in a deviated posture compared to the stabilising hand. However, there is still some deviation of the stabilising hand when manipulating the fish;
- Holding the knife allows for a power grip, while a pinch grip is observed when gripping parts of the fish during the filleting task;
- The filleting task is performed in a chilled environment. Gloves may make the filleting task more difficult, particularly on the knife hand.
### Table A10 Summary of upper limb injury risk using the ART tool when manually filleting fish

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Stabilising arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>R6</td>
</tr>
<tr>
<td>B Force</td>
<td></td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td></td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td></td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>R2</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>G0</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td></td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td></td>
</tr>
</tbody>
</table>

**Task score**
- 30
- 22

**Exposure score**
- 30
- 22

**Estimated exposure level**
- High: further investigation required urgently
- High: further investigation required urgently

---

**POSSIBLE SOLUTION: LASER FISH FILLETING MACHINE**

Some of the filleting tasks can be done automatically using a variety of computer-controlled machines to fillet the fish.

**Details**

- Machines may be capable of processing between 25-120 fish per minute.
- Gutted, de-headed fish are placed in the in-feed chute and the sensor automatically adjusts the knives to allow for accurate cutting.
- Requires two people to operate the machine.
Benefits

- Adjustable to fillet different types of fish weighing between 2-10kg.
- Can perform exact cuts resulting in high-quality fillets with a high yield for different fish sizes.
- Easy to operate.
- Reduces the need to manually fillet fish.
CASE STUDY 8: TYING REBAR

THE PROBLEM: MANUAL REBAR TYING

‘Rebar’ is a steel bar, which is commonly used in reinforced concrete and reinforced masonry structures (e.g. for floors and staircases) where metal bars are tied together to make frames prior to concrete pouring. The tying task requires repetitive use of the upper limbs while using pliers to ‘tie’ the steel together. The tasks often occur at ground level and require individuals to adopt awkward, stooped postures. Individuals are exposed to a medium level of ULD injury risk.

TASK DESCRIPTION AND DETAILS

This case study and ART assessment is based on prefabricated units (staircases) that would then be transported to site for installation, therefore the tasks are not occurring at ground level. The key tasks require workers to:

- Tie the steel bars together with wire and then use pliers to twist and secure the wire around the steel. Short periods of rest and recovery from the tying task occur when workers select and cut the rebar into the required lengths, and bend it into position. The handling, cutting, bending, and tying tasks occur repetitively over the duration of the workday;
- The weight of the steel differs depending on the shape, diameter and length of the steel/bar. However tying is the same process irrespective of the size of the bars. In this case study a weight of up to 2kg per bar was used;
- Pliers are used to tie the rebar and this requires repetitive hand and forearm actions while applying a force to the pliers;
- The work rate is variable and workers reported they did not have difficulty keeping up with the task; and
- The worker performs the task without a break for about 2.5 hours. The task is performed for about 5.5 hours per 8-hour shift.

Photograph 24 Working postures when manually tying rebar
ULD RISK FACTORS AND ART ASSESSMENT

Under the circumstances described in this case study the rebar tying task presents a medium level of upper limb injury risk to workers. Table A11 presents the ART assessment of risk of upper limb injury that operators are exposed to when tying prefabricated rebar. The key areas of concern when rebar-tying are:

- Very frequent arm movements that are almost continuous and occur largely over the majority of the workday;
- The highly repetitive twisting actions of the wrist and forearm and when applying a force to the pliers (e.g. when cutting the wire);
- The sideways and twisted posture of the back for more than 50% of the time. However, when tying rebar on-site (at ground level) workers will have to adopt stooped or squatted postures. The static loading may lead to the back muscles fatiguing quickly and increase the risk of injury. Low lighting levels may also encourage workers to adopt forward bent postures to enable them to get close enough to see what they are doing; and
- When working on-site workers may also be exposed to the elements and this may place them at increased risk of developing a MSD.

Table A11 Summary of upper limb injury risk using the ART tool when manually tying rebar

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>A3</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>A3</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>A2</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>R2</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>G0</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A4</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>R2</td>
</tr>
<tr>
<td>Task score</td>
<td>16 19</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>1 1</td>
</tr>
<tr>
<td>Exposure score</td>
<td>16 19</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Medium: further investigation required Medium: further investigation required</td>
</tr>
</tbody>
</table>
POSSIBLE SOLUTION 1: AUTOMATIC REBAR TYING TOOLS

A variety of rebar-tying machines are available, but have not been observed in use by HSL researchers, therefore the following information comes from manufacturer websites and published studies regarding the benefits of these types of equipment. Further assessment may be required to fully understand how these are used and any potential disadvantages that are not immediately apparent. For example, static neck flexion from constantly looking down at the ground, and the weight of the tool.

