Master Thesis

Evaluation of systems for piperun installation

A comparison based on ergonomic and productivity factors

Veronica Andersson & Magdalena Bosson

Division of Machine Design • Department of Design Science

Faculty of Engineering LTH • Lund University • 2013

LUND UNIVERSITY

Evaluation of systems for piperun installation

A comparison based on ergonomic and productivity factors

Veronica Andersson & Magdalena Bosson

Division of Machine Design • Department of Design Science

Faculty of Engineering LTH • Lund University • 2013

Division of Machine Design, Department of Design Science
Faculty of Engineering LTH, Lund University
P.O. Box 118
SE-221 00 Lund
Sweden

ISRN LUTMDN/TMKT 13/5465 SE

Preface

This report is the result of a project carried out in collaboration with Hilti Svenska AB, the division of Marketing and the Divisions of Ergonomics and Aerosol Technology and Machine Design, Department of Design Science, Faculty of Engineering at Lund's University. The thesis is the final part of the master program, Master of Science in Mechanical Engineering with Industrial Design.

The purpose of the thesis project was to analyse and evaluate different systems used for installation of piperun in ceilings with focus on mainly ergonomics. We chose this project since we both have a strong interest for ergonomic factors and the relationship between products and the people who use them.

The project has given us valuable insight of how research projects can be conducted and knowledge on how to apply different research methods. It has also been very interesting to explore areas unknown to us such as the subject of working environment and to explore the construction and Plumbing and Heating (P&H) industry.

We would like to say thanks to our supervisor at Hilti, Christopher Overton (Marketing Director) for giving valuable support and advice. Johan Leufstedt (Product Manager Installation & Measuring) has been of great assistance in planning and performing the Posture and Time study. Kent Tomeby (Key Account Manager) and Mikael Levin-Heimer (Account Manager) have aided in finding suitable participants for the study. Several Account Managers from the Installation BU deserves acknowledgement for letting us come with to visit different construction sites. Furthermore, Herbert the frog has kept a watchful eye on us during our time at the office. All participants in our studies deserve a great thank you for taking the time to demonstrate how they work and answer all our questions. A special thank you to the two participants of the Posture and Time study who worked very hard with all of our test installations.

Many people have assisted with their knowledge, inspiration and encouragement during this thesis project and it has been greatly appreciated. Our supervisor at Lund's University, Per Odenrick (Professor) has provided the most support and for that we are ever thankful.

Finally we would like to thank our families and friends for their encouragement during this thesis and our previous years as graduate students.

Lund, June 2013

Veronica Andersson & Magdalena Bosson

Abstract

The purpose of this thesis project was to analyse and evaluate different systems for installation of piperun in ceilings. Main focus lay on how the systems influence the installer from an ergonomic point of view as well as productivity in terms of installation time. Several studies have been performed during this project using a variety of methods such as observations, interviews, questionnaires and hierarchical task analysis. The results from these studies showed that often a variety of different systems for pipe installations are used. The working conditions of Plumbing and Heating (P&H) installers are very demanding and the categories working postures/loads/space, climate and lighting conditions are most unsatisfactory. Furthermore 60% of the participants of the questionnaire study had Musculoskeletal Disorders (MSD) and believed it to be work-related. These results led to the design of a test named Posture and Time study.

During the Posture and Time study three systems for pipe installation were evaluated. System 1 represented a more traditional and inexpensive system, system 2 was intermediate and system 3 represented the most modern and expensive version. The systems were analysed using two methods for posture analysis, Hand Arm Risk assessment Method (HARM) and Rapid Entire Body Assessment (REBA). A time study was also conducted in order to define the installation times for both systems.

The time study showed that systems 2 and 3 were about equally fast to install while system 1 took about 30 % longer. HARM and REBA both turned out to be to unspecific to define which system was better from an ergonomic aspect although they gave valuable insight to the importance of choosing good working postures. To get objective results of how the systems affect the P&H installer perhaps methods such as Electromyography or Inclinometry could be used. Even though the work posture analysis did not show a clear difference between the three systems, observations and interviews with P&H installers made it clear that they found system 1 to contain too many small parts and operations and therefore found this system harder to install.

All studies performed during this thesis project have been very small in terms of number of participants. The project is therefore to be seen as a pilot study of how an investigation like this could be executed. Results from the studies have, when possible, been compared to statistic data in order to increase the reliability. However if more generalizing results are preferred, the studies need to be larger in scale.

Keywords:

Posture analysis, Musculoskeletal disorder (MSD), Pipe installation, HARM, REBA

Sammanfattning

Detta examensarbete har utförts i samarbete med Hilti Svenska AB och kan ses som en förstudie inför fortsatta studier. Med detta examensarbete har en jämförande studie utförts av olika system för installation av rörgata i tak med avseende på ergonomi och produktivitet. Fokus har legat på att urskilja systemen genom att undersöka den fysiska belastningen samt tidsåtgång vid montage för respektive system.

Olika system för installation av rörgata finns idag på marknaden och konkurrensen mellan dem är hård. Systemen går från billigare och mer traditionellt till dyrare och mer modernt. De faktorer som avgör vilket system som köps in är kostnad, typ av uppdrag, tidsram för uppdraget samt personliga preferenser. I detta examensarbete undersöktes tre olika system. System 1 var det billigaste och mest traditionella med klämsvep och takjärn. System 2 var en mellanvariant med gummisvep och takjärn. System 3 var det dyraste och mest moderna av systemen med gummisvep och takskena.

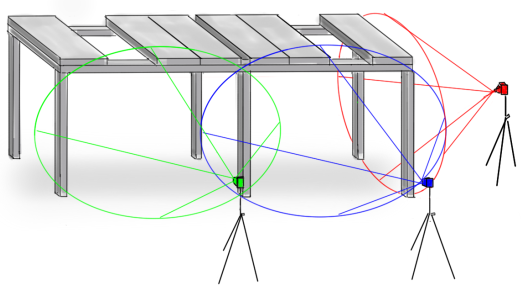
Värme, Ventilation och Sanitets (VVS) branschen är en av de branscher som är mest utsatta för fysiska påfrestningar. Arbetsuppgifterna för en VVS installatör innefattar bl.a. installation av rör, element och handfat. Arbetsställningar är ofta obekväma och kan leda till belastningsskador. I detta examensarbete har fokus legat på installation av rörgata i tak där det mesta av arbetet sker ovan axelhöjd vilket belastar kroppens övre regioner såsom axlar och nacke.

För att uppnå målen med examensarbetet användes många metoder av anledningen att skapa triangulering och säkerställa resultaten. En telefonstudie genomfördes för att kartlägga de vanligaste problemområdena samt få en allmän uppfattning av VVS branschen. 43 personer inom branschen deltog i undersökningen och svarade på frågor om bl.a. ackord, belastningsområden och om företaget jobbade aktivt med miljöfrågor. Samtidigt med telefonundersökningen utfördes en studie där arbetsmiljö stod i fokus. Genom en serie observationer i kombination med intervjuer, på fem olika byggarbetsplatser, kunde arbetsmiljö, arbetsställningar, tillvägagångssätt och arbetstakt inom VVS branschen undersökas. 11 intervjuer fångade upp installatörernas egen uppfattning om deras arbetsmiljö baserat på neutralt ställda frågor.

I en enkätundersökning delades enkäter ut till 10 VVS installatörer från olika företag där målet vara att fånga upp hur många av deltagarna som hade arbetsrelaterade belastningsskador och i vilken utsträckning.

Deltagarna fick också svara på frågor kring deras livsstil ifall några slutsatser kunde dras mellan livsstil och belastningsskador.

För att kunna jämföra systemen utifrån arbetsställningar och tidsåtgång utan påverkan från yttre faktorer genomfördes ett test i en uppriggad miljö. Testet planerades utifrån skapta Hierarcial Task Analysis (HTA) över arbetsordningen för varje system samt den redan insamlade informationen. En stålkonstruktion på 1x6x2 meter riggades upp i en inomhusmiljö. Två installatörer deltog i testet under två dagar varav den första installatören deltog dag 1 och den andra dag 2. Båda installatörerna ombads installera i ordningen; system 1, system 2 och slutligen system 3 med 30 min paus emellan. För att dra slutsatser om installatörerna kunde representera VVS installatörerna i allmänhet besvarade de samma enkät som använts i enkätundersökningen. Testet dokumenterades med tre videokameror som tillsammans täckte in hela testområdet, se figur 0.1.



Figur 0.1 Uppställning av stålkonstruktion samt av kameror

Filmerna analyserades sedan med Hand Arm Risk assesment Method (HARM) och Rapid Entire Body Assesment (REBA) metoderna. HARM gav en detaljerad analys av överkroppen såsom hand, arm och nacke. Med HARM utvärderades varje arbetsmoment i hela filmsekvenser baserat på olika kroppsdelars positioner, tid för moment, kraft använd för att utföra momentet, vibrationer mm. HARM kompletterades med REBA som gav en övergripande analys av hela kroppen genom utvärderade stillbilder (figur 0.2) av utvalda arbetsställningar för varje arbetsmoment. Varje installation delades upp i sex arbetsmoment t.ex. förmontering eller fixering av rör. Arbetsställningarna valdes så att de täckte in både bra och dåliga arbetsställningar för ett arbetsmoment.

Figur 0.2 Stillbild av installatör under testdag 2

Samtidigt med testet togs tiden det tog att installera rörgata med de olika systemen. System 2 och 3 som var ganska jämlika i installationstid, tog 2/3 av tiden det tog att installera system 1.

En del av deltagarna i telefonundersökningen arbetade med installationer där rörgata inte var vanligt förekommande och därför togs beslutet att bortse från de resultaten. Av 43 intervjuer var 30 relevanta, varav 90 % rapporterade att de eller någon av deras kollegor hade belastningsskador. Telefonundersökningen visade även att system 2 var det vanligaste följt av system 1 och sist system 3.

Observationerna gav en god uppskattning om vardagen för en VVS installatör och framförallt den viktiga vetskapen om att ingen byggarbetsplats är den andra lik. Allt från väder och belysning till vilka hjälpmedel som används på de olika byggarbetsplatserna varierade mycket. Överlag var det väldigt kallt och dunkelt på många av platserna vilket kraftigt påverkades av att besöken gjordes i februari månad.

Enkäterna var för omfattande med sina 70 frågor och för få deltagare för att ge pålitliga resultat. P.g.a. svarsbortfall samt inkonsekventa svar togs en stor del av de mer detaljerade frågorna bort. Resultatet som kunde användas var mer övergripande frågor där 60 % av deltagarna rapporterade att det hade arbetsrelaterade belastningsskador. Tendenser på att belastningsskador ökade med ökad ålder kunde påvisas och kan styrkas av tidigare publicerade studier. Inga klara samband mellan belastningsskador och livsstil (t.ex. användning av tobak) kunde göras. En mindre enkät med fler deltagare samt kontroll av svaren på plats hade varit lämpligt för att undvika dessa problem.

HARM och REBA var båda för ospecifika för att upptäcka skillnader mellan systemen. Båda påvisade dock en stor skillnad i resultaten mellan deltagarna och inom resultaten för den enskilde deltagaren. Med andra ord hade de individuella arbetsställningarna en stor påverkan på resultaten. Utöver detta har materiella och tekniska brister haft en viss påverkan på resultatet, t.ex. avsaknad av lift. För att kunna dra några statistiskt säkerställda slutsatser skulle testet behöva genomföras av en mycket större grupp deltagare.

Inför fortsatta studier är rekommendationen att utföra en större enkätundersökning där fler deltagare kan nås via t ex mail. Med undersökningen är förhoppningen att statistiskt säkerställa vilka områden som är mest utsatta för arbetsrelaterade belastningsskador. Detta bör sedan undersökas ytterligare genom ett test med installatörer som installerar rörgata men med en större grupp deltagare än i detta projekt. Ett förslag är att genomföra objektiva mätningar av enskilda muskelgrupper istället för en subjektiv helkroppsanalys av olika kroppsställningar. Baserat på enkätundersökningen kan de muskelgrupper som är mest exponerade lokaliseras för vidare analys. Metoderna EMG och Inklinometri kan användas för detta ändamål men man kan även använda sig av datasimulering med hjälp av manikiner t.ex. Jack.

Table of Contents

Terminology

BU	Business Unit
Byggnads	Trade union for all workers within the construction industry
Channel	Long rectangular component with a rail that attaches directly to the ceiling. Link between ceiling and connector
Chilled pipe rings	Component between pipe and pipe ring for insulated pipes
Connectors	Component that link pipe rings to channels/ takjärn
HARM	Hand Arm Risk assessment Method
Hilti	Hilti Svenska AB
Locomotor apparatus	An organ system that gives humans the ability to move using the muscular and skeletal systems
MSD	Musculoskeletal Disorder
P&H	Plumbing and Heating
Piecework salary	Form of payment, mainly within the manufacturing and construction industry. The size of the salary is dependent on the individual worker's or work team's performance, through an in advance defined compensation.
Pipe ring	Ring shaped component that enclose the pipe and serves as a link between connector and pipe
Pipe ring with insulation	Pipe ring with insulation in order to cancel out vibrations and noise
Pipe run	Pipes installed in a formation that run straight and far
REBA	Rapid Entire Body Analysis
SWEA	Swedish Work Environment Authority
System 1	Traditional system for pipe installation
System 2	An intermediate system, between traditional and modern systems for pipe installation
System 3	Modern system for pipe installation
Takjärn	(The Swedish term is the same as the English term)
	Long rectangular component with holes that attaches directly to the ceiling. Link between ceiling and connector

1 Introduction

This chapter gives some background to the problem and an introduction to the company Hilti Svenska AB, the commissioning body for this thesis. The aims with the thesis are described and the working process is explained.

1.1 Background

For installers within the Plumbing and Heating (P&H) industry the work description consists of numerous tasks. Installing pipes for sewage, water, heat and climate control is frequently performed as well as installing products like radiators, toilets and basins. The work is often strenuous due to unsatisfactory working postures such as working below knee or above shoulder height. Both these types of working postures are very strenuous and should be avoided as far as possible [1].

There are several systems available on the market for pipe installation. Choosing the right system depend on various factors such as cost, time limit, type of job (i.e. new construction work or repair work), the extent of the job and the preference of the P&H installers.

1.2 Hilti Svenska AB

This master thesis project was executed in collaboration with Hilti Svenska AB (Hilti). Hilti develop, manufacture and market high quality products and services (e.g. hand tools and products for installation) towards the trade of industry and construction. Hilti have since the 1990's been promoting a product system consisting of channels and pipe rings with insulation for the installation of pipes. This product system has since been refined and the version used in this project was released in 2010. This type of product is more or less standard in the rest of Europe but the implementation in Sweden, and partly in Finland, has not been as successful. One explanation for this could be that an older system, consisting of takjärn and pipe rings is still used by many installers due to old habits and a construction industry with strong traditions. Older and more experienced installers can sometimes be opposed to change and will teach the younger generation what they have been taught and are familiar with. The younger generation being inexperienced and seeking approval has the tendency to embrace the way things are done and letting the old traditions live on.

1.3 Problem statement

In an aspiration to find stronger arguments for their product system, Hilti initiated this project to get a comparison between their product system and the more traditional systems being used. Emphasis was put on the ergonomic conditions and working postures of the installer as well as of the productivity of the systems referring to installation time.

1.4 Aims

The aim of this master thesis project was to analyze and evaluate similarities and differences between different systems for installation of piperun in ceilings.

The project had four questions at issue:

- Can any distinction be made between the different systems for installation based on an ergonomic investigation of observing working postures and loads handled by the P&H installer?

- By conducting a time study of the systems, what conclusions can be drawn on the productivity of the different systems?

- By exploring the relationship between productivity and working conditions, can any conclusions be drawn on weather one of the two can be improved without impairing the other?

- Can any conclusions be drawn on weather individual prerequisites prevent or induce work-related disorders?

1.5 Delimitations

The project consisted of 20 weeks full-time work per person, which meant delimitations had to be done to fit the time frame. The focus area was restricted to installation of piperun in ceilings. The installation systems can also be used for installation of piperun on walls or in other applications. These applications will not be evaluated in this project. The studies have also been restricted to new construction sites where long straight piperuns are common, leaving spacing, bends and corners out of the study. Focus was put on the ergonomic effects and the influence work environment has on the body and work performance. Individual and psychosocial factors were partly taken into consideration while the effect that cognitive ergonomics has on the body and work performance was not. Productivity, in terms of installation times, and its effects on ergonomic factors have also been studied during the project.

1.6 Thesis structure

In this report the master thesis project is documented, describing the process, choices and conclusions made. The first two chapters give an introduction to and background information needed to understand the rest of the report. Chapters 3-4 describe the process (i.e. methods and materials used) of the studies conducted in this project. This is followed by the results and analysis of the studies, in chapter 5-6. Chapter 7 is a discussion about the methods and results and lastly conclusion and recommendations are reviewed in chapter 8-9. Materials used during the project such as score sheets, questionnaires and list of materials used during tests etc. can be found in the appendix.

2 Theory

In this chapter the theory needed to further understand the working conditions of the construction and P&H industry is presented. The different systems of pipe installation used in this project are defined. Important facts concerning ergonomics in relation to performed work are presented and finally the theory behind the methods used during the project is described.