- Rebar-tying tools are battery-powered and are placed around the intersecting rebar rods. Examples of these tools are shown in Photograph 25a-c.
- When a trigger is depressed, the tool feeds the wire around the bars, twists it and cuts it automatically. Tools with a trigger grip allow workers to tie horizontal or vertical rebar while keeping their wrist in a neutral posture. This reduces the need to perform high frequency twisting or bending motions of the wrist and lower forearm, but could introduce risks from repetitively operating the trigger and supporting the weight of the tool.
- Rebar-tying tools can be fitted to a long handle or extension bar allowing the employee to stand up straight while the steel is being tied, an example of this is shown in (Photograph 25c). It can be seen that these types of tools allow the employee to work with an improved upright posture, reducing stooping and bending.
- It is reported that these types of tools increase productivity and may be up to twice as fast as hand tying.

POSSIBLE SOLUTION 2: JIFFY SHOT 1™ GUN

Details

- Jiffy CLIP products (Photograph 26) are similar to the automatic wire tying tools outlined above but use clips inserted into a gun device that then clip around the rebar when activated by pushing down, allowing the worker to stand while securing rebar.
- There is a long, 40-inch gun used for large mat areas, and a shorter, 27-inch gun for hard to reach or vertical operations. The cost is approximately $300USD (e.g. approximately £185).

Benefits

The manufacturer reports the following benefits:

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Photograph 25 Examples of automated tying tools

3 Photograph cited in Almeida & Vi [24].
• Simple, fast, and easy to use;
• Eliminates wire-tying, and reduces constant bending and repetitive wrist motions;
• Reduces labour by up to 80%; and
• Increases productivity, installing between 30 to 50 clips per minute.

Photograph 26 JiffySHOT™ applicator guns

4 Photograph used with permission from JiffySHOT (http://www.jiffyclip.com/products/jiffyshot.htm).
CASE STUDY 9: POTATO GRADING

THE PROBLEM: MANUAL SORTING
Potatoes are manually inspected for size, shape, color, bruising, etc. as they travel along a series of conveyors. Workers are required to remove rejects or ‘culls’ from the flow and dispose of them for alternative processing. The manual grading and sorting of potatoes presents a high level of upper limb injury risk to workers.

TASK DESCRIPTION AND DETAILS
Potatoes are fed onto the packing line by tipping full storage bins onto a receiving conveyor belt. Severely damaged or rotten potatoes are removed in an initial sort. Potatoes are then cleaned using a barrel washer, which contains a series of rotating brushes, under a rinse-water spray, or through a water flume designed to wash off dirt and soil. The potatoes are then transported by a drying conveyor for further processing. Workers are then required to:

- Remove potatoes that are undersized or damaged, these are referred to as culls;
- Inspect potatoes for shape, colour, bruising, insect damage, rot, and cuts. Rejects and culls are removed from the flow and are thrown in a bucket for disposal or down a chute for other product processing;
- Clean and pre-size sort. Afterwards, the potatoes move onto a roller-sorting table for final sorting. The roller-sorting table is designed to continually rotate the potatoes as they move past the manual sorters (Photograph 27);
- Pick out one or more grades that comprise the minority of the potato flow (usually very large potatoes) while the predominant grade is allowed to flow onto the next processing station. This is known as ‘Reduction Sorting’ and is the most common type of sorting performed in potato packing houses;
- Store the sorted potatoes in temperature and humidity controlled bins where they are cooled and dried before packaging to increase shelf life. Large-scale use of controlled atmosphere storage allows packing houses to hold large amounts of potatoes for up to one year and has allowed packinghouses to move from seasonal to year-round work;

Photograph 27 Roller conveyor sorting table for manual potato grading

- The sorting cycle consists of only one task when undertaking the visual inspection task: picking up a potato and placing it on a conveyor, chute, or bucket. The full cycle takes a mean time of 2-4 seconds; variability can be explained by the quality of potatoes processed that day;
• Given a cycle time of 2-4 seconds, a sorter could possibly perform 7,000-14,000 cycles over a typical 8-hour shift, which contains two 15-minute breaks and a 30-minute lunch break;
• The force of handling potatoes during sorting is low (<1kg/hand); and
• Work pace is dictated by the speed of the conveyor and the number of potatoes on the conveyor and numbers of workers undertaking the task.