2.1 Construction and P&H Industry

The working conditions in the construction industry are different from other industries and often very demanding. Many actors work in the same area with contractors and sub-contractors, which put high demands on planning and time management so that the workers are not in the way of one another. The location and prerequisites of the work place are always shifting, which means no workplace/work environment is like the other. [2] The general contractor of a building project has the main responsibility for all actors working on the construction site [2]. The competition is strong in the construction industry and it is important for companies to have a price worthy an offer in order to gain new contracts and win public procurements. Some companies even take on contracts that are calculated to go breakeven in order to keep their employees occupied. This makes it very important to cut unnecessary costs and the price level of materials is therefore of great importance.

2.1.1 Working conditions

The working conditions in the construction industry vary a lot from time to time depending on the phase of the construction (e.g. if walls and roof are in place). It can therefore be hard to reach continuity when working with work environment issues. It is therefore important to have well established structures, regulations and guidelines for how work environment issues are controlled. Many companies have their own rules and guidelines but all companies have to follow the decrees posted by The Swedish Work Environment Authorities (SWEA).

SWEA was reorganized to its present form in 2001. It has the commission of the Swedish parliament and government to make sure that the legislation concerning working environment is followed. SWEA is also responsible for developing new decrees that are compulsory, and regulations that are suggestions to complement the legislation. They also supply information concerning work environment factors and are responsible for the statistics of working conditions and work injuries in Sweden.

If the work environment of a work place is questionable, SWEA perform inspections to make sure that rules are being followed [3]. It is however hard for SWEA to perform inspection on construction sites since they change rapidly.

The employer has the ultimate responsibility to make sure that the work environment is satisfactory and that each employee has the means to perform his/her work in a satisfying manner. Furthermore the § 5 of AFS 2012:2 states that:

> "The employer must, to the extent of what is practically possible, arrange and design tasks and workplaces so that the employees can use postures and movements that are beneficial for the body…" (Authors translation)

This means that the employer is obligated by law to supply the employees with ergonomically preferable equipment. An example of this can be lifts that make it easy to manoeuvre into a suitable elevation when working close to the ceiling. Another example is the presence of appropriate workbenches where parts can be preassembled if less fortunate working postures are required. Even though the employer holds the most responsibility, each employee has to make sure to follow rules and regulations posted at the work place. They also need to inform the employer if any problems in the work environment occur so that the employer can take actions.

2.1.2 Piecework

Many companies within the construction and P&H industry use piecework as its main form of compensation. According to the Swedish National Encyclopaedia piecework is defined as:

> ”Piecework, form of payment, mainly existing within the manufacturing and construction industry, where the size of the salary is dependent on the individual worker's or the individual work team's performance, through an in advance defined compensation [4]." (Authors translation)

This means that the installers get paid the same amount of money irrespective to the time it takes them to fulfil their tasks. It is rather the number of instalments that decides the amount of pay. In other words, by working faster the installers will finish more instalments and earn more money. Piecework is a very debated form of payment. There are many arguments both for and against it and sometimes both sides use the same arguments.

Byggnads, which is the union most P&H installers belong to, has a positive take on piecework since they feel that it gives their members the opportunity to influence their pay and also to be involved in the project they are working on. The installers do supervision of work and self-screening themselves, which creates some extra work opportunities [5].

VVS-företagen, an association that bring forth the interest of the employers, states that piecework could be a liability since there is a risk that it has a negative effect on the working environment and the quality of the work performed. With piecework as form of payment, a worker receives a set salary for a specific job and if carried out faster the pay per hour gets higher. Some companies prefer piecework because this requires less control by the employer since employees put pressure on themselves to show up on time, work efficiently etc. The union wants piecework since it has a positive impact on salaries. According to VVS-företagen, piecework could be a disadvantage when it comes to investments in tools and aids that would be beneficiary to the overall ergonomics but will not be profitable for the employers. Improved production time will not make more money for the employer because of the piecework salary [6].

Piecework and other types of salaries based on performance could have a negative effect on the worker as it may increase the risk of getting injuries or disorders. Studies of work with performance-based salaries have shown a correlation between these types of salaries and an enhanced will to take risks. This risk taking could lead to an increased amount of physical exhaustion as well as the workers being more prone to injuries and early retirement [7]. Performance-based salaries can also create a stress-full working environment as the individuals working in teams pressure each other to work faster hence causing stress amongst the participants. Stress over a long time can lead to tension in neck and shoulder, sickness and high blood pressure amongst other symptoms [8].

2.1.3 Definition of systems for pipe installation

Components for pipe installation often get purchased separately, sometimes even from several distributers. The most important components are takjärn/channels that are attached to the ceiling and holds the entire construction in place. Connectors are the link between the pipe rings holding the pipes and the takjärn/channels, providing a distance between the pipes and the ceiling. Chilled pipe rings are always used when pipes with insulation are needed. An example of pipe installation can be viewed in figure 2.1.

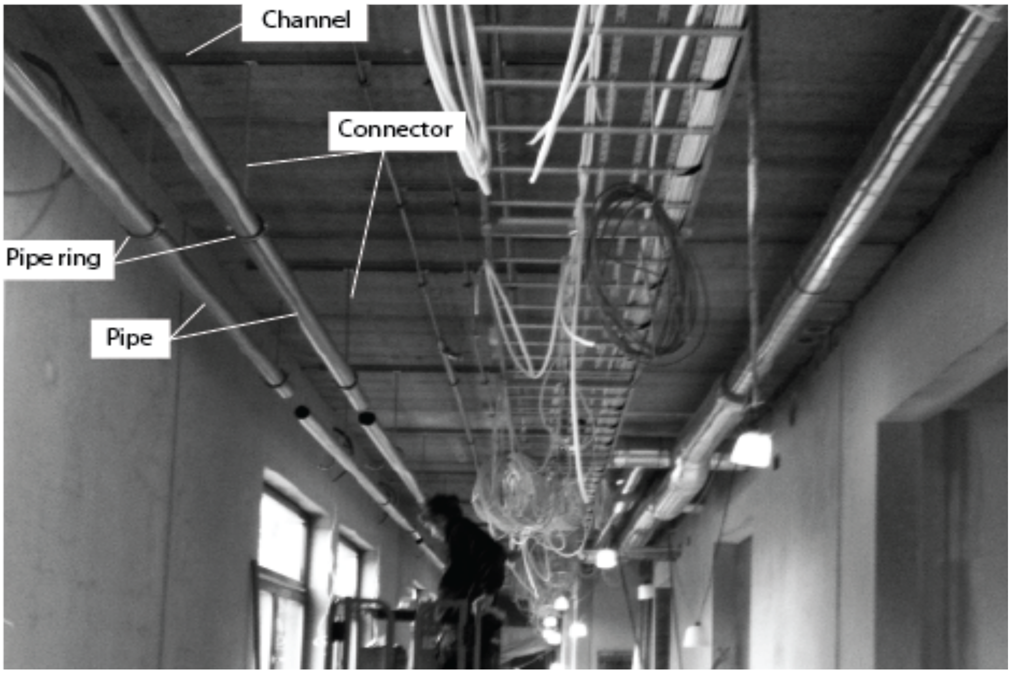


Figure 2.1 Piperun in ceiling

For this thesis project, three different systems for pipe installation have been evaluated. System 1 represents a more traditional and inexpensive system and contains takjärn, connectors, pipe rings and the necessary screws and bolts to connect the components to each other and attach the system to the ceiling, see figure 2.2.

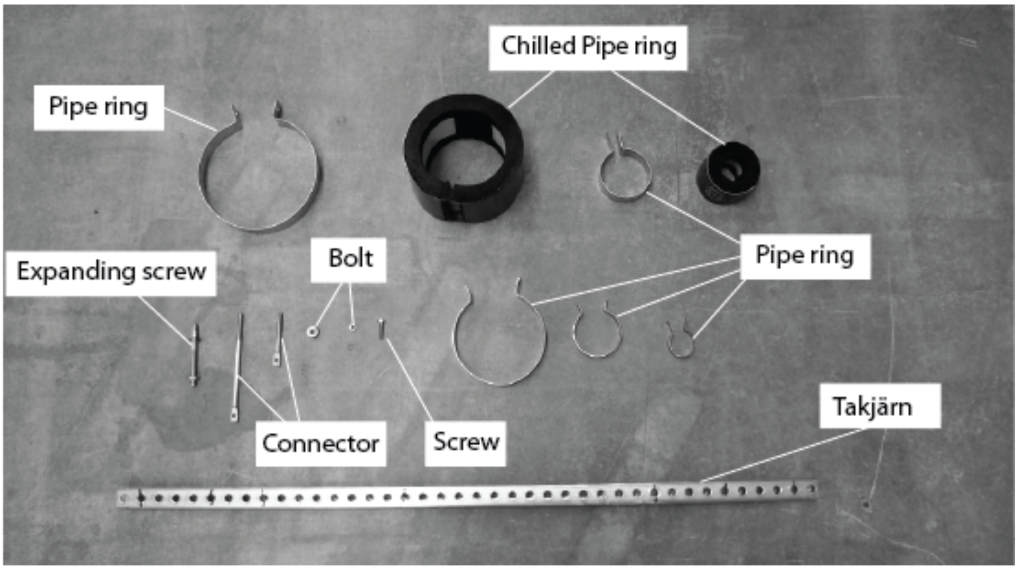


Figure 2.2 Components in system 1

System 2 is intermediate and consists of takjärn, connectors, pipe rings with insulation, from the cheaper end of the price range, and the necessary products to connect and fasten the system. A view of the individual components of system 2 can be seen in figure 2.3.

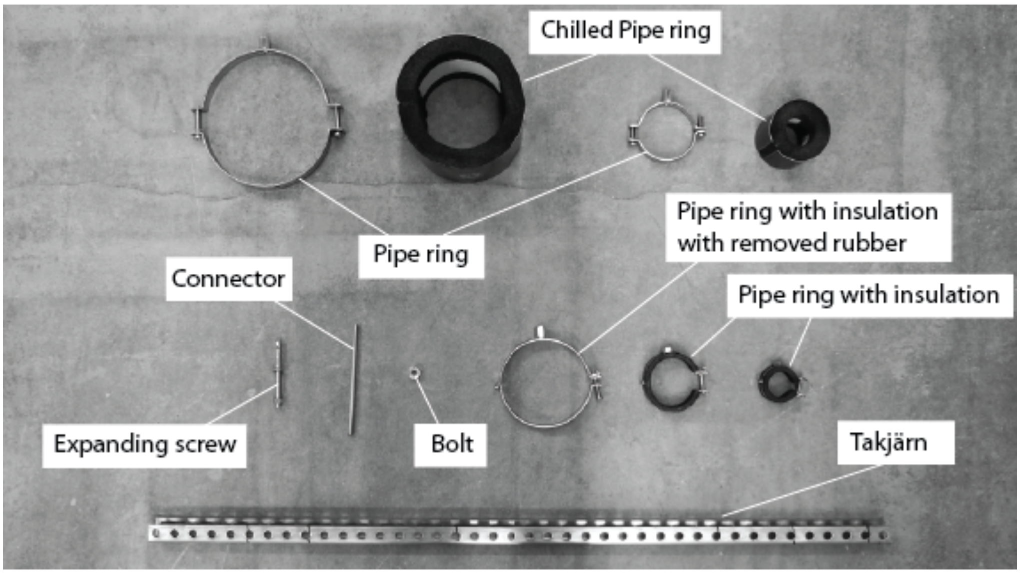


Figure 2.3 Components in system 2 (the rubber insulation was removed from the largest insulated pipe ring, see chapter 7.2.6)

System 3 is the most expensive and modern system of this thesis project. It contains channels, connectors, pipe rings with insulation of a higher quality as well as screws and bolts to connect and fasten the system see figure 2.4.

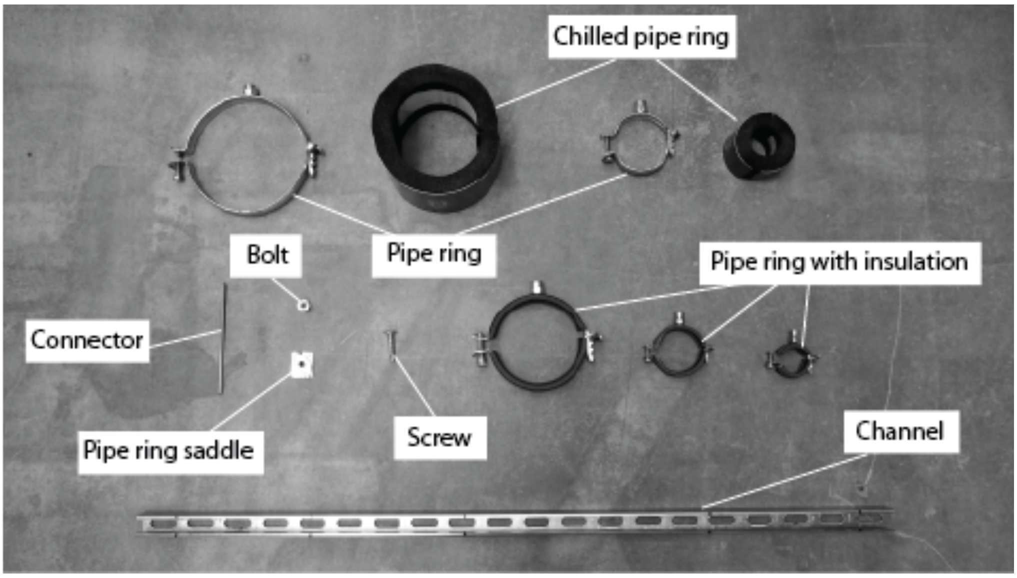


Figure 2.4 Components in system 3

2.2 Ergonomics

Ergonomics is a term with many definitions, the authors agree with the International Ergonomics Association's (IEA) definition:

> "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance [9]."

The focus of this study lies on ergonomics for the prevention of musculoskeletal disorders (e.g. strenuous working positions). Working environment, individual prospects and psychosocial factors will partly be taken into account.

2.2.1 Musculoskeletal disorders (MSD)

Musculoskeletal disorders (MSD) can be found in the overall population [10]. The term MSD refers to health problems that affect the locomotor apparatus of the body such as tendons, muscles, the skeleton, cartilage, ligaments and nerves [11]. Most of the work-related MSD:s develop over time and are either caused by the work performed, the working environment or by an accident [12].

Strain on muscles, tendons and/ or joints is one of the most common reasons for an employee to be absent from work [13]. A study on work-related disorders conducted by SWEA in 2012 show that 17.8±6.8 % of the P&H installers participating in the study have had work-related disorders (not caused by accidents at work) during the last twelve months. 5.8 ±4.3 % were absent from work for one day or more. Of the 12 different groups of professions taking part in the study P&H came on fourth place of having the most work-related disorders [14]. One out of seven P&H installers' state that they have work-related disorders.

2.2.2 Working postures

The tasks within the field of P&H are often executed while holding bad working postures (e.g. with a bent or twisted back, above shoulder height or away from the body). These postures are held for both shorter and longer periods of time and sometimes in combination with an additional weight (e.g. a handheld tool). The risk of getting an injury increases with a bad working posture [13]. It is sometimes good to extend or fold parts of the body as far as possible. However, when joints and tendons are placed under load or in extreme positions (e.g. an arm fully extended, folded or rotated) often or at long intervals, the risk of injury increases. While in these positions the muscles are not able to produce the same amount of force and work in a coordinated manner [13].

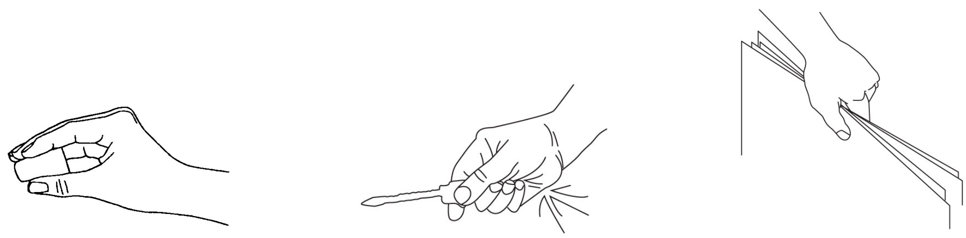
There are many aids available on the market and one of them is a lift. The lift is quite small without becoming unstable and can easily be manoeuvred. Using a lift allows the user to adjust the height and distance to the working area after his/her own need while standing on a stable ground.

The lift can however be to big for some passages and might get stuck in cords lying on the floor and then a ladder will be used instead. The use of a ladder is prohibited in many larger construction sites as to avoid accidents. Still ladders are prevalent in some workplaces, especially in cases when the use of a lift is not possible. Using a ladder is not good for several reasons; its inflexibility leads to bad working postures and tension in individual muscles, there is less room on a ladder to work on and there is a risk of falling off that might lead to injuries.

The study on work-related disorders show that of all work-related disorders experienced, by the P&H employees participating in the study, during the previous 12 months, 15.3 ±4.7% was due to strenuous working postures, 11.4 ±4.2% to heavy manual handling, 3.7 ±2.5% to repetitive work and 7.0 ±3.4% to mental stress [14].

2.2.3 Hand and grip

Many of the tasks performed within the P&H industry are carried out with some sort of handheld tool. Using a handheld tool is a common contributing factor to MSD in hands, wrists and shoulders. This is partly due to the way the tools are designed (i.e. if the tool fit the hand of the user) [13]. The design of a tool will affect how a task is carried out and what positions the user have to assume (e.g. position of the wrist) [15]. The type of grip also affects the risk of MSD in hands and wrists. One common grip is the pinch grip (see figure 2.5, 2.6, 2.7), where the force is placed primarily between the fingers and the thumb. The grip becomes hazardous when gripping objects weighing ≥1kg or with force of ≥2N per hand for more than two hours total per day [16].



Figures 2.5, 2.6, 2.7 The pinch grip [16]

A tool should be as light as possible, as to minimize the extra load on the body, with the exception of certain applications when the weight of the tool can be useful (e.g. bringing a hammer down on a nail). The recommended weight, based on well-founded studies, is for precision tools 1.75kg and for other tools 2.3kg [17]. The centre of gravity should be placed as close to the wrist as possible as to avoid unnecessary strain, again with the exception of cases when the centre of gravity adds a functional advantage of being placed elsewhere as with the hammer [15]. Also keeping the weight as close to the body as possible will lessen the load.

Direct exposure to vibration can lead to injuries such as lost feeling and powerlessness in the hand. If the exposure to vibration is too great over time, the user can suffer from Reynauds Disease (white fingers). This means that the individual might experience sudden attacks of lost feeling in contact with cold and when smoking as the blood circulation slows down [18].

2.2.4 Troubled areas

The most troubled areas experienced by P&H employees participating in the study by SWEA, are the back with its 14,9 ±4,6% followed by the shoulder and arm 9,4 ±3,9 the hip-joint, leg and knee 6,9 ±3,3%, the hand, wrist and fingers 4,8 ±3,0% and finally the back of the head and neck 3,7 ±2,5% [14].

Many areas of the body are prone to injuries some areas are more exposed than others. The shoulder, having a shallow joint, is built for rotation up to 180°. This means that the ligaments and muscles will take up most of the strain and not the bone structure surrounding it. Because of the weakness of the ligaments in the shoulder, this area is very exposed to injuries.

The distance between the centre of the vertebras and centre of the back muscles is 5 cm and very small compared to the large distance from the back to the object for lifting. This means that even a moderate weight will place a great load on the vertebras and back muscles. The risk of getting a slipped disk is greatest in the lumbar region since the strain will be greatest there. Lumbago is a condition caused by a sudden strain on the back in an unexpected direction. Back problems might also occur when the back have been twisted and/or bent for a long time [18].

2.2.5 Working environment

A good work environment is fundamental in order to prevent disorders and accidents. This involves the technical, physical, social and organisational aspects as well as the design of the work itself. The focus of this report is however on the physical aspects of work environment (e.g. lighting, sound, air and climate).

Working in the P&H industry means working in all sorts of climates since a large portion of the work is done outside or inside buildings with or without heating. With temperatures ranging from well below- to well above zero this will affect both body and work performance. In extreme cold the joints get stiff, the finer motor skills degenerate resulting in discomfort, increasing the risk of injury and a slower work pace. Other than temperature there are other factors regarding climate that affect body and work performance such as moist level, wind and downpour.

Another factor greatly affecting the working environment is lighting. Without being able to see sufficiently, the risk of an injury or accident increases. It is important with the right amount and type of light (i.e. a light that is not reflected in a bad way nor blinding). SWEA's regulation on lighting (AFS 2009:2) states in 10 §; " The lighting should be planned, executed and maintained, tested and assessed to the extent necessary to prevent illness and accident" (Authors translation) [19]. This applies to both the immediate workplace but also the surrounding area.

With heavy physical activity the intake of air increases. This air is often filled with dust at construction sites as it is released frequently (e.g. by grinding or drilling). Even though steps are taken to reduce the amount of dust it is still a problem. At some construction sites using a broom is forbidden as it stirs up the dust and sometimes air cleaners are used [20].

Inhaling too many harmful dust particles can lead to different diseases such as pneumoconiosis (occupational lung disease), chronic obstructive lung disease and different types of cancer [20].

A construction site often has a high noise level with many sudden and uncontrolled peaks. It is therefore very important for people at these sites to use hearing protection. The Swedish Work Environment regulation on noise (AFS 2005:16) states, ”The employer shall provide affected employees the opportunity to participate in the selection of hearing protection. Hearing protection should be selected so that the risk of hearing damage is eliminated or minimized” (Authors translation) [21].

2.2.6 Ergonomics and productivity

Many companies today have a view on ergonomics as something that takes time and resources away from the core business and is beneficial primarily for the individual. However, a correlation between improved ergonomics and positive effects on business have been found in many cases [22].

Previous research within the field of ergonomics shows that a person’s ability to perform work tasks in an effective manner depends on what conditions the individual encounter in the workplace. If tasks are strenuous this often leads to fatigue or discomfort and therefore affecting the work in a negative way. It is normal to compensate for this by performing tasks faster (e.g. reducing the time spent on fine-tuning or quality control of the work performed). The individual simply minimizes the amount of time exposed to strain [22]. As an example, a study compared postures evaluated with the Rapid Upper Limb Assessment (RULA) method to quality data of registered defects in work performance. This showed that jobs with bad working postures also had the highest percentage of quality defects, up to ten times more than in areas with less demanding working postures [23]. RULA is a method used on sedentary work but the results can probably be transformed to other types of work as well such as pipe installation. The main factor causing the defects in quality is probably the workers feeling of discomfort, not the actual postures themselves.

There is some disagreement among researchers if ergonomic improvements have an affect on MSD. Some argue that the research is not strong enough when it comes to establishing what causes MSD (e.g. duration, intensity and pattern, etc). Other researchers think there is enough information about this in order to take measures as to improve the ergonomics when it comes to putting load on the musculoskeletal system [22]. The human capital is an important component of a company's business and affect productivity, quality, image and hence profitability. Although there are some limitations in the research regarding the connection between reduced problems with MSD and ergonomic interventions, there are signs showing that ergonomic improvements could springs results in the form of fewer problems with MSD, and in many cases an increase in productivity [22].

When it comes to the relationship between productivity and ergonomics it is important to keep in mind that improvement in productivity, such as shorter installation times, could affect ergonomics in both a good or bad way [24].

If shorter installation times lead to more installations being performed each day the strain on the installer could be the same as before or even increase since similar working postures are held. If the time saved due to improved productivity is used performing other tasks that engage different parts of the body the productivity improvements are beneficial, since it is always good to vary the strain on the body. It is therefore important to investigate exactly how improvements in productivity influence working patterns in order to understand how it affects ergonomics [24].

2.2.7 Other factors

Many factors other than working postures and working environment affect the risk of getting work-related MSD, such as psychosocial factors (e.g. stress), life style, visual conditions or age of the individual. Every employee has different individual prerequisites and can therefore not be presumed to perform work in the same way, pace or with the same settings. An individual can to some extent take measures in order to prevent MSD but most effective is to fit the work and working conditions after the need of the individual.

2.2.7.1 Lifestyle and individual prerequisites

The lifestyle chosen by an individual will not only affect that individual's spare time but also work performance and possibly prevent work related injuries. A sound lifestyle will lead to the individual having more energy during and after work. By eating healthy food, exercising and having other sound habits (no smoking or intake of other sorts of tobacco) the individual can keep its body in good shape. A good physique, coordination and body recognition have often proven to prevent damage to the locomotors of the body. It is however not always possible to compensate a bad working environment with a good physique [13] and [18].

Individual prerequisites can vary in age, gender, physical condition, motivation, experience, age and a possible handicap making it difficult to satisfy all needs. The foundation of the Work Environment act is to create a balance between the occupational demands and individual prerequisites by primarily adapting the environment to fit the individual [13]. This can be met to some extent and is more applicable in some occupations than others, depending on the type of work and the flexibility of the workplace. The P&H industry need to work a lot with using and improving aids since many other factors are hard to change (e.g. climate).

2.2.7.2 The influence of age

After the age of 25, the human body has reached its physical peak, signifying a gradually deteriorating muscle- and skeletal resilience, less ability to absorb oxygen and a worsening of vision and hearing. By the age of 60 the maximal muscle force will have been reduced with approximately 25% and the ability to withstand axial force on the vertebras will be halved compared to that of a 40 year old [18]. The risk of getting a work related injury/ disease and the prevalence of MSD increases with age [18] and [25].

According to a study from 2003, the age-adjusted prevalence of MSD is higher in nine body regions for foremen and construction workers compared to white-collar workers [25].

It is rare for workers in some of the more physically demanding professions in Sweden to retire at the age intended for their trade. Many construction workers are forced into early retirement due to injuries or not keeping up with the work pace. When paid in the form of piecework salary the slower worker might feel pressure from co-workers to quit as not to affect the group's work performance. Keeping on an older workforce is advisable due to their experience and know-how [18].

2.2.7.3 Vision

Sight is an important sense that affects the entire body. Attaining a good line of sight is so important that humans automatically adjust their body postures in order to attain as clear of a view as possible. This could lead to an increased risk for strain or tension in areas such as shoulders, neck, arms and back. Individual factors such as age has an impact on sight. As one gets older it is more important with good lighting conditions and it also gets harder for the eye to accommodate, which increases the need for using glasses. The need for glasses imposes one problem for workers such as P&H-installers who need to tilt their head backwards a lot. Progressive glasses are designed to give good vision in short distances in the lower part of the glasses. Workers using these types of glasses therefore have to tilt their heads even further back in order to achieve good vision, which increases the strain on the neck muscles. However there are special glasses suitable for people working in these types of working postures, with a reading zone in the upper part of the lens, usually used by electricians and pilots [26].

2.3 Methods

2.3.1 Observations

Observing activities, people performing those activities, their behaviour and patterns is an effective technique in collecting data and a very useful tool for an ergonomist. There are three ways of observation: direct observation (i.e. watching live performance), indirect observation (i.e. watching and/or listening to a recording) and participant observation (i.e. participating in the task oneself) [27].

Observation has the disadvantage of possibly affecting the observed. People who feel that they are being observed might change their behaviour or patterns without intending to do so. There are different techniques that can be used as to prevent this phenomenon (i.e. piloting the test beforehand, careful planning of the different tasks and choosing the right participants). The observer should also familiarize with the person being observed prior to the observation [27].

2.3.2 Interviews

Interviews are an easy method to collect information in an organised way. Interviews can be open, semi-structured or structured. Open interviews focus on the opinion and experiences of the participants while structured interviews focus quantitative factors that can be measured such as how often something occur or if a certain model, of for example a car, is preferred over another. A semi-structured interview combines open questions with structured ones in order to capture the participants' opinion of both qualitative and quantitative aspects [28].

2.3.3 "Se om miljön" – a risk assessment guide for the workplace

The Work Environment study conducted in this thesis project was based on "Se om miljön" which is a model developed by Sveriges Verkstadsförening & Svenska Metallindustriarbetarförbundet. The model, created in the 1970:s, is used to map and assess the work environment particularly in factories but can be useful in many different types of workplaces. The model was altered in 1990 to better respond to modern demands of the workplace. One of the benefits with this study is that the opinions of the participating employees are given equal value as the opinions of the observers.

The model focus on twelve different categories: noise, lighting conditions, climate, dust, vibrations, factors affecting the skin (such as dirt), accident risks, working postures/ workload/ lack of mobility, work content, freedom of action, control of chemicals and fire hazards. The model aims to be simple enough for practical use while producing reliable data. The data is based on interviews with employees (in order to capture their subjective opinions), observations and measurements when possible. Accurate measurements are the best way of getting a reliable result, however the prerequisites for measuring different factors vary. For example a Lux meter gives a value of the illuminance, meaning how much light hits a particular surface. Getting representative measurements of the lighting conditions is difficult due to variations of light in the workplace, for example the contrast between work area and the surroundings. Noise can be measured with a Sound Level meter. In order to get the equivalent value of noise, measurements should be taken close to participants work area and preferably during a whole workday. The easiest way to do this is by using a Sound Level meter that attaches to the back of the worker. If accurate measurements are not possible to obtain, observations of the environment will suffice. The data gathered from interviews, observations and measurements is later analysed and divided in to zones. The zones ranges from very satisfactory to very unsatisfactory for the participants and target zone to action zone for the observers, according to pre-established standards [29].

2.3.4 Questionaires

The advantage of using questionnaires is that it is very efficient when collecting a large amount of data with little effort from the experimenter. The method also allows the participant to complete the study on paper thereby not requiring the presence of the experimenter [27].

Questionnaires are however inflexible and do not allow follow up questions [27]. The work of compiling the collected data is often extensive and usually takes a lot of time. The method is intrusive and will disrupt the every day tasks of the participant.

2.3.5 Hierarchial Task Analysis (HTA)

Hierachial Task Analysis (HTA) is a method used to describe a system by breaking up a task in separate elements that are organized in a sequenced order [30]. HTA can be used in many applications such as error prediction, system design and team performance assessment [27].

2.3.6 Posture analysis

There are several methods to choose from when analysing how work affects the body. Inclinometry can be used to measure positions of different parts of the body such as the neck, arms and shoulders. First measurements are taken when the test object stands relaxed with the arms to the side in order to define reference positions. The positions of different body parts are then measured in relation to the reference positions. This provides detailed data of how often and to what extent a person bends for example the neck. Electromyography (EMG) can be used to measure the load on certain muscles such as trapezius (the muscle that bends the neck forwards and backwards) but also provide information on how much time out of the workday a person may rest or recuperate [24]. EMG detects the action potential of contracting muscles. Before starting the measurements a rest level and reference contraction level (e.g. maximum contraction or contraction when handling a predefined external load) are defined. Measured levels of contraction can thereby be compared to the reference levels and are presented as percentages of the reference contraction. The method can therefore be used to compare contraction levels between different individuals [31].

The affect work has on the body can also be analysed using methods for posture analysis were working postures are analysed visually. There are many different methods for work posture analysis available. A common factor for many of them is that the observer score points on individual working postures either by observing the action live or from video film or photographs. In some methods such as Ovako Working posture Assessment System (OWAS), postures held by the participant, are chosen based on frequency thereby getting a representative selection of postures. Other methods select postures based on how strenuous or frequently appearing they are, thereby focusing on postures that are likely to be a risk factor. In many methods the data is collected only by the observer while others like Quick Exposure Check (QEC), requires the participation and opinions of the person being observed during the analysis.

2.3.6.1 Hand Arm Risk assessment Method (HARM)

HARM was developed as a method for occupational health officers to evaluate the risks of developing pain in the neck, shoulder or arm regions of the body during hand and arm tasks. HARM is suitable for tasks carried out mainly by the hands and arms since the lower body is not assessed. The task should be preformed for at least an hour per day and not include forces or loads over 6 kg/60 N per hand [32].

The method is simple to understand and does not require prior training. The analysis can be performed either from observing work postures live or from video. The type of work to be analysed is defined in different tasks that are analysed separately. Factors such as how long and how often a task occurs, if breaks or other tasks activating different muscle groups occurs regularly are taken into consideration. The amount of force used is calculated both with focus on duration and frequency. Positions of individual body parts are scored based on the average duration of each body movement [32].

Other factors such as vibrations, climate and predefined break times are also taken into consideration. In HARM the whole workday is assessed giving tasks performed for a longer set of time a higher time score than shorter tasks. This time score is multiplied with the scores received in other segments of the analysis and then the final HARM score is calculated. Finally the HARM score is used to decide the possible risks for developing MSD by categorizing the scores into three zones. Scores from 0-25 are in the green zone were the risk of developing MSD is considered very small for a majority of workers. Scores ranging from 25-50 are in the yellow zone were there can be a risk for developing MSD for some of the workers. Scores over 50 are in the red zone were there is a high risk for MSD amongst a majority of the workers [32]. For a full view on how the scoring is done, see appendix A.

Both the validity and the inter user reliability of HARM have been tested. Comparing results from HARM to measured results and expert estimations tested the validity. The inter user reliability was measured by comparing results of eleven practitioners to each other. The results were fair to good for the risk evaluation of different tasks but some risk factors showed poor results. To improve the results, the maximum force was set to 6kg/60N instead of the original 10kg/100N. Furthermore some categories have been reduced in number and the instructions have been improved with better descriptions. A 20 ° angel was introduced as a guiding tool [24] for easier evaluation of postures. Further studies of the validity and reliability are being performed or planned within the next couples of years [32].

2.3.6.2 Rapid Entire Body Assesment (REBA)

REBA was developed as a practical tool for assessment of hazardous work postures. It is a simple tool that does not require any special training and can be carried out with a pen and paper. REBA was established to investigate musculoskeletal risks in occupations such as health care or other service professions that often includes unpredictable postures. In REBA, postures can be chosen either by frequency, because they are commonly occurring or because they are estimated to be very strenuous. Postures are divided into two groups, A: covering neck, trunk and leg analysis and B: arm and wrist analysis. Scores are given for both groups separately and factors such as force/load, coupling and activity are considered before the final REBA score is calculated, see appendix B. The REBA score is also defined into categories were a score of 1 is defined as a negligible risk for MSD, 2-3 is defined as a low risk and changes in work posture may be needed. 4-7 means there is a medium risk for MSD and further investigations need to be done. 8-10 is defined as high risk and investigations and implements of changes are necessary [33].

A score of 11 or more means there is a very high risk for MSD and changes need to be implemented right away. The posture analysis can be done either directly or from recorded material. REBA has shown an inter-observer reliability of between 62-85% of agreement [33].