ULD RISK FACTORS AND ART ASSESSMENT
A high level of upper limb injury risk to workers when undertaking the manual potato-sorting task was assessed using the ART tool and the risks are shown in Table A12. The key areas of concern when sorting and grading potatoes are:

• Very frequent arm movements that are almost continuous;
• Similar motion pattern of the arms and hands that is repeated more than 20 times per minute;
• The head/neck is bent or twisted for the majority of the shift (85% of shift time);
• The arms are raised away from the body for more than half the time;
• The hand/wrist are bent or deviated part of the time;
• The posture of the back is bent forward for more than 50% of the time; and
• Workers were maintaining a static standing posture for 67% of the shift time.
POSSIBLE SOLUTION: OPTICAL GRADING AND SORTING

An optical grading station was introduced in an attempt to reduce the level of risk that operators on the potato sorting line are exposed to. Photograph 28 shows an example of an optical grading machine and the various stages of operation.

Details

- A variety of optical graders are available as either off the shelf products or as bespoke engineering solutions.
- Optical potato graders/sorters use a combination of pulsed lighting, image processing software and advanced microprocessors to separate the good potatoes from those with defects.
- The range of defects the optical sorter can identify includes: black spot, cuts, dry cut, mechanical damage, scabs, and discolouration. In addition, graders can sort by size (diameter and length) to help make packing more efficient and consistent.
- Optical grading systems are capable of processing large volumes of potatoes, for example between 20-26 tonnes per hour.
- An operator can adjust the settings to meet the customer’s needs for size as well as for rejection priorities on an easy-to-use, touch-screen computer located at the potato sorter.
Benefits

- There is an increase in the accuracy of correctly graded and sized potatoes, in comparison to manual grading. There is a reported reduction in the volume of potatoes incorrectly identified as ‘cull’; maximising crop yields.
- Additional cost savings can be made through a reduction in the number of staff required to operate the grading and sorting line.
- Different varieties of potato can be sorted by changing between various saved programs, speeding up the grading process further.

However, the majority of first grade potatoes are still hand-checked several times for damage and rot that the optical sorter may have missed. After which, they are either packaged to meet the customer’s specifications or packed on a refrigerated trailer to be sent to the customer. Additional training may be required to ensure optimum performance and that the machine runs smoothly.
CASE STUDY 10: CARTON FILLING

THE PROBLEM: MANUAL CARTON FILLING

Workers have to repetitively pick sachets off a conveyor and slide/place them into a cardboard carton located on a second conveyor (Photograph 29a&b). The carton-filling task presents a medium level of upper limb injury risk to workers. Job rotation means that the exposure to the task and subsequent level of ULD risk is reduced. However, some operators reported that they found it difficult to keep up with the machine, which may place additional stress on the individual.

![Photograph 29](image)

Photograph 29 Manual carton filling in a standing (a) or seated (b) posture

TASK DESCRIPTION AND DETAILS

- The machine pace can be altered slightly to speed up or slow down the process depending on the experience and speed of the operator, but generally operates at a speed of 60 sachets per minute and averages between 53 and 55 per minute.

- Operators reported that they sometimes have difficulty in keeping up with the machine and that the task requires little force to place the sachets into the cartons.

- There is a perch stool that individuals can sit on to undertake the task and job rotation occurs every 25-30 minutes and is shared between four people. This equates to about 2 hours per day spent doing this task.

- Both hands are used at the same time to move the sachets from the front conveyor and line them up with, and insert them into the cartons that are moving on the second conveyor. Therefore, each arm is moving from one conveyor to the next every 2 seconds, or 30 times per minute. Photograph 30a-c shows the postures of the arms and hands when placing the sachets into the cartons.

![Photograph 30](image)

Photograph 30 Upper limb movements when filling cartons
ULD RISK FACTORS AND ART ASSESSMENT

Under the circumstances described in this case study the carton-filling task presents a medium level of upper limb injury risk to workers. The organisation had implemented administrative controls by imposing a two-hour maximum limit on the manual cartoning task that has reduced the score slightly but still presents a medium risk. The ART assessment is shown in Table A13 and the key areas of concern when inserting the sachets into cartons are:

- Very frequent arm movements that are almost continuous;
- Similar motion patterns of the arms and hands that are repeated more than 20 times per minute;
- The forward bent posture of the neck for more than 50% of the time; and
- Deviated wrist postures for more than half the time.