2.3.7 Subjective assessment methods

Subjective assessment methods are often used by ergonomists to capture subjective sensations when a participant performs a task. Borg's Rating of Perceived Exertion (RPE) scale was developed in 1970 to assess perceived exertion. The scale goes from 6 (No exertion at all) to 20 (Maximal exertion) and is linear to heart rate and oxygen consumption. In 1982 Borg developed the Borg Category-Ratio 10 (CR-10) scale that assess the sensory intensity on a scale from 0 (Nothing at all) to 10 (Extremely strong). This scale can be useful when comparing experiences between different individuals. It can be useful to use a Body map i.e. a sketch of the body as a tool when defining sensations. Participants can mark on the body map where a certain sensation is located [31].

3 Methods

The methods of the different studies conducted during this project as well as the order in which they were performed are described in this chapter.

3.1 Structure of methods

For this thesis project a large number of methods have been used. The methods are meant to complement each other in order to gain more information from various aspects of pipe installation and the work conditions of P&H installers. The use of several methods also creates an opportunity to triangulate the results, making them more reliable. The studies conducted with the methods described in this chapter were conducted in the order presented in in figure 3.1. An analysis was made after each conducted study and a final analysis was made in the end combining the results from all conducted studies.

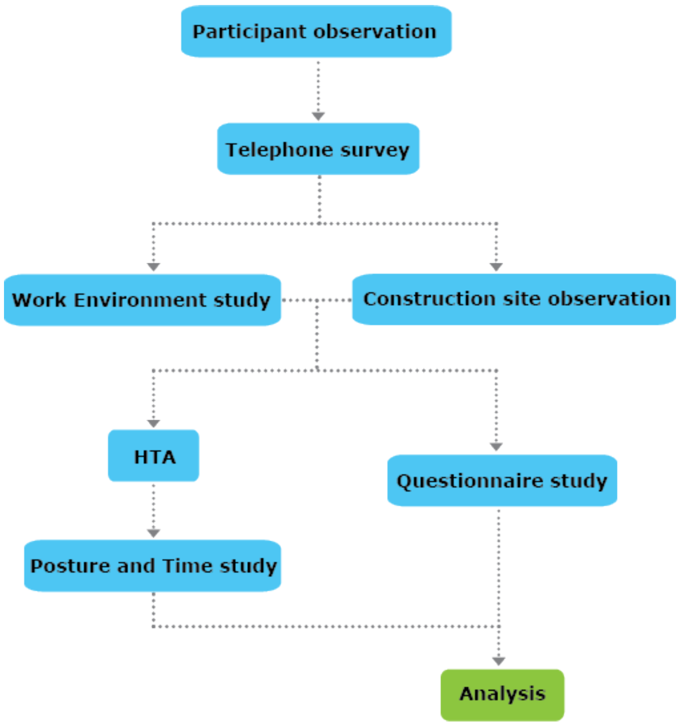


Figure 3.1 Structure and order of studies conducted in the project

3.2 Observations

3.2.1 Participant observation

The objective with this study was to get a better understanding of the process of pipe installation, investigate differences between the systems and to locate problem areas and/or actions to further investigate. The observers used the technique of participant observation while installing two different systems for pipe installation. The first installation was with system 1 and the second was with a system similar to system 3 (the exception was having pipe rings that click on to the connectors instead of screwed on) and will therefore be referred to as system 3. System 2 was excluded from the participant observation since this system is a combination of system 1 and 3. The observers had no previous experience with either system and therefore an employee from Hilti assisted with knowledge on how to install the systems during the observation. The observers worked together when installing the systems. In order to get as much information out of the test as possible some things were kept in mind during the installation (e.g. good/bad working postures, difficult tasks and time/ frequency of tasks).

The participant observation was conducted in a spacious indoor environment with a comfortable temperature and good lighting conditions at Hilti HQ in Arlöv. A two-meter high and three meter long steel construction with concrete blocks characterising a ceiling served as test rig. The pipes installed during the observation were two-meter long steel pipes with a diameter of 50 millimetres. Both systems were installed with Hilti-tools, although system 1 had not, in contrary to system 3, a vacuum cleaner attached to the cordless rotary hammer. The conditions of the observation differs from those found on construction sites where factors such as climate, light, noise etc. have impact on work performance.

3.2.2 Construction site observation

The purpose of the direct observation at construction sites was to further investigate the findings from the participant observation on working postures. The purpose was also to examine working conditions and become aware of new aspects. Furthermore the observations were important in creating an understanding for the daily work of a P&H installer and helped in preparing for the Posture and Time study.

The construction site observations were conducted at five different sites. The observations were performed whenever visits to construction sites were possible and since those were few it was often during the same visit as the Work Environment study was conducted. At each visit pictures of the work environment (i.e lamps, lifts, water puddles, work benches) and working postures (i.e. P&H installers drilling in the ceiling) were taken. Both short and long videos of P&H installers working and recordings of noise were made. Notes on climate, cleanliness and relations between co-workers were also taken into consideration. The pictures and videos served as a memo and were reviewed later. The observations were done before or after the Work Environment study and varied in time depending on if for example recording a working pattern and shorter if taking a picture of a lamp.

An opportunity was given to observe an P&H installer for 5h and gave further information on working conditions. This was possible as the participant had the time for a longer observation. The participant was partly working on installing a piperun in the ceiling at the time of the observation and could therefore give valuable insights.

3.3 Telephone survey

The Telephone survey was conducted to get a general idea of the P&H industry for example the use of piecework salary, which systems for pipe installations were used and which system was the most common.

The interviews for the Telephone survey were conducted in a semi-structured way with both structured and open questions. Depending on the answers given some spontaneous follow-up questions were asked that were not defined beforehand. The questions asked during the interviews can be viewed in appendix C.

Each interview took around 3-5 minutes to complete and was conducted sometime during a standard workday for a P&H installer. Breakfast and lunchtime was also avoided.

3.4 Work Environment study

The Work Environment study was conducted to get an overall picture of the Construction industry and the everyday of an P&H installer. Unlike the Construction site observation study, the objective was to get the subjective opinion of the H&P installers on site. The information in the Work Environment study was collected in interview form. Much thought was put into how to ask questions in order to receive the opinion of the participants without influencing the answer. Neutral questions such as “What is your opinion regarding the noise?” were asked as opposed to questions like “Do you think the noise level is high?”. A total list of questions asked (see appendix D). The questions were developed based on the definition of zones presented in (appendix E) and described in chapter 3.2.2. The ambition was to create a dialog between the P&H installer and the observer in order to receive more information than if questions were only read from a paper.

During the interviews the answers given by the participants were registered and follow-up questions were asked as to keep the conversation going and get as much information as possible. The answers were assessed at a later time and placed in the zone that best corresponded to the answer. The risk of influencing the answers were reduced by listening first and analysing later in the case the participant felt inhibited to speak freely if judged by his answer [29]. The interviews were held with participants in their workplace. Sometimes interviews were held during on-going work in the work area and sometimes during breaks in a lunch area. The interviews were held individually with two interviewers present.

To categorise the workplaces in an objective way, the definition of zones presented in “Se om miljön” was used. A full list of the zone definitions can be viewed in, see appendix E. Psychosocial factors have not been taken into consideration since focus was on physical aspects of the workplace, not the overall working environment of the individual construction sites.

It seemed possible beforehand to measure noise level and lighting conditions. Noise was measured with a Sound Level meter and light with a Lux meter. In the cases where objective measurements could not be taken, the observers' opinion of the workplace conditions in addition to the measurements was noted as a supplement to the opinion of the participants. The category vibrations was neither measured nor discussed by the observers, as an estimation of the vibrations would require handling the tools first hand or placing a measuring device on the tool. The observers made an assessment of the work area in order to create a general opinion of the working conditions. Comments were recorded for the different categories and later the categories were assigned zones based on the previously described definitions.

3.5 Questionnaire study

For this project a questionnaire on work-related disorders was created, see appendix F in order to locate disorders, see if the experienced disorders were work-related and to see if any connections between disorders and lifestyle choices could be made. Another reason for the questionnaire study was to discover if the two participants that took part in the Posture and Time analysis could represent the target group.

The questionnaire was created with inspiration from "The Upper Extremity Questionnaire", University of Michigan but altered as to better apt the purpose. The structure and type of questions were based on the upper extremity questionnaire. Some questions regarding women were disregarded since the target group for the study were only men and questions on the lower extremities of the body were added to get a full overview. The layout was changed to some extent and the questionnaire was translated into Swedish. The questionnaire consisted of around 70 questions and took approximately 10-15 minutes for a participant to answer.

When the opportunity to visit a construction site twice arose, the questionnaire was handed out during the second visit. However, three out of four construction sites were only visited once and then the questionnaire was handed out during the same visit as the "Work Environment study". The questionnaires were handed out during break or active work depending on the time of the visit. In cases when the questionnaire was handed out during active work, the participant would go somewhere quieter to fill it out.

3.6 Hierarchical Task Analysis (HTA)

In this study the HTA served a very important function as it set the frames for the Posture and Time study. By creating an HTA of the most common work scenario of an P&H installer, variables (e.g. tools, time and space needed) could be revealed. The three HTA:s all described one of many scenarios since there were many deviations due to the fact that every installer has their own way of working. The HTA:s were products of previous observations and interviews. The HTA:s were later evaluated by three P&H installers from construction site 4 in order to ensure its validity.

3.7 Posture and Time study

The Posture and Time study took place in the demonstration room at Hilti HQ. This was because no suitable construction site was found where a test like this could be fitted into its timeframe. This meant that the test was performed in an artificial and controlled environment. The benefits of this were that variables such as climate, lighting conditions and temperature could be controlled. A six-meter long and one-meter wide test rig was constructed with six concrete blocks simulating a ceiling (see figure 3.2).

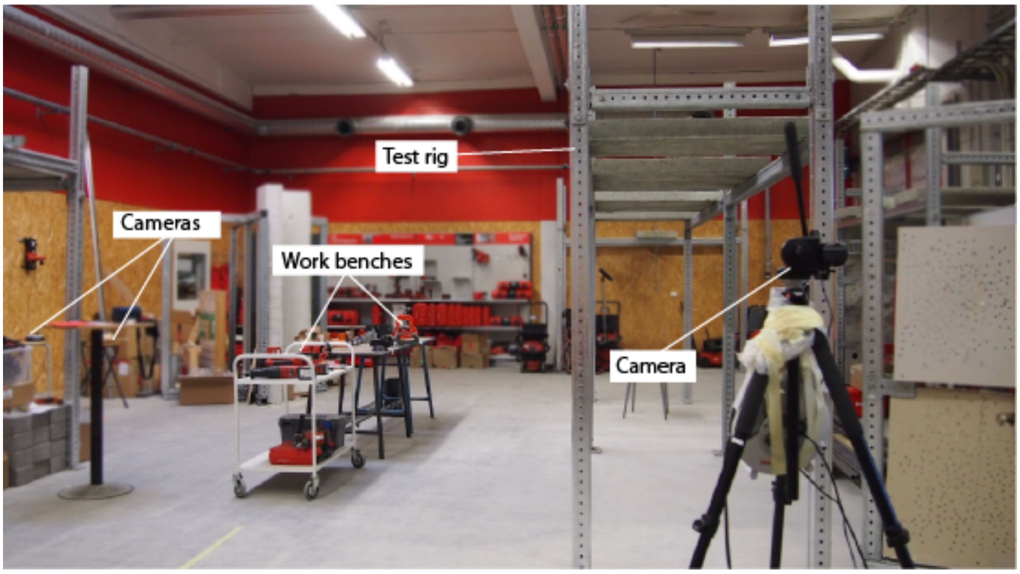


Figure 3.2 Two workbenches with tools and material and two cameras to the left and the test rig and one camera to the right

The overall height of the test rig was set at what was thought to be the optimal height for both installers since a lift of the kind used in construction sites was not available. Based on the results from the Participant observation see chapter 5.1.1 the decision was made to let the vacuum cleaner be attached to the cordless rotary hammer during the whole installation. The temperature in the demonstration room was 18 ° C on both test-days. The lighting conditions were the same during both days measuring approximately 611±20 lux by the work bench, 434±98 lux at ground level directly under the rig and 93±61 lux under the rig at working level (defined as 15 cm below the concrete blocks).

Small distances were put under some of the concrete blocks (see figure 3.3) in order to create a small height variation. This forced the participants to adjust the length of the connectors in order for the pipes to hang levelled. This was of interest since the ceiling in construction sites seldom has an even surface and adjustments of this kind is often occurring.

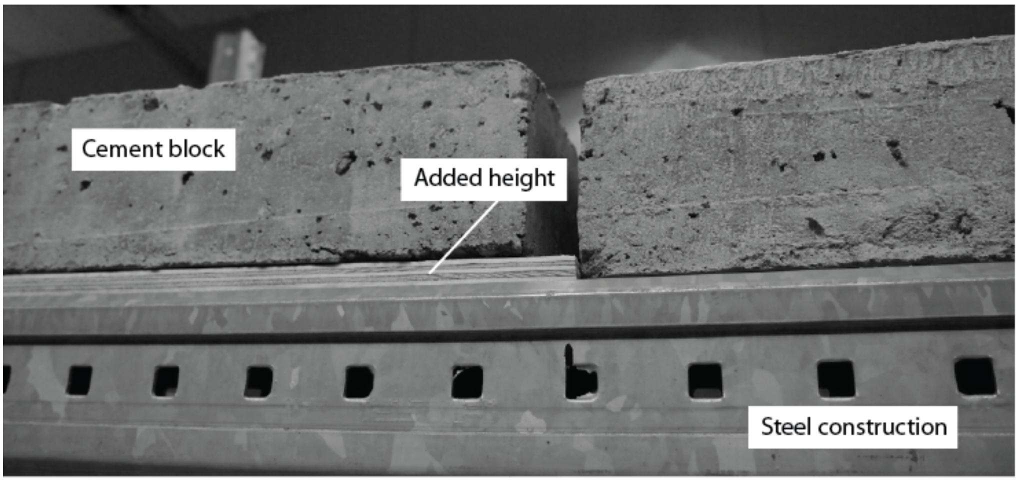


Figure 3.3 Small pieces of wood under the cement blocks gave extra height

During the study the three different systems for pipe installation, defined in chapter 2.1.3 was installed. In order to keep the two separate test days as similar as possible a fixed order in which to install the systems was decided. System 1 was estimated to take the longest time to install and was placed first, followed by a 30 minutes lunch break were the test participant was able to rest. Then system 2 was installed followed by a 30 minutes break and finally system 3 was installed.

During all three installations a total of 18, two-meter long pipes, was to be installed. The pipes held three different dimensions, Ø25, Ø50 and Ø100 millimetres. Half of the pipes were to be installed with chilled pipe rings, which are used when installing insulated pipes for cooling systems and the other half with standard pipe rings, some with rubber insulation. For a full layout of the installation, (see figure 3.4). The installers had access to the same tools during the test, for a full list of material see appendix G.

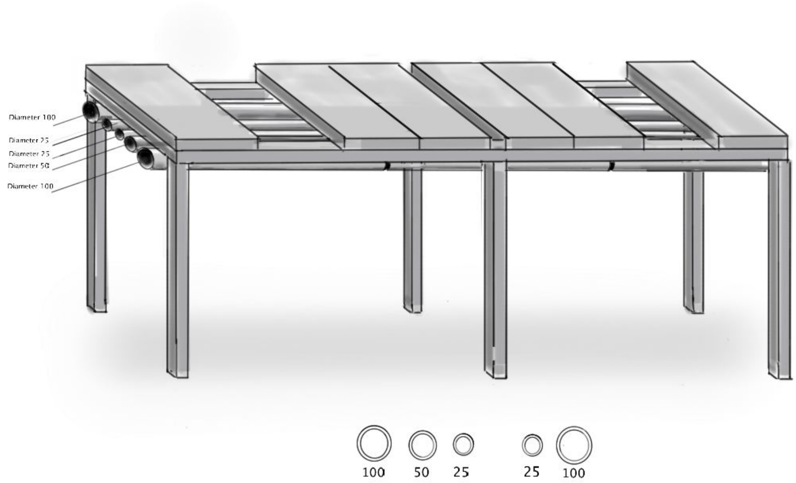


Figure 3.4 The full layout of the installation

The test was videotaped with three video cameras recording simultaneously, one camera positioned at the short side of the rig and the two others, placed side by side, covered the long side of the rig (see figure 3.5). This set up enabled the observers to view a posture from two angles and thereby providing as much information of the posture as possible. A fourth camera was kept close by in case any problems would occur during the test.

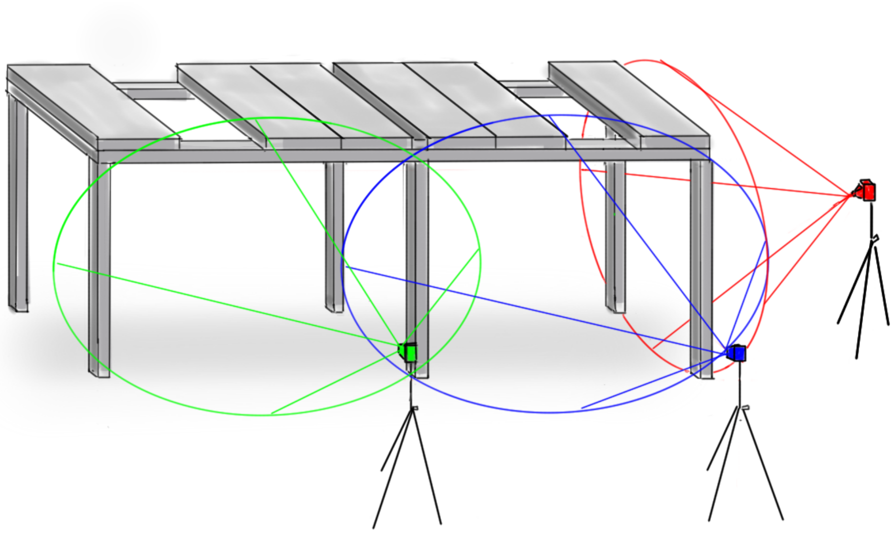


Figure 3.5 Two cameras faced the long side and one camera faced the short side of the test rig

The participants of the study were contacted beforehand in order to exchange information as well as create trust between the participants and the observers. They were also sent a copy of the test day schedule.