Table A13 Summary of upper limb injury risk using the ART tool when manually filling cartons

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>R6</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>G0</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>G0</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>R2</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>G0</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>G0</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>A1</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
</tr>
<tr>
<td>Task score</td>
<td>17</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>0.75</td>
</tr>
<tr>
<td>Exposure score</td>
<td>12.75</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Medium: further investigation required</td>
</tr>
</tbody>
</table>

POSSIBLE SOLUTION: AUTOMATIC CARTONER

The example outlined above has not yet been automated, however automatic carton-filling machines are available and an example of a task where one has been implemented in a chocolate factory is presented here. Small trays of chocolates were inserted into a windowed box sleeve, erected and sealed automatically by the cartoner ready for packing. Photograph 31a&b shows the automatic cartoner and the steps involved in the automated process. However, this process still requires the worker to manually place the trays into the boxing machine (Photograph 31a).
Photograph 31 Automatic cartoner

Details

- The initial cost of the stacking station was £75,000, with a payback period of 14 months achieved through increased productivity and reduced labour costs.
- The machine is capable of filling a variety of carton sizes and can be used on other products that need packing. Change parts allow cartons of different sizes to be filled.
- The rate at which the automatic cartoner can fill boxes is variable and is dependent on the size of the product and design of the carton; rates of up to 200 cartons per minute can be achieved.
- The stacking station is an off the shelf product that compliments the company’s existing equipment. Maintenance is reported to be minimal as the company are familiar with the machinery.
- The stacker contains a small number of basic moving parts and on-site engineers solve issues as they arise.
- It is beneficial to involve packaging specifiers at the implementation phase in order to reduce the likelihood of issues relating to the packaging/machine interaction causing production delays.
- No extra resource is required to operate the machine, the current workers on this line monitor the machine, clear blockages and perform other simple maintenance tasks. On-site engineers deal with more complex issues.

Benefits

- The introduction of the automatic cartoner has served to reduce the demands placed on the operator during the packaging of trays of chocolates.
- The frequent and repetitive arm movements associated with packing cartons is eliminated by the introduction of the automatic cartoner.
- It is faster, cheaper and requires less resource.

However, the finished chocolates are manually packed in boxes for transportation. This is still repetitive and labour intensive. The packing tasks are shown in Photograph 32a&b. Therefore while some of the repetitive tasks have been eliminated some residual handling tasks are still required which may expose individuals to a risk of upper limb injury.
Photograph 32 Manually packing completed product at the end of the production line
CASE STUDY 11: LABELLING

THE PROBLEM: MANUAL APPLICATION OF LABELS
Manual application of labels may require operators to select a product off a production line, peel a label off its packaging and apply it to the bottle neck before placing it back onto the production line. This is a highly repetitive task that presents a high level of upper limb injury risk to workers.

TASK DESCRIPTION AND DETAILS
This particular example refers to manually placing labels around the necks of bottles; however, there are no photographs available to show this task. The task requires the worker to:

- Repetitively lift bottles off a conveyor, applying the label and replacing the bottle onto the conveyor;
- The work is machine paced and workers often find it difficult to keep up with production; and
- Undertake the labelling task for their entire 7.5 hour workday, and there is no job rotation.

ULD RISK FACTORS AND ART ASSESSMENT
A high level of upper limb injury risk to workers was assessed using the ART tool; the findings are presented in Table A14. The key areas of concern when labelling bottles are:

- Repetitive and similar motion patterns of the arms are performed for the majority of the time;
- The head and neck are bent for more than half the time and the shoulder and arms are held away from the body;
- A pinch grip is required during the task; and
- There is no job rotation and workers often find it difficult to keep up with production demands.
**Table A14** Summary of upper limb injury risk when manually labelling bottles using the ART tool

<table>
<thead>
<tr>
<th>Assessment of Repetitive Tasks (ART)</th>
<th>Right Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>G0</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>G0</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>G0</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>A2</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>R2</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A4</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>R2</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
</tr>
<tr>
<td><strong>Task score</strong></td>
<td>11</td>
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<tr>
<td><strong>Exposure score</strong></td>
<td>11</td>
</tr>
<tr>
<td><strong>Estimated exposure level</strong></td>
<td>Low: Consider individual circumstances</td>
</tr>
</tbody>
</table>

**POSSIBLE SOLUTION**

While HSL is not aware of a specific solution for the above task there are a number of automated labelling machines available that can apply labels to a wide variety of products (shown in Photograph 33 to Photograph 36). For example:

- Adjacent side pallet label applicators – applies labels to the side of pallets;
- Cylinder applicators – applies labels onto cylinders;
- Beak applicators – applies labels onto packaged products;
- Wrap around, side and top applicators – applies labels onto boxes;
- Side and corner label applicators – applies labels onto boxes;
- Wipe on applicators – applies labels to the side of boxes or cylinders; and
- Different height applicators – applies labels to pallets loaded at different heights.

**Benefits**

- Eliminates the need to manually label items and therefore reduces the upper limb injury risk.
- The use of automatic labelling applications can reduce production bottlenecks as the machine keeps pace with production demands.
- Facilitates accurate product labelling i.e. batch numbering, serial number, and use by dates, etc.
- Improved product presentation with increased labelling accuracy.

**Photograph 33** Different types of automated label machines

**Photograph 34** Wrap around side automated label applications

**Photograph 35** Wipe on label applicators

**Photograph 36** Labelling pallets at different heights

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5 Photographs sourced with permission from www.kelgray.co.uk
CASE STUDY 12: BREAD MAKING

THE PROBLEM: MANUALLY LOADING AND UNLOADING BREAD OVENS

Workers are required to load and unload a reel oven with trays of baked goods (bread rolls, breakfast muffins, artisan loaves, etc). The loading and unloading task presents a medium level of upper limb injury risk to workers.

TASK DESCRIPTION AND DETAILS

This task requires the worker to:

- Load and unload trays of bread rolls into and out of a reel oven. The worker loads trays of uncooked rolls onto the door of the reel oven and slides the trays into an empty space in the oven. The worker also removes cooked rolls from the oven, returning the trays to an empty trolley where they are transported to the cooling area.

- A reel oven (also called a revolving tray oven) is an approximately six or seven feet high insulated enclosure that has a door front almost the width of the oven, but usually less than a foot high. Inside it consists of a reel structure that revolves around a horizontal axis within the baking chamber and supports the baking trays in a Ferris wheel fashion. It moves four to eight shelves in a circle centred on the sides of an oven, so that each shelf is brought past the door during every rotation.

- The shelves in the oven move continuously through a vertical loop making it impossible for an operator to unload a full tray of baked product and reload the same shelf with a new tray. This means that the oven operates at reduced capacity, as shelves rotate empty.

Trays of rolls are loaded into the oven  a. Sliding the trays into the oven  b.
Removing cooked rolls from the oven  c. Placing trays of cooked rolls into trolleys  d.

Photograph 37 Manually loading and unloading the oven

ULD RISK FACTORS AND ART ASSESSMENT

A medium level of upper limb injury risk to workers when undertaking the loading and unloading task was assessed using the ART tool. The assessment is shown in Table A15, with all of the risk factors presenting a medium level of risk. In the first instance improving the
number of breaks or variety of tasks could help to reduce the level of risk by reducing the amount of time workers are exposed to the task, then all other risk factors could be subsequently be considered.

**Table A15** Summary of upper limb injury risk using the ART tool when manually loading and unloading the reel oven

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>A3</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>A3</td>
</tr>
<tr>
<td>B Force</td>
<td>A2</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>A1</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>A2</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>A1</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>A1</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A4</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>A1</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>A1</td>
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<tr>
<td><strong>Task score</strong></td>
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</tr>
<tr>
<td><strong>Exposure score</strong></td>
<td>20</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Medium: further investigation required</td>
</tr>
</tbody>
</table>

**POSSIBLE SOLUTION: ROBOT-ON-A-REEL OVEN**

The nature of reel ovens is that the shelves continually move making it impossible for a single operator to unload a full tray of baked products and replace the same shelf with dough. In practice many shelves are left to rotate without anything loaded onto them while the operator aims to keep them filled. An automated system to load and unload baked products into the reel oven was developed that integrates an articulated robot arm with the companies existing equipment. Photograph 38a-d shows the robot-on-a-reel oven and the steps involved during the automated process.
Robot arm selects a tray from the trolley

Tray is placed on the oven door

Tray is placed on the oven door

Tray is pushed into the oven

Photograph 38 Automated process (robot-on-a-reel) for loading and unloading the ovens

Details

• The initial cost of the machine was £60,000 and an additional £5,000 was spent providing extra training for existing staff.

• Fresh dough for rolls is supplied on a trolley of vertically stacked trays. The gripper design allows loaded trays to be collected from shelves or deposited to shelves when receiving a signal from the robot control system.

• The robot aligns the gripper with a full tray of dough products and, after gripping the end of the tray, retracts it from the infeed trolley into the gripper framework.

• It moves the gripper to the reel oven, which moves trays on to a continually operating vertical loop.