In order to build the test rig in an as appropriate height as possible, the heights of the participants were registered. The participants were asked to wear regular work pants in order to make the test situation as realistic as possible. Furthermore they were asked to wear a dark, tight shirt such as an underwear shirt on the upper body in order for their body positions to be as visible, against the background, as possible. The participants were also marked with white tape on their upper body along the spine, between the shoulders, along the upper arm and on the front- and backside of the lower arm (see figure 3.6, 3.7). The purpose of this was to make it easier to analyse the working postures and see if the participant was bending or twisting.

Figures 3.6, 3.7 Tape was placed on chosen parts of the body of the participants

Before starting the installations the participants were asked to fill in the same questionnaire answered by P&H installers during visits to constructions sites. After each installation the participants were asked to provide their spontaneous thoughts on the system, answer if any particular operations were more easy or difficult to perform or if they had any additional feedback. The participants were also asked to mark on a body map if they felt strain in any part of the body and define how much using Borgs RPE scale. The participants were asked to give their view on how realistic the setting of the study was compared to pipe installation on construction sites.

3.7.1 *Hand Arm Risk assessment Method (HARM)*

HARM was chosen as the main method for the posture analysis since it covers many factors that influence the work situation of P&H-installers. The fact that the method focuses on the upper body was an important aspect since the upper body and mainly the neck, arms and shoulder are much affected when working above shoulder height. HARM also takes into consideration the duration of the work task, which is useful when comparing the systems to each other. For the HARM analysis the work of installing piperun was divided into six tasks. The observers analysed the work of one participant each in order not to bring unnecessary variations in judgement when comparing the three systems to each other.

3.7.2 Rapid Entire Body Assessment (REBA)

REBA was chosen because it analyses the entire body. The method takes both static and dynamic loads into account as well as changing or instable postures, which can often be found when installing piperun in ceilings. The work of installing piperun were divided into eight different tasks, see table 3.1. The REBA analysis where divided into two parts, one overall covering all tasks and one deeper analysis. The first part was the overall analysis of all eight postures, evaluating a posture for each task and participant. Postures found to be strenuous but still representative for each task were chosen for evaluation. The second part was a deeper analysis where five postures for each of the most interesting tasks (i.e. tasks were obvious differences in work techniques occurred between the three different systems) were evaluated. The five postures showed neither the best nor worst-case scenario but still gave a representative variation.

Table 3.1 The process of installing pipes were divided into eight different tasks

Task	Definition
Cutting takjärn/ channels	Participant holding the saw in the act of cutting takjärn or channel
Fastening with a wrench	The participant fastening a screw with a wrench (e.g during preassembly or fixating pipes)
Drilling holes	The participant in the act of drilling a hole in the concrete ceiling
Mounting takjärn/ channels	The participant holding the takjärn/ channel to the ceiling either fastening it with a impact driver or hammering it with a hammer
Height adjustment	The participant adjusting the height of the pipes before or after the pipes are in place
Installing pipes	The participant holding the pipes and placing them in the pipe rings
Fixating pipes	The participant fastening the pipe rings around the pipes
Placing chilled pipe rings	The participant placing chilled pipe rings between the pipes and pipe rings

3.7.3 Time study

The total installation time for all three systems was measured in order to get a rough idea on how effective the systems were compared to each other. The time spent on the different tasks within the systems was not clocked since this could be evaluated from the video films later.

4 Materials

The selection of participants for the different studies conducted in this project is described in this chapter.

4.1 Selection of participants

The target group for this project, installers within the P&H industry, were in 2011 consisting of 99 % males with a middle age of 40 [34] and [35]. The selection of participants was located through Hilti sale-staff, working within the Installation Business Unit (BU), and was meant to represent the target group.

The participants, 13 in total, were all P&H installers working at the chosen construction sites. All of the participants were male with a middle age of 38, the youngest being 19 and the oldest 64. Based on the information from 2011 the selection of participants could be said to represent the target group. The average years of professional experience of the participants was 18 years. Some participants took part in more than one study, see figure 4.1. The aim was to have the same group of participant taking part in as many studies as possible as to easier draw conclusions between the studies and limiting the variable of individual differences.

The Telephone survey had a group of 43 randomly picked participants not including the 13 mentioned earlier. For the Posture and time study, two P&H installers took part that had not participated in any of the other studies.

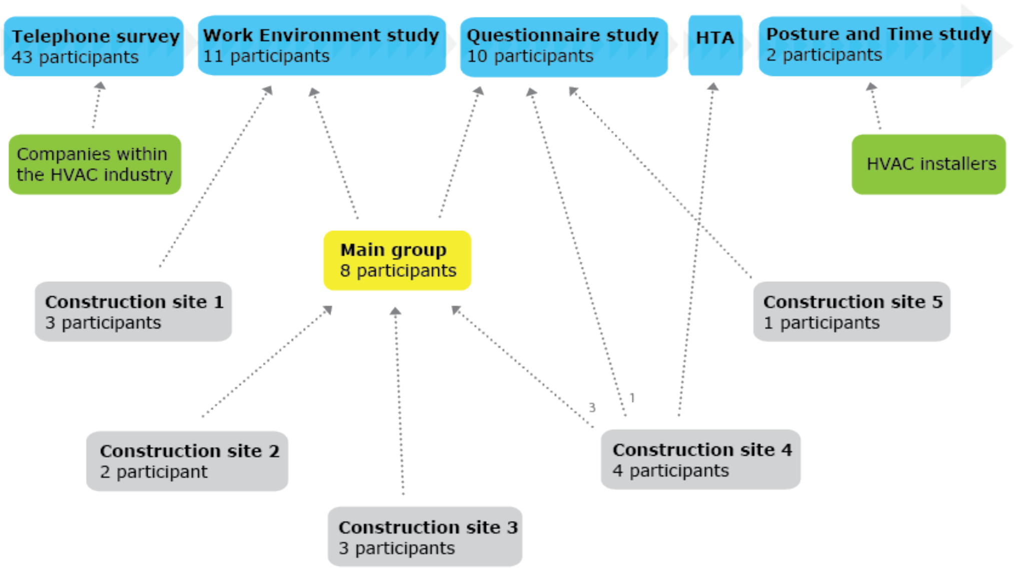


Figure 4.1 Overview of the selection of participants and which study they took part in

4.2 Observation

4.2.1 Participant observation

The observers (authors of this thesis) taking part in the participant observation were both females, ages 24 and 27. The observers differ much in height, one being 1.65m and the other 1.89m. Both participants had no prior experience of pipe installation.

4.2.2 Construction site observation

In total five construction sites were chosen though Hilti sale-staff, Installation BU, due to their accessibility, size and development phase. The sites had to be in the phase of installing pipes, although not necessarily working on that phase at the time of the visit, which greatly limited the selection. All five sites were new constructions and were placed in Skåne, the southern region of Sweden. The participating P&H installers were asked to rate the size of their working place on a scale from small to large and the labelling was based on the outcome. The size of the five construction sites varied from medium to large with construction site 1 being the largest according the P&H installers. One of the construction sites was to become a school and one a municipality building, the rest of the sites were to become office buildings.

4.3 Telephone survey

The participants of the telephone survey were chosen from Hilti's list of customers. In the list, companies are segmented ranging from mini, small, medium to large based on the customer potential. The potential is mainly dependent on the prospective of how much the customer could buy (i.e. how much of the Hilti product portfolio applies to the costumer) and how large the company is in terms of number of employees.

In addition to the segmentation, information was provided on how much companies have purchased during the previous year, both in total and within the installation BU. Since only a limited number of participants could be called, stratification was done in order to get representative results. Participants were called at random but with an ambition to cover companies from different potential segments and both buyers and non-buyers from the Installation BU.

Initially 43 participants were called, one from each participating company, representing companies ranging from mini to large see appendix H. Later on participants from companies defined as mini or small were found redundant since these were not thought to fit the target group of this project. The focus of the study lay on installation of piperun i ceilings which is only applicable in larger constructions. Companies classified as mini or small usually perform repairwork or smaller constructions. This left a total of 30 companies for the telephone study with the majority within the medium category. A majority of the companies were customers of the Installation BU see figure 4.2.

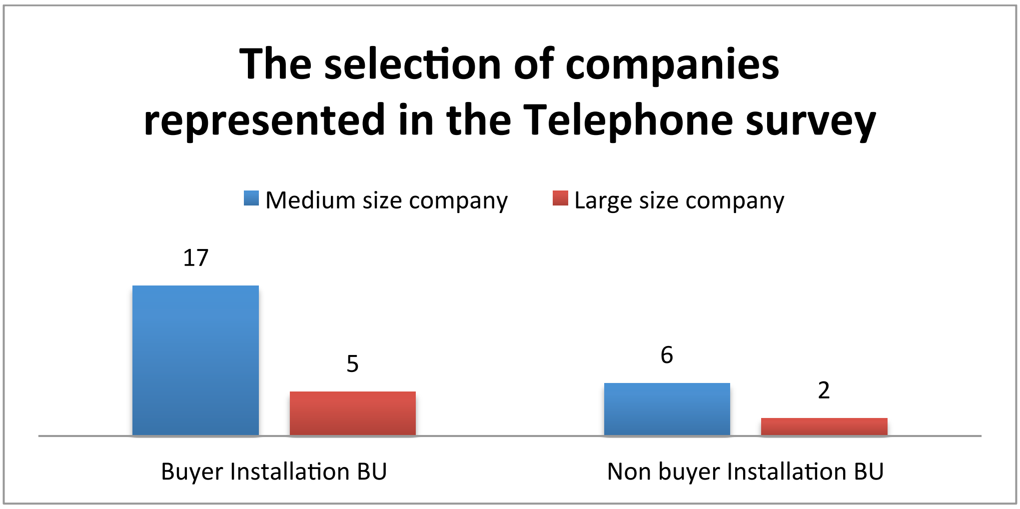


Figure 4.2 The selection of companies represented in the Telephone survey

Primarily foremen or mechanic tradesmen were contacted since employees in these positions were thought to be most knowledgeable in answering questions related to pipe installation. However these employees were not always available. When the preferred positions were not defined in the customer lists or unreachable, other positions were contacted instead. The position of the contacted participants can be viewed in figure 4.3.

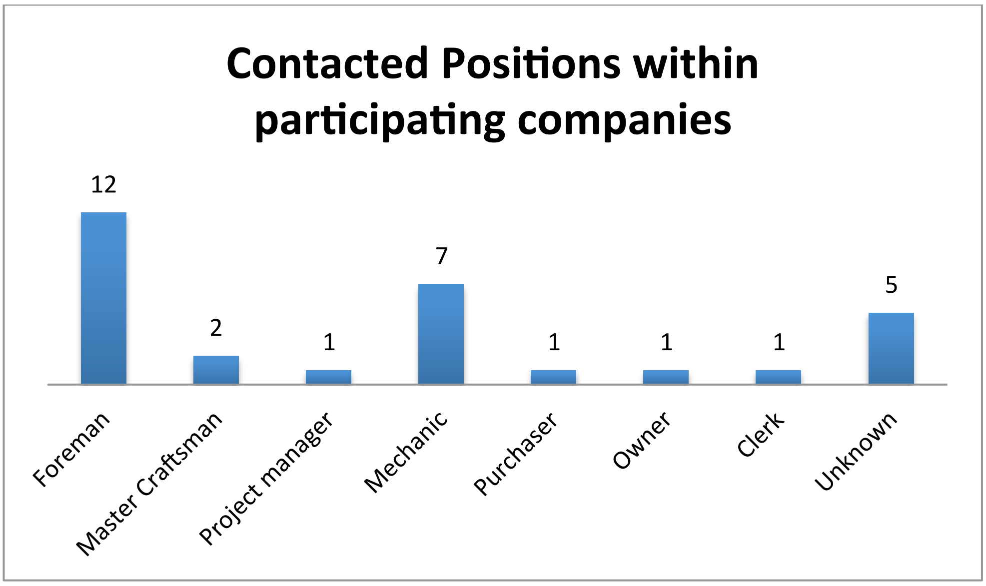


Figure 4.3 Positions contacted within the participating companies

4.4 Work Environment study

There were eleven participants taking part in this study, all being P&H installers coming from four different construction sites as can be seen in figure 4.0. Only four sites were chosen due to the time limit of the project. The observers (authors of this thesis) had little experience of the environment at construction sites.

4.5 Questionnaire study

The questionnaires were given to 10 P&H installers, from different companies, at their current workplace. Every participant got one questionnaire each and answered them individually. Up to three persons answered the questionnaires at the same time and in the same room.

The two P&H installers who participated in the lab test were given the same questionnaire as the other ten P&H installers. They were given the questionnaire prior to starting the Posture and Time study.

4.6 Posture and Time study

Two experienced P&H installers (participant A and participant B) were invited to participate in the Posture and Time study that took place during two days. One participant came the first day and the other the second day. Participant A was 38 years old with a professional experience of 20 years and participant B was 55 years old with an experience of 29 years. Both participants were physically active during their spare time although participant B was more active than participant A.

Participant A had no previous experience of system 3 unlike participant B. Both participants had experience of system 1 and 2 although not worked actively with system 1 for some years. The participants were given information of the purpose of the study, what their participation would be and that they would be videotaped during the study.

5 Results

The results of the different studies are presented in this chapter.

5.1 Observations

5.1.1 Participant observation

The observers found system 3 to be the easiest to use and quickest to install. The importance of adapting the working environment after the individual became evident. The observers found the available aid of an attachable vacuum cleaner was preferable and worth the extra weight.

5.1.2 Construction site observation

During the Construction site observation installation of piperun in ceilings were seen in action at 4 out 5 sites. However, only parts of the installation were seen and different parts were seen at different sites. In other words, a whole installation was not seen at one time. Many of the construction sites differed from one another in terms of lighting, climate, noise level, aids used, safety regulations and cleanliness. But also working postures, way of working, pace and jargon differed between the sites.

The sites were cold both inside and outside. At some sites an occasional heat fan could be found. Some of the sites had water puddles or ice on the floor but then less dust in the air as a result, see figure 5.1.

Figure 5.1 Water on the floor at construction site 2

The noise level varied from site to site depending on the time of day and the size of the site. The lighting could be placed in regular intervals in the ceiling at some sites and with portable floor lamps at others see figures 5.2 and 5.3. However, the overall impression was that it was dark and dim inside most of the time. Some P&H installers were found wearing a headlamp.

Figure 5.2, 5.3 Floor lamps at construction site 4

At least one ladder was found at each site, although some sites had more than others. The use of a lift was more common than the use of a ladder at the majority of sites. The floor of the lift was sometimes cluttered with things like tools, cords and screws see figures 5.4 and 5.5. The sites differed in cleanliness (i.e. less cords and other things covering the floor).

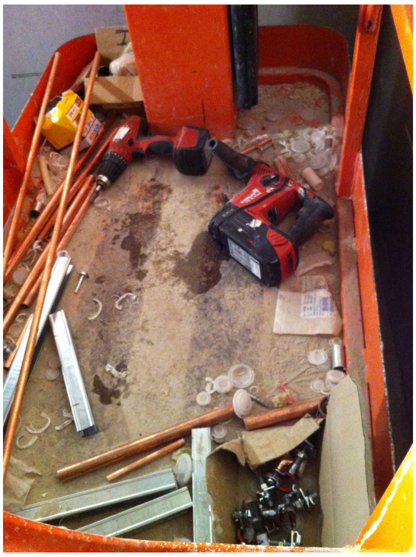


Figure 5.4 Floor of a lift, construction site 4

Figure 5.5 Lift, construction site 4

System 2 was the most common system found at the five sites and preassembly was either done onsite or offsite. Preassembly was done to some extent at all sites visited. One of the companies preassembled the majority of components offsite, although onsite preassembly was the most common.

The safety regulations on the sites were basically the same. Some had more visible emergency signs, safety pamphlets to read and more security steps such as to who were allowed to enter the premises. There was a special jargon between the workers that can be described as tough but friendly and there was a clear hierarchal structure. The way of working and held work pace was strictly depending on the individual.

5.2 Telephone survey

The participants were asked to define which system they use most often and to make an estimation of how often that system was used compared to the others. As visible in figure 5.6 system 2 was most frequently used followed by system 1. Most participants stated that the system defined as most common was used about half or more than half of the time. Some were unable to define which system they use most often and these cases fall under the fourth column named "not defined". Since these participants were unable to define the most common system, the question of occurrence was not applicable for the fourth column.