• The robot waits at the loading area until a sensor indicates that a tray is aligned, and, while simultaneously moving at a pre-programmed speed, clamps and withdraws a tray of baked products and then pushes a tray of dough on to the oven shelf.

• The robot then moves to the trolley and unloads the finished bread rolls ready to be taken to the cooling area.

• The robot is able to unload and reload trays within the available cycle time, allowing the oven to operate at full capacity.
Benefits

- The capacity of the reel oven was increased by 80%.
- There was an associated energy saving of around 50%.
- Reduction in ULD risk due to automation.
- The introduction of the robot-on-a-reel oven served to eliminate the repetitive actions observed when manually loading and unloading the reel oven.

Important Information/Lessons Learned

Since the introduction of the robot-on-a-reel-oven there have been a number of issues:

- Several variables in the process e.g. trays, positioning and tray trolleys, had not been accounted for sufficiently during the initial implementation phase. These issues were related to the operation of the robot in an extreme thermal environment. The oven often reaches 240°C and at this temperature the metal trays become pliable. Many of the trays and racking became bent and damaged during use, meaning that the robot can have difficulties in picking up the trays, which led to production delays.

- In addition to the initial cost of implementing the robot-on-a-reel oven (approximately £60,000) the company have spent around £50,000 trying to remedy these problems, without success.

- Furthermore, there has been a change in business dynamics. New contracts (to produce breakfast muffins) with high volumes, has meant changes to the production process. The robot cannot cope with the trays for the new product, as they are cooked in a tin with a lid, for three cycles of the oven and then cooked without the lid for another cycle to brown the top. The machine has difficulties lifting the trays with lids on and there is no way to automate the lid removal without further expenditure.

- The company in question have already invested a significant amount of time and money into trying to implement this automated solution and unfortunately are unable to continue this level of investment. As a result they have since removed the robot-on-a-reel machine.

- In the future the only way the organisation would try to automate the process was if they were to move to new premises. This is because they are currently operating a 24-hour shift rotation where production is continuous and any remedial work would involve stopping production while the changes were implemented. For this reason, any automation that was to be introduced would need to be right first time as any delays in getting the machine up and running would severely impact on production volumes.

- The key lesson learned from this experience is to always ensure that the systems engineering provider is fully proficient with food sector robotics and automation.
CASE STUDY 13: BISCUIT PRODUCTION

THE PROBLEM: MANUAL SHAPE CUTTING

Operators are required to cut gingerbread men shapes out of a flat sheet of dough. Shapes are cut by hand and then placed on a baking tray ready for cooking. The cookie-cutting task presents a medium level of upper limb injury risk to workers.

TASK DESCRIPTION AND DETAILS

This task requires the worker to:

- Feed the gingerbread mix into a machine that rolls it into flat sheets, which are then passed along a conveyor;
- The worker, manually cuts the dough into the required shapes using a cookie cutter and places them on baking trays ready to be cooked;
- The work takes place in a warm environment, due to the heat of the nearby ovens;
- Workers bang the gingerbread mould on the edge of the conveyor to loosen the biscuit, using their hand as a tool for much of the time;
- The standard shift pattern is 07:00 – 15:00, with one 15-minute break and a 45-minute lunch break;
- Gingerbread men are produced four days a week and two workers spend approximately 5 hours per shift cutting the dough into the correct shape (dependent on the size of the order); and
- Workers rotate to other tasks on the finishing and packing lines, when the order is filled.

Photograph 39 Work postures adopted when manually cutting cookie dough
ULD RISK FACTORS AND ART ASSESSMENT

A medium level of upper limb injury risk to workers when undertaking the cookie-cutting task was assessed using ART and the risks are shown in Table A16. The key areas of concern when manually cutting cookie shapes are:

- Very frequent arm movements that are almost continuous;
- Similar motion patterns of the arms and hands that is repeated 11-20 times per minute;
- Head and neck postures that are bent or twisted more than half the time;
- Back posture that is bent forwards, or twisted part of the time;
- Use of the cookie cutting tool that is struck against the hand more than ten times per minute; and
- Working in warm temperatures.