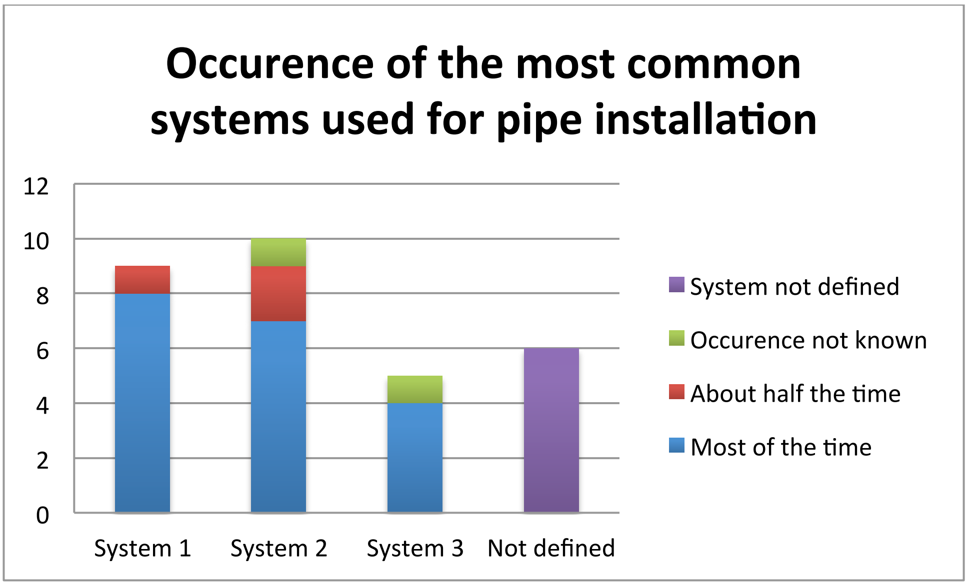


Figure 5.6 Occurrence of the most common systems for pipe installation, Telephone survey

The results on whether or not preassembly was possible are presented in figure 5.7, showing that most participants can either preassemble to a large extent or not at all.

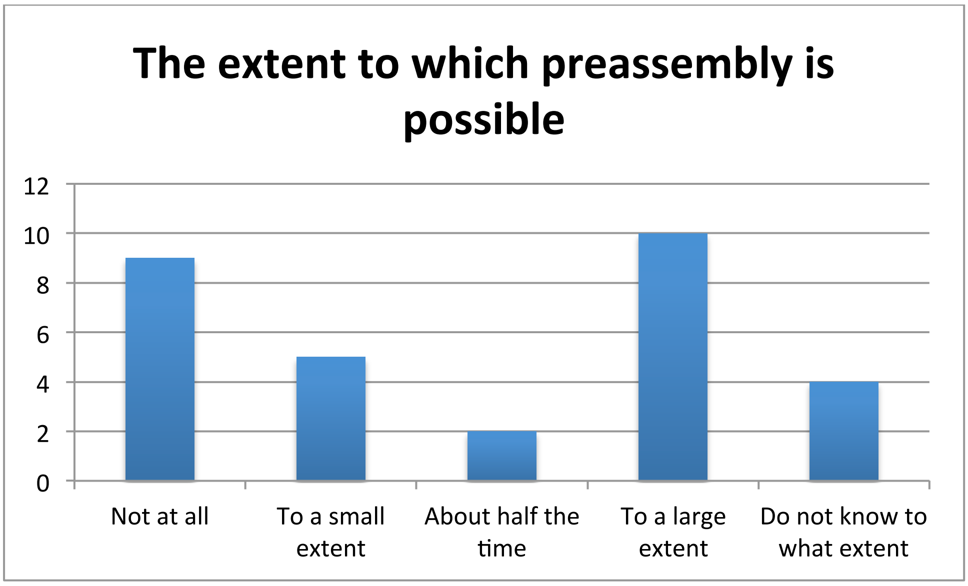


Figure 5.7 The extent to which preassembly is possible, Telephone survey

MSD is frequent among the participants and their colleagues. 90% of the 30 participants in the survey responded that they or someone at their workplace have some sort of work-related disorder. In order to investigate which areas of the body that are most exposed to MSD the participants were asked to state areas that they or a colleague find troublesome. 50 different body areas were declared in total as some participants mentioned several areas. The result is presented in figure 5.8 in percentage of how many times each body area was stated. The shoulders turned out to be the most troubled area followed by the back and neck.

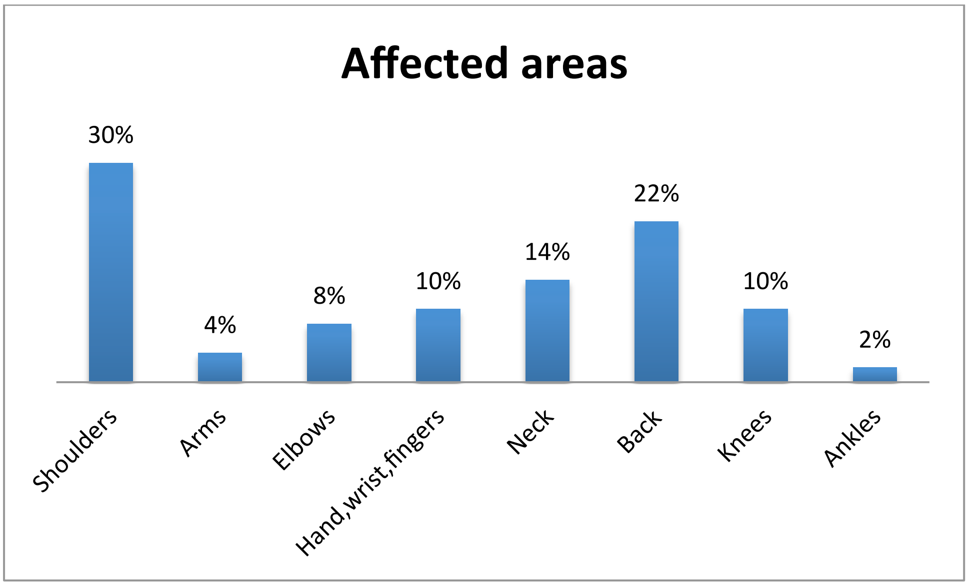


Figure 5.8 Affected areas, Telephone survey

Other factors that have an influence on the work situation for P&H installers are presented in figure 5.9. The results of the survey show that piecework was not the most common form of payment amongst the examined companies as 20 participants answered that it is not used. Nine participants answered that they work on a piecework salary. Furthermore, a majority of the participants responded that their company work actively or somewhat actively with work environment issues. When asked if ergonomic factors play a part in choosing which installation system to purchase and if the installers can affect the decision the responses were varied. 9 replied yes, 8 no, 9 sometimes and 4 not sure.

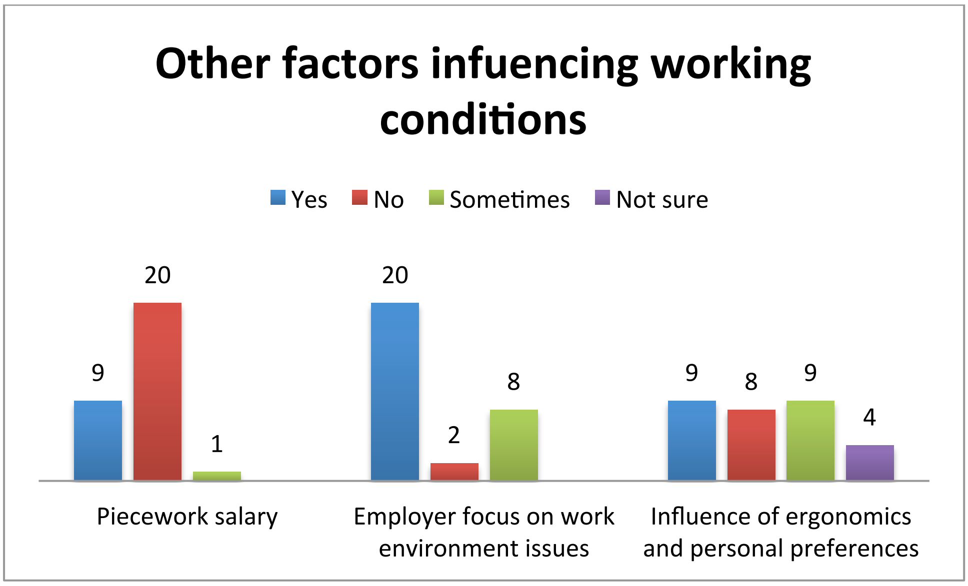


Figure 5.9 Other factors that can influence working conditions, Telephone survey

It was considered of interest to know if piecework salary had any impact on the willingness to invest in installation systems considered more ergonomically or preferred by P&H installers of the company. In figure 5.10 the results are presented in four columns. The columns are categorised in a way describing to what extent the employees feel they can influence the choice of installation system the company will purchase based on ergonomic preference. Weather or not piecework is used as form of payment is defined for each column.

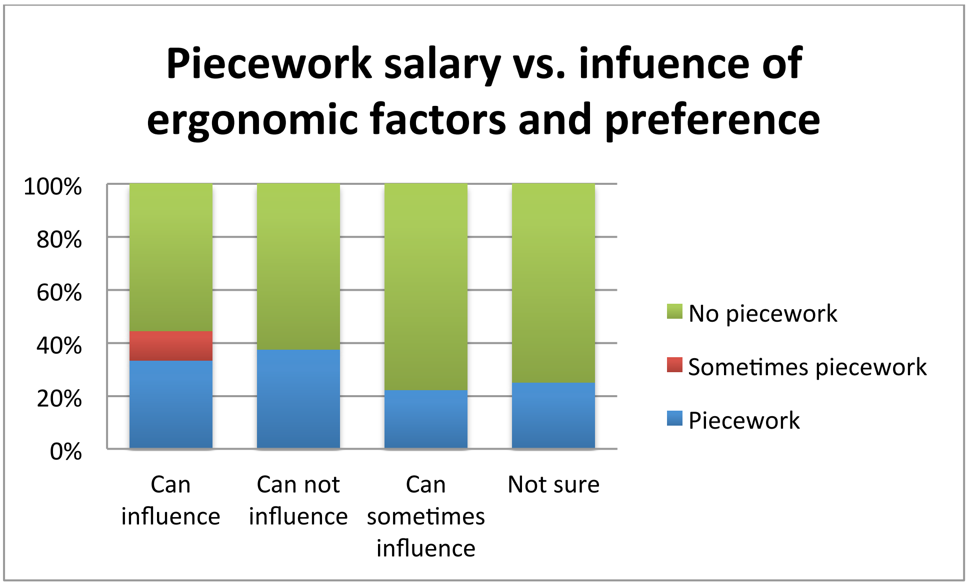


Figure 5.10 Piecework salary vs. influence of ergonomic factors preference, Telephone survey

5.3 Work Environment study

The results from the Work Environment study are presented in figure 5.11 as the mean value of opinion for each construction site visited. For data of individual participants, see appendix I. The opinions of the participants are presented on the left side with the first bar representing construction site 1, the second bar construction site 2 etc. The opinions of the observers are presented correspondently on the right side. For the vibration category no opinion is presented for the observers. This was because without using the tools directly, no opinion could be made on the subject.

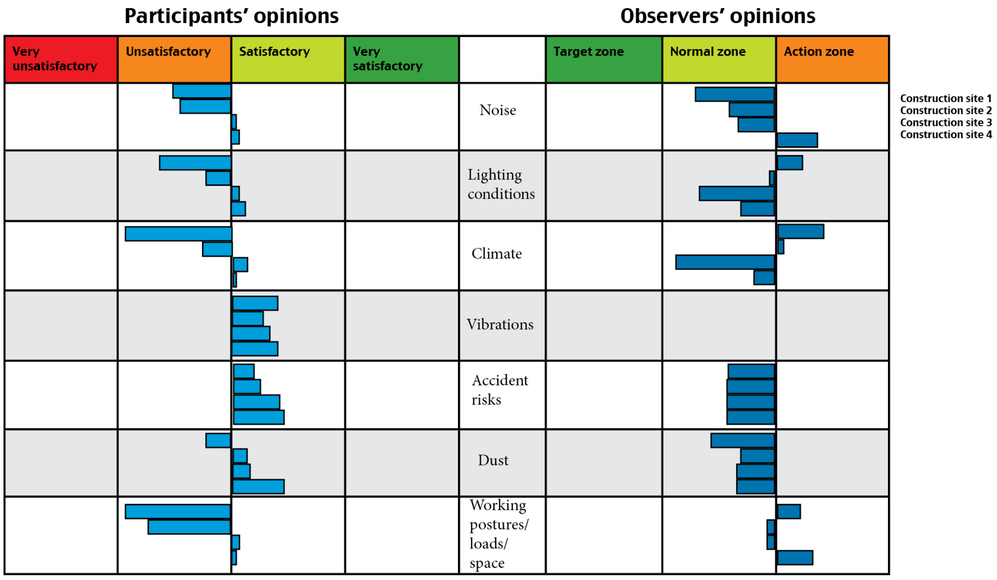


Figure 5.11 The results from the Work Environment study

The results show that for some categories there are quite a variation of opinions between the various participants and also between the participants and the observers. Climate and working postures/ loads/ space shows the most variation in opinion between participants from different construction sites. Vibrations, accident risks and dust get the most unanimous answers. The observers' opinions also vary for climate but are more unanimous for working postures/ loads/ motion. This category was judged as being more hazardous by the observers than some of the participants.

Both the participants and the observers found the categories of accident risks and dust to be satisfactory and the P&H installers also allocate vibrations as being satisfactory. Working postures/ loads/ space and climate were considered most unsatisfactory by participants from some of the constructions sites although participants from other sites found these categories satisfactory. Working postures/ loads/ space, climate and noise were, for some construction sites, found to be furthest into the action zone by the observers as well. For the noise category the observers' opinion varies noticeably from the participants, defining the noise of construction site 4 as being in the action zone while the participants defined it as bordeline satisfactory. For construction sites 1 and 2 the participants defined the noise as being unsatisfactory while the observers defined it as satisfactory.

5.4 Questionnaire study

Only a small part of the results from the questionnaire study was useful. Some of the more detailed questions were disregarded due to unsatisfactory answers. The results that could be used from the study are presented in table 5.1 and the amount of unanswered questions for each participant is presented in table 5.2.

Table 5.1 The results from the Questionnaire study

	Age	Years in the trade	Use tobacco	Physically active (spare time)	Have MSD	Number of MSD:s/ affected person	Believe their MSD is work related
Participant 1	30	11	No	Yes	Yes	4	Yes
Participant 2	44	25	No	Yes	Yes	3	Yes
Participant 3	64	24	No	Yes	Yes	2	Yes
Participant 4	26	6	Yes	Yes	Yes	2	Yes
Participant 5	-	-	Yes	Yes	No	-	-
Participant 6	30	12	Yes	Yes	No	-	-
Participant 7	19	0	Yes	Yes	No	-	-
Participant 8	22	3.5	No	Yes	No	-	-
Participant 9	56	38	Yes	Yes	Yes	3	Yes
Participant 10	59	42	Yes	No	Yes	2	Yes
Average	**38**	**24.5**	**60%**	**90%**	**60%**	**2.7**	**100%**

Table 5.2 Unanswered questions, Questionnaire study

	Number of unanswered questioned
Participant 1	0
Participant 2	1
Participant 3	2
Participant 4	2
Participant 5	4
Participant 6	2
Participant 7	0
Participant 8	0
Participant 9	5
Participant 10	1

5.5 HTA

The HTA:s for the three different systems have been divided into six main tasks (to the left in figures 5.12-5.14). The first task in the work pattern was placed at the top of the page starting with the number 1.0 and ending with the last task in the work pattern with the number 6.0 at the bottom. From right to left the main tasks are divided into sub-task that in turn are divided into sub-task. Every task was again given a number for example; the main task “install pipes” has the number 5.0, its sub-task “attach pipe ring to connector” 5.1 and the following sub-task “place screw and bolt through the pipe ring and connector” 5.1.1. This means that the tasks should be performed in that order. Systems 1-3 can be viewed in figures 5.12-5.14.

Figure 5.12 The HTA for system 1

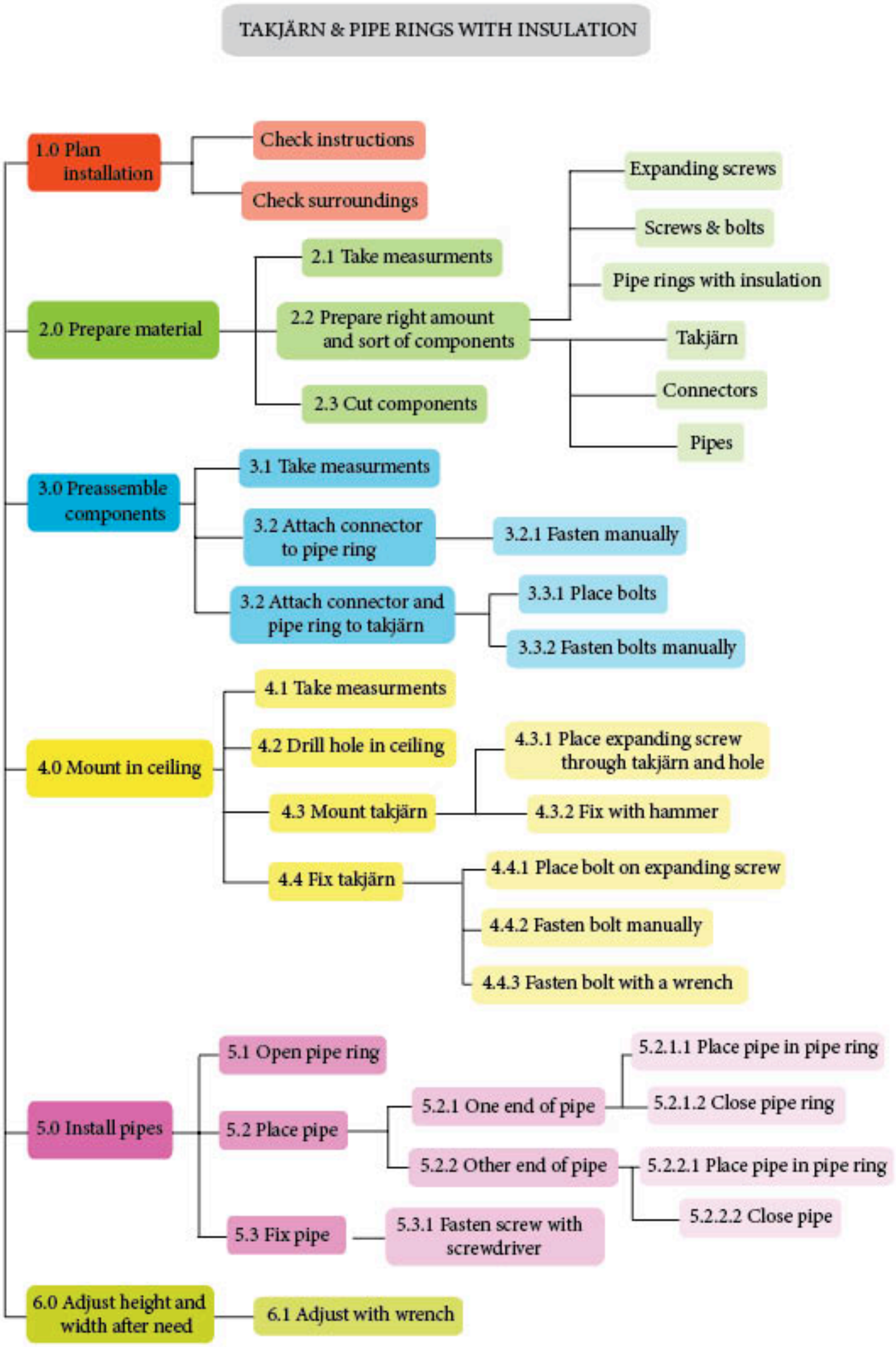


Figure 5.13 The HTA for system 2

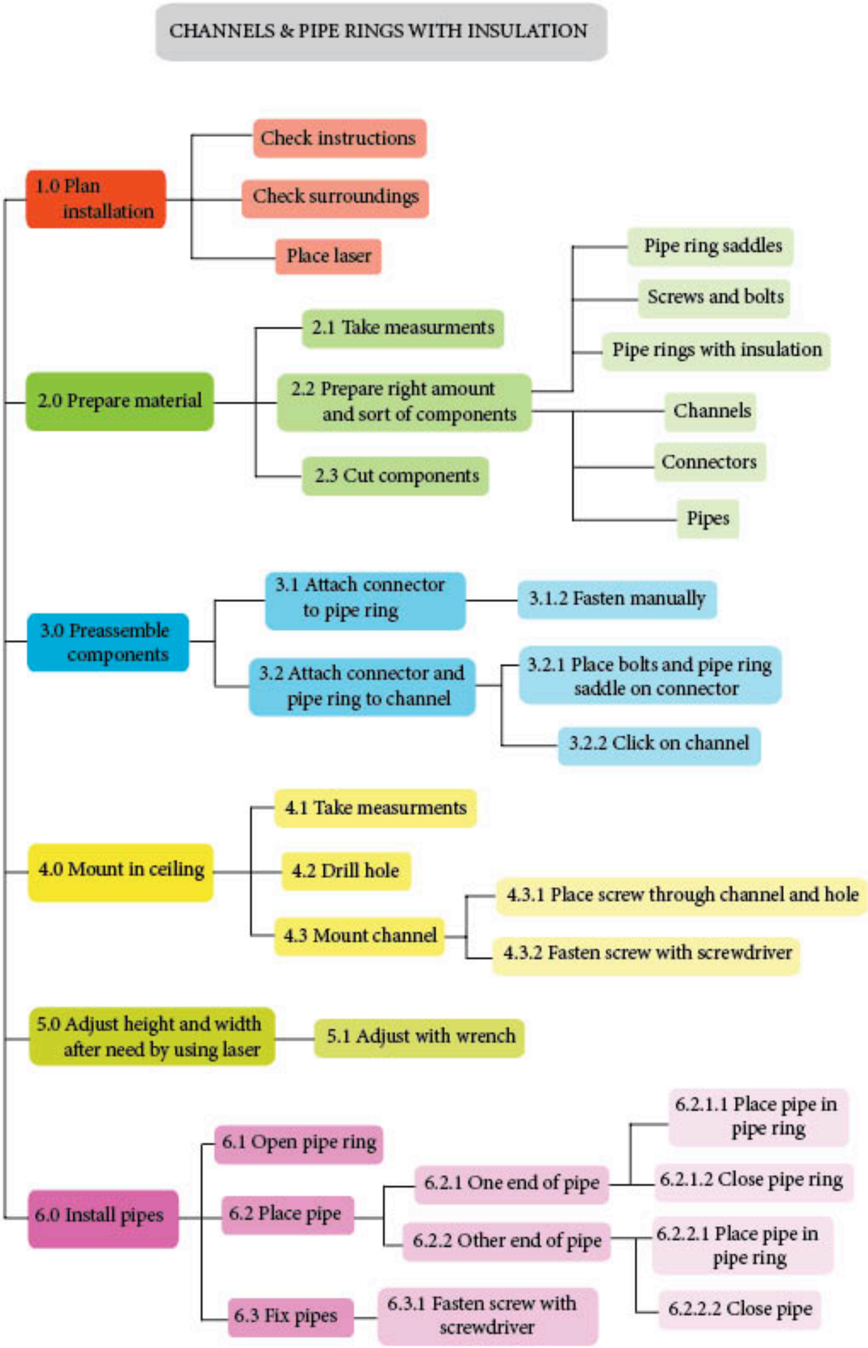


Figure 5.14 The HTA for system 3

5.6 Posture and Time study

Prior to starting the test both participants were asked to fill out the same questionnaire as the participants in the Questionnaire study. The results are presented in table 5.3.

Table 5.3 The participants answered the questionnaire prior to the Posture and Time study

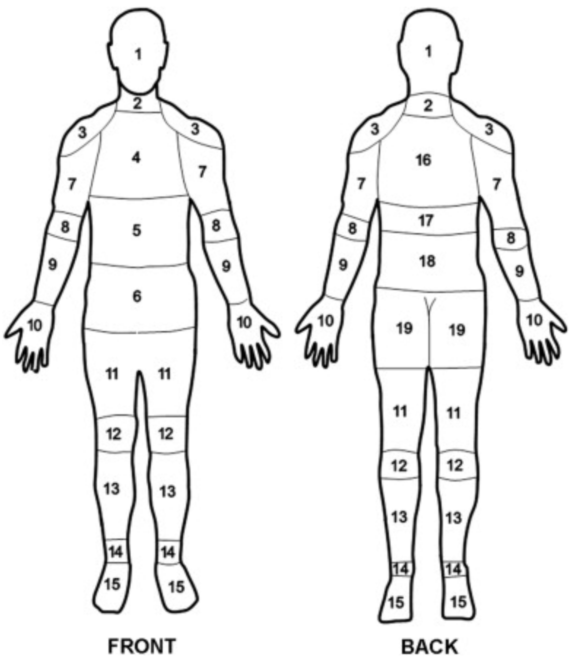
During Posture and Time study	Age	Years in the trade	Use tobacco	Physically active (spare time)	Have MSD	Number of MSD/ affected person	Believe their MSD is work related
Participant A	38	20	No	Yes	No	-	-
Participant B	55	39	No	Yes	Yes	3	Yes
Average	**46.5**	**29.5**	**0%**	**100%**	**50%**	**3**	**100%**

After each test installation both participants were asked to give their spontaneous thoughts on the system. They were also asked if any specific task was extra easy or hard to perform. Their opinions are presented in table 5.4.

Table 5.4 Comments made by the participants on the three different systems

Opinions about the systems	Participant A	Participant B
System 1	• Takjärn works well. • Pipe rings are hard to attach because of the small screws and bolts. • To many operations.	• This is an old system. • The screws and bolts are hard to handle, especially if it is cold outside or if gloves are mandatory. • It is good that height adjustment can be done after the pipes are assembled.
System 2	• Hard to slide pipes in to the insolated pipe rings, some were too tight.	• Easier to install than system 1 because less screws and bolts.
System 3	• A good system. • Hard to adjust the height of the pipes.	• More planning required, need to know the required height beforehand. • Good that the insulated pipe rings are frictionless.

Furthermore, the participants were asked to define, on a body map, if they felt any exertion or strain, see figure 5.15. They were also asked to define, using the Borg RPE scale, the extent of the exertion, see figure 5.16.



6	No exertion
7	
8	
9	
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	
20	Maximal exertion

Figure 5.15 Body map, [36]

Figure 5.16 Borg RPE scale, [37]

Participant A marked that he felt exertion in the front right shoulder (number 3 in figure 5.15) after all three installations. For all three systems participant A rated the exertion as 15 (hard) on the Borg RPE scale.

Participant B felt exertion in back right shoulder (number 3 in figure 5.15) when installing system 1 and 2. For system 3 the exertion was in the lower neck (number 2 in the middle picture). He rated the exertion as 13 (somewhat hard) for system 1, 9 (very light) for system 2 and 12 (between light and somewhat hard) for system 3.

5.6.1 Hand Arm Risk assessment Method (HARM)

The results of the HARM study can be seen in figures 5.17-5.19. The three different systems for pipe installation are presented separately with the results from the two participants presented individually.

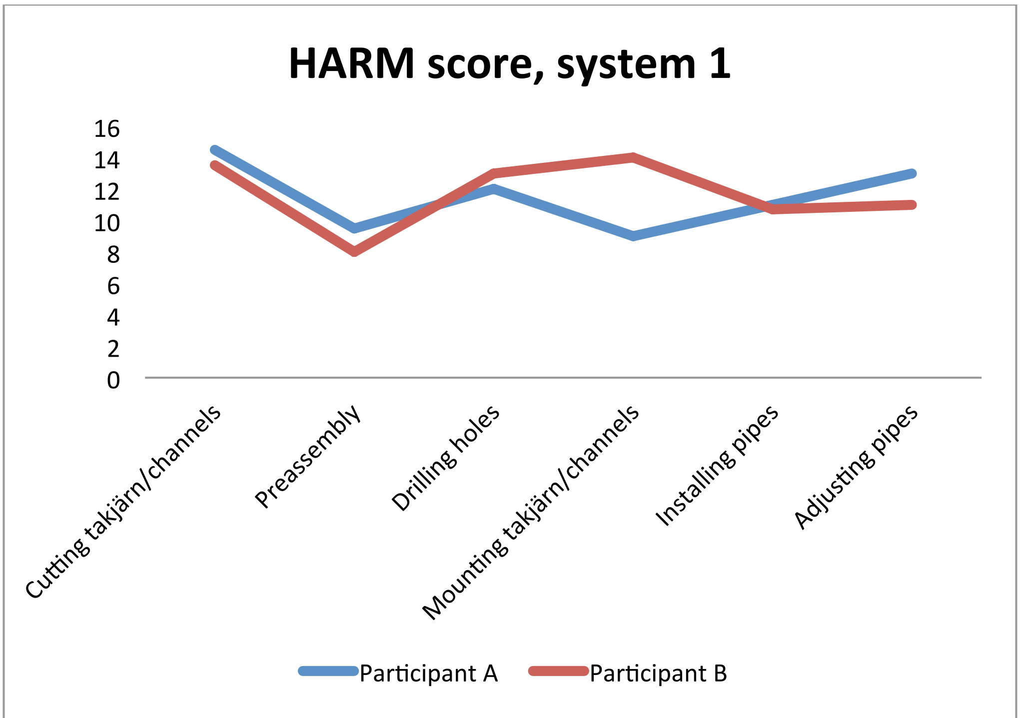


Figure 5.17 The HARM score for both participants, system 1, Posture and Time study

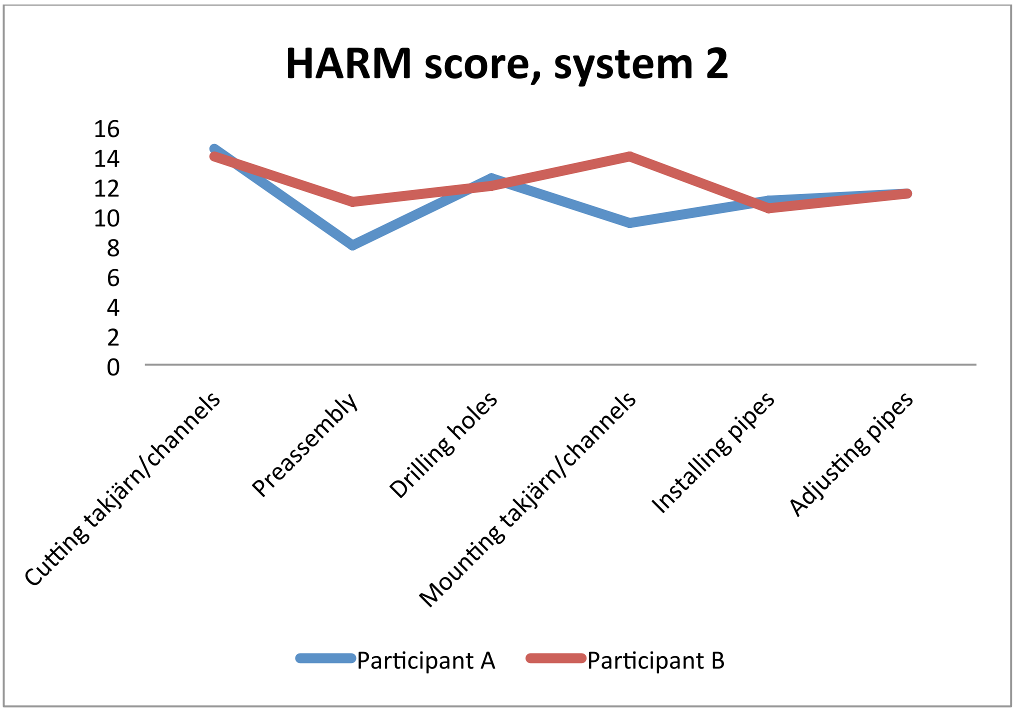


Figure 5.18 The HARM score for both participants, system 2, Posture and Time study

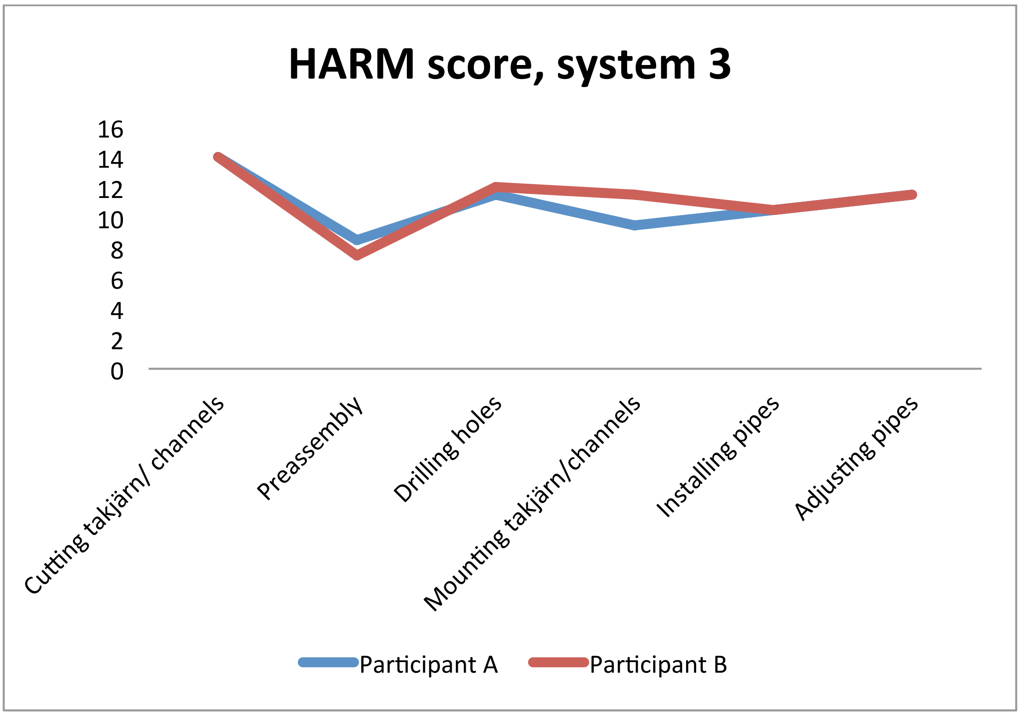


Figure 5.19 The HARM score for both participants, system 3, Posture and Time study

The individual variations in HARM score are smaller for system 3 than system 1 and 2. The exact HARM score of the participants, the estimated time of a standard workday and the actual time it took to perform each task can be found in appendix J. The estimated time of a standard workday is a calculation of how much time the installer would spend preforming a certain task if the installation of the system would be on going throughout an 8h workday.

In figure 5.20, the average HARM score for both participants is presented for the three systems.