Table A16 Summary of upper limb injury risk using the ART tool when manually cutting cookie shapes

<table>
<thead>
<tr>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Arm movements</td>
<td>R6</td>
</tr>
<tr>
<td>A2 Repetition</td>
<td>A3</td>
</tr>
<tr>
<td>B Force</td>
<td>G0</td>
</tr>
<tr>
<td>C1 Head/neck posture</td>
<td>R2</td>
</tr>
<tr>
<td>C2 Back posture</td>
<td>A1</td>
</tr>
<tr>
<td>C3 Arm posture</td>
<td>A1</td>
</tr>
<tr>
<td>C4 Wrist posture</td>
<td>A1</td>
</tr>
<tr>
<td>C5 Hand/finger grip</td>
<td>G0</td>
</tr>
<tr>
<td>D1 Breaks</td>
<td>A4</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>G0</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>R2</td>
</tr>
<tr>
<td><strong>Task score</strong></td>
<td>20</td>
</tr>
<tr>
<td><strong>Duration multiplier</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Exposure score</strong></td>
<td>20</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>Medium: further investigation required</td>
</tr>
</tbody>
</table>

POSSIBLE SOLUTION: COOKIE CUTTING MACHINE

An automatic cookie-cutting machine was introduced in an attempt to reduce the level of risk that operators on the gingerbread man production line were exposed to. Photograph 41 shows the cookie cutting machine and the steps involved during the automated process.
Fresh dough goes into the hopper, either in crumbs or in the form of sheets, and is formed between the feeding roller and pattern roller. The shapes are cut off by the teflon coated blade and are set on the belt and then on the tray. The space between the shapes on a tray can be regulated. The blade is adjustable, so shapes can be formed out thinner than originally engraved on the roller. Trays will be placed from behind into the machines and shapes are formed into these trays. There is an automatic tray limit switch on every machine to stop after each tray. Both rollers can be removed without tools in seconds for cleaning and can be cleaned by hand or in a dishwasher.

Details

- The initial cost of the cookie-cutting machine was £20,000. A number of optional extras can be purchased, including automatic tray system, automatic feed in system and extensions to the conveyor.
- A number of standard roller designs are available, bespoke designs can be manufactured to the customer’s specification, prices range between £3,000 and £5,000 per roller.
- The machine can process approximately 200kg per hour depending on the size and complexity of the cylinder used.
- The cookie cutting machine is an off the shelf product that compliments the company’s existing equipment.
• The cookie cutter contains a small number of basic moving parts and the company have a team of five on site engineers who fix problems as and when they arise.

Benefits

• The introduction of the cookie-cutting machine has served to reduce the demands placed on the operator during the gingerbread production task.

• The frequent and repetitive arm movements associated with manual cookie cutting have been eliminated.

• Production has increased as the cookies can be cut at a higher rate compared to when they are manually cut.
CASE STUDY 14: PALLETISING CONTAINERS

THE PROBLEM: MANUAL PALLETISING OF SMALL GROUT CONTAINERS

The manufacture of grout and adhesives for the do-it-yourself (DIY) market requires workers to manually palletise small containers of grout weighing between 1-5kg. This task presents a high level of upper limb injury risk to operators.

TASK DESCRIPTION AND DETAILS

- Two operators collect the finished buckets of grout as they reach the end of the filling line/conveyor which can weigh between 1-5kg depending on their size;
- Pick and place the finished grout onto a pallet; and
- Move full pallets from the end of the line into the storage area ready for dispatch to the warehouse.

ULD RISK FACTORS AND ART ASSESSMENT

Table A17 presents the ART assessment of risk of upper limb injury that operators are exposed to. The key areas of concern when palletising buckets of grout are:

- Very frequent arm movements associated with picking up grout buckets off the conveyor and placing them onto the pallet;
- Sideways twisted posture of the back for more than 50% of the time, as buckets are placed on the lower layers of the pallet, results in considerable exposure to risk of injury for the back.
- Reaching to stack the higher layers of the pallet results in considerable exposure to risk of injury for the shoulder and arms.
- Pinch or wide finger grip for more than half the time, as workers pick and place the buckets;
- The pace of work is dictated by the rate at which the machine fills and seals buckets of grout; and
- The lack of job rotation, or rotation onto tasks that are sufficiently different.

Under the circumstances described in this report and observed during the assessments, the grout-palletising task presents a high level of upper limb injury risk to workers.
Table A17 Summary of upper limb injury risk using the ART tool when manually palletising buckets of grout

<table>
<thead>
<tr>
<th></th>
<th>Assessment of repetitive tasks (ART)</th>
<th>Right arm</th>
</tr>
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<tbody>
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<td>A1 Arm movements</td>
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<td>B Force</td>
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<td>Right arm</td>
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<td>C1 Head/neck posture</td>
<td>A1</td>
<td>Right arm</td>
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<td>C2 Back posture</td>
<td>R2</td>
<td>Right arm</td>
</tr>
<tr>
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<td>A4</td>
<td>Right arm</td>
</tr>
<tr>
<td>D2 Work pace</td>
<td>A1</td>
<td>Right arm</td>
</tr>
<tr>
<td>D3 Other factors</td>
<td>G0</td>
<td>Right arm</td>
</tr>
<tr>
<td>Task score</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>D4 Duration multiplier</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Exposure score</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Estimated exposure level</td>
<td>High: further investigation required urgently</td>
<td>High: further investigation required urgently</td>
</tr>
</tbody>
</table>

POSSIBLE SOLUTION: ARTICULATED ARM ROBOT

An automated palletising line was installed in order to reduce the level of risk that workers on the grout production line were exposed to although no pictures are available from the site visit conducted. The design of the gripper arm is commercially sensitive, as it gives the company a competitive advantage. Photograph 42 shows a similar set up designed to palletise totes.

Photograph 42 Articulated arm robot

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6 Photograph used with permission from [http://www.vanriet.co.uk/](http://www.vanriet.co.uk/)
Details

- One issue with the introduction of the machinery is that it introduces two new tasks that should be assessed for ULD risk. Workers are required to manually load a conveyor with empty buckets, which are automatically filled with grout. Lids are then manually placed on top of the buckets and a lid presser seals the bucket shut. Lids are difficult to automate due to machine and lid/bucket tolerances.

- At the end of the production line the articulated arm robot automatically rotates the bucket so that the handles are in the right place to be stacked. The gripper arm on the end of the robot uses suction cups to pick and place the filled buckets on the pallet. If the gripper cannot pick and place the product then an alarm signals and the arm parks.

- Getting the product in the right place is important to enable the robot to pick the grout up and place it correctly onto the pallet.

- The suckers on the gripper can accommodate different size and shape buckets (pitch, handle size, etc) by toggling adjustable suction cups.

- The machine can be programmed to accept different sized pallets. However, the tolerance on the pallets have to be exact, damaged or repaired pallets can cause problems, as the machine will try to pick and place product where it thinks it should go.

- This system can pack approximately 15 tonnes of grout per hour and is cell based so that if any of the machinery breaks down the rest of production can still operate.

- The articulated arm robot is maintained 24 hours a day as part of a service contract with the robot supplier, but operators are able to deal with minor problems if they arise.

- The approximate cost of the device was £700k with a cost-benefit of just under five years

In addition to the robotic arm the company has invested heavily in additional automated equipment to ensure that the risks associated with heavier manual handling tasks are also reduced. For example, they have introduced an automated trolley cart system to move the pallets around the factory floor and a machine that places surface layer pads between the different layers of the pallet. These complimentary systems allow the company to operate an automated ‘just-in-time’ (JIT) system. The JIT system informs the warehouse what product is available and maintains a perceptual inventory by removing a layer of administration. This system can also produce orders in order of delivery so they can be grouped together with other elements of the order, reducing the amount of repetitive handling during delivery.

Benefits

- Repetitive handling of 1-5kg loads are eliminated and therefore so too is the ULD risk.

- Productivity has improved with approximately 54 buckets per minute being palletised, if this was done manually it would require approximately 12 people over two shifts.

- Risks associated with heavier manual handling tasks are also reduced due to additional mechanisation introduced.
8. REFERENCES


An investigation into mechanical aids and automation for reducing the risks of repetitive handling tasks involving the upper limbs

The Health and Safety Executive (HSE) produced a document (INDG 398; [1]) that provides practical advice on mechanical aids that reduce the risk of heavy manual handling. However, there is little information on the mechanisation and automation available to reduce upper limb disorder risks that can arise with repetitive handling (ie handling light loads at least every few seconds). HSE guidance ‘Upper limb disorders in the workplace’ [2] suggests a hierarchical approach to risk reduction and asks ‘can machinery do the highly repetitive functions and leave more varied jobs for the workers?’ However, no further information on this important risk reduction measure is provided. As such, it is difficult for HSE and Health and Safety Laboratory (HSL) specialists to advise Inspectors and duty holders on whether mechanisation or automation is a reasonably practicable control option to reduce upper limb disorder risks.

The introduction of the ART tool [3] has provided inspectors and duty holders with a risk assessment tool where tasks that predominately use the upper limbs can be assessed. This is likely to lead to an increased knowledge and awareness of ULD risk factors. However, there is little guidance for inspectors and duty holders regarding reasonably practicable control measures where the tasks are performed manually and there is no mechanisation or automation in place. The aim of this document is to provide practical examples of risk control measures used in industry.

This report and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.