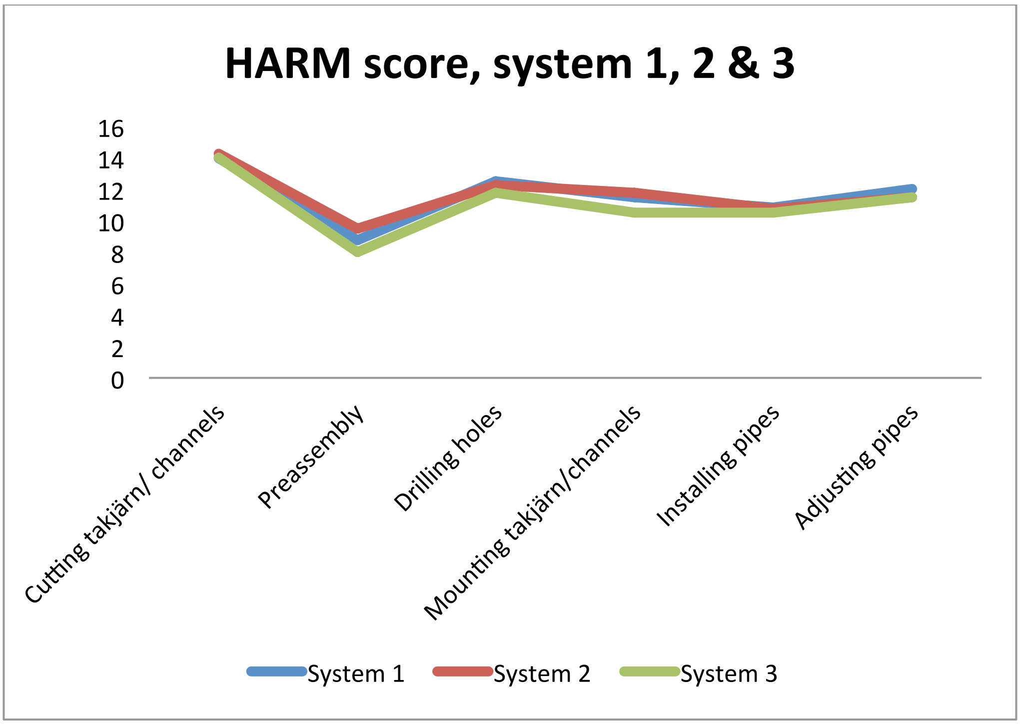


Figure 5.20 The combined HARM score for participants, all three systems, Posture and Time study

The HARM score for the three systems are quite similar with only some small variations for the tasks of preassembly and mounting takjärn/channels.

None of the participants received a HARM score greater than 25, which means that they all end up in the green zone, which is defined as no elevated risk for MSD amongst the majority of the workers.

5.6.2 Rapid Entire Body Analysis (REBA)

The first four figures present the results from the first part of the REBA analysis where figures 5.21-5.23 show the individual REBA scores for participant A and B for the different tasks within the three systems. Each of the first three figures represent one system each as to easier see variation between the participants.

The result varies for all tasks within system 1 making it hard to see any tendencies between the induvidual results.

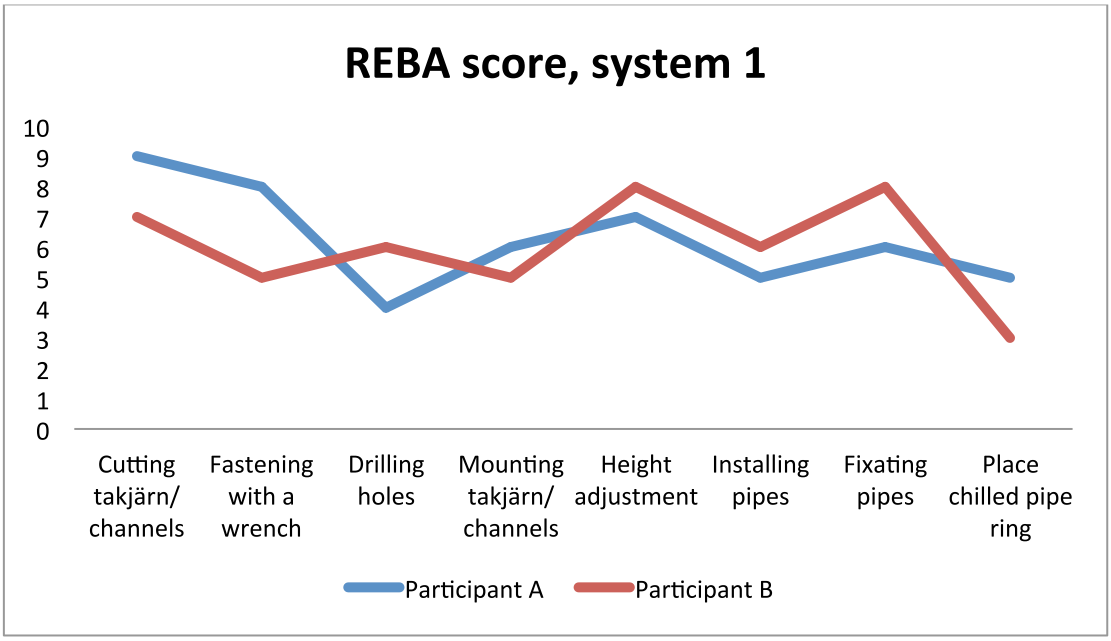


Figure 5.21 The REBA score for both participants, system 1, Posture and Time analysis

The task of placing chilled pipe rings vary the most in system 2.

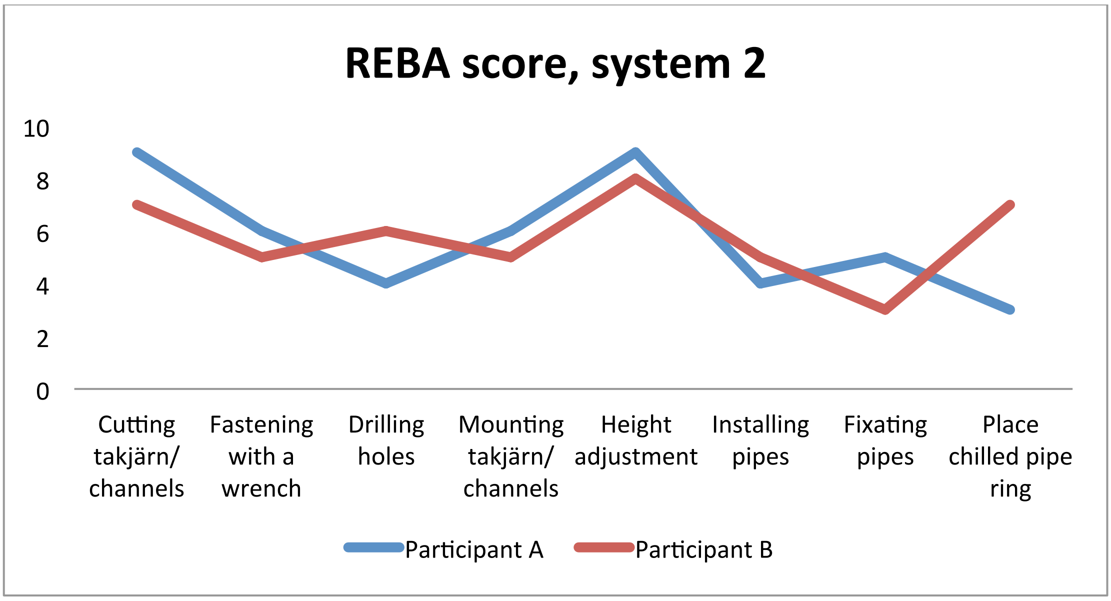


Figure 5.22 The REBA score for both participants, system 2, Posture and Time analysis

The biggest variation in system 3 can be found for the task of height adjustment.

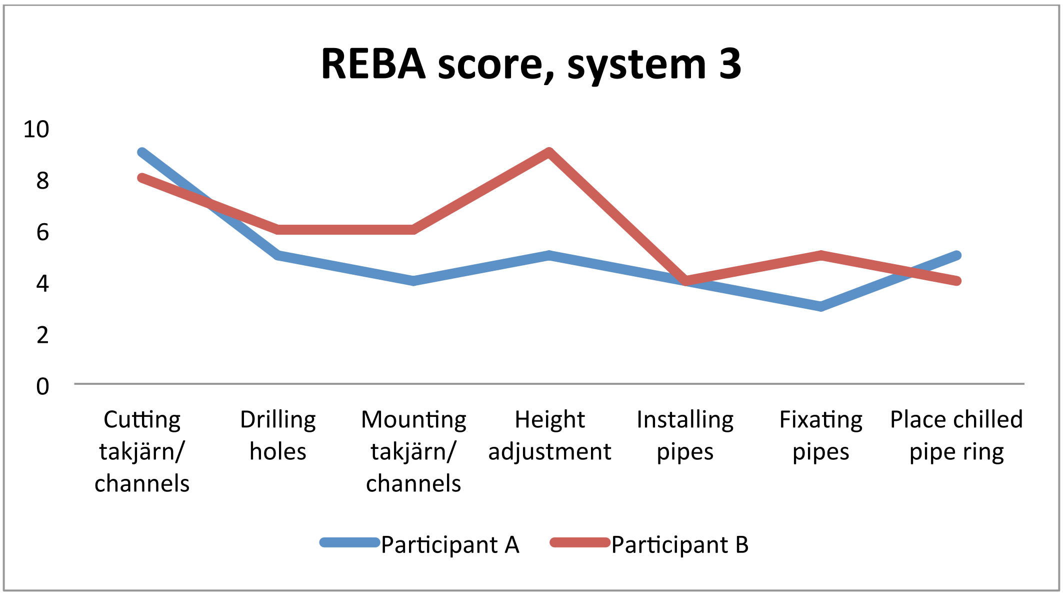


Figure 5.23 The REBA score for both participants, system 3, Posture and Time analysis

The results from the second part of the analysis are presented in table 5.4-5.6. Each table represent one of the three chosen tasks (mounting of takjärn/channels, fixating pipes and height adjustment), first presenting the individual scores for both participants but also the average score. Large variations can be found between the two participants but also between the individual scores within a task for each participant.

The task of mounting takjärn/ channels is the same for system 1 and 2, therefore only system 1 is presented in table 5.5.

Table 5.5 The REBA scores for each participant, the task of Mounting takjärn/ channels, Posture and Time study.

Mounting of takjärn/ channels **System 1**	Participant A	Participant B	Mounting of takjärn/ channels **System 3**	Participant A	Participant B
	9	8		4	7
	9	6		7	7
	5	7		3	7
	6	7		8	8
	6	5		5	6
Average	**7**	**6.6**	**Average**	**5.4**	**7**

The task of fixating pipes is the same in system 2 and 3, therfore only system 2 is presented in table 5.6.

Table 5.6 The REBA scores for each participant, the task of Fixating pipes, Posture and Time study.

Fixating pipes **System 1**	Participant A	Participant B	Fixating pipes **System 2**	Participant A	Participant B
	5	3		5	7
	4	4		6	2
	5	8		6	3
	10	3		5	5
	6	8		3	7
Average	**6**	**5.2**	**Average**	**5**	**3.8**

The task of height adjustment is the same in system 1 and 2, therfore only system 1 is presented in table 5.7.

Table 5.7 The REBA scores for each participant, the task of Height adjustment, Posture and Time study.

Height adjustment **System 1**	Participant A	Participant B	Height adjustment **System 3**	Participant A	Participant B
	5	7		5	8
	4	8		4	2
	7	8		8	6
	5	6		3	5
	3	8		9	9
Average	**5**	**7.4**	**Average**	**5.8**	**6**

5.6.3 Time study

The total installation time and time spent per task for each system can be viewed in table 5.7. The time result is presented for each participant starting with participant A (grey colour) and followed by participant B (white colour). The task of cutting takjärn/ channels has in this case been incorporated into the task of preassembly. Cutting was performed in the same way in all three systems and the time spent on this task was similar between the systems. Furthermore the task of drilling has been included in the task of mounting of takjärn/ channels since this task also was identical between the systems.

Table 5.7 The installation times for each of the three systems, Posture and Time study

	System 1 (min)	System 2 (min)	System 3 (min)
Total installation	96.88	67.46	67.73
Total installation	96.97	67.42	65.73
Preassembly	34.61	21.61	21.00
Preassembly	24.99	28.00	23.92
Installation takjärn/channels	19.85	16.50	14.62
Installation takjärn/channels	18.98	18.55	15.14
Installation pipes	28.59	17.38	12.80
Installation pipes	35.77	12.49	11.62
Adjusting pipes	12.88	11.97	19.22
Adjusting pipes	17.23	8.38	15.05

It is clear that system 1 takes the longest time to install, almost 30 minutes longer than system 2 and 3. The installation times are very similar for the two participants. Preassembly during system 1 is the task that takes the longest time to complete for participant A while participant B spends the most time on the task installation of pipes. System 2 is the fastest system for the task adjusting pipes for both participants. System 3 is the fastest system for the tasks preassembly, installation of takjärn/channels and installation of pipes.

6 Analysis

The results from the different studies and the conclusions that can be drawn from them are presented in this chapter.

6.1 Observation

6.1.1 Participant observation

The outcome of the participant observation was a better understanding of the process of installing pipes. With no previous experience the observation gave many valuable insights such as differences between the systems and areas prone to MSD. The observers found potentially harmful working postures to further investigate when observing and interviewing P&H installers at actual construction sites.

The observers found system 3 to be easier to use, faster, with fewer elements and less fiddling with screws and bolts. This was also one of the reasons that system 1 took a longer time to install. The differences found between the two systems were most noticeable when mounting takjärn/ channels in the ceiling, attaching the connectors and installing the pipes. With system 1 the task of mounting the takjärn to the ceiling involved beating an expanding screw through the pre-drilled hole with a hammer, see figure 6.1. This lead to a bad working posture. The corresponding task for system 3 was carried out by attaching a screw through the channel with a screwdriver, see figure 6.2.

Figure 6.1 Mounting of takjärn, system1

Figure 6.2 Mounting of channel, system3

A big difference was found when attaching the connectors to the takjärn/ channels. The connectors were attached in system 1 by screwing them on the takjärn, see figure 6.3. In system 3 the connectors were attached by clicking them to the rail of the channel, see figure 6.4.

Figure 6.3 Preassembly, system 1

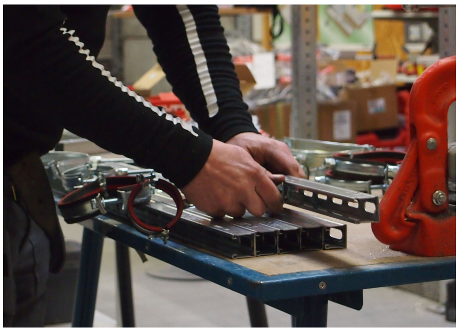


Figure 6.4 Preassembly, system 3

The task of installing pipes was also very different between the systems. When attaching the pipe rings in system 1, the observer had to hang the pipe ring on the connector by placing a screw through holes in the pipe ring and connector. Then the pipe was placed through the pipe ring and the bolt and screw was fastened manually, see figure 6.5. More than one time the screws fell out during this task, which caused interruptions and frustration amongst the observers. This can be compared to the corresponding task in system 3 where the pipe ring was attached to the connector simply by clicking the two parts together. Placing the pipe in the pipe ring and clicking it shut attaches the pipe, se figure 6.6.

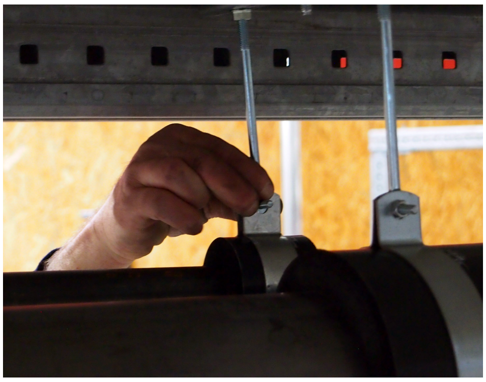


Figure 6.5 Closing pipe ring, system 1

Figure 6.6 Closing pipe ring, system 3

The observers could tell a significant difference when drilling with or without attaching the vacuum cleaner to the cordless rotary hammer. The vacuum cleaner had the advantage of sucking the concrete-dust directly from the source resulting in much less dust ending up in the face, hair, mouth and nose of the person holding the machine. The vacuum cleaner adds little weight but covers the drill area making it harder to see where to put the drill head.

The importance of adapting the working environment to the individual became evident when the shorter observer could not reach the working area without standing on pallets. The distance to the working area also affects the way of holding (e.g. a cordless rotary hammer in relation to the body) resulting in better or worse working postures as further discussed in chapter 2.2.7.1.

An interesting notion when the vacuum cleaner was not used was that one of the observers, being taller than the other observer and therefore having a wider range of motion, held the rotary hammer farther away from the body as to avoid getting dust in the face. The shorter observer held the rotary hammer straight over the head, therefore using less force but ending up with a lot of dust in the mouth and face area. As mentioned in chapter 2.2.3 when the weight of a handheld tool is involved the task should be carried out close to the body in order to lessen the load. Holding the rotary hammer further away from the body (i.e. creating a longer lever) will make the task heavier but it will stop the worst of the dust from reaching the face.

6.1.2 Construction sites

All visits took place during the winter and the construction sites were therefore exceptionally cold and dark. Even though it might be very cold during the winter, summertime can become to warm for a good working climate as some P&H installers pointed out. One P&H installer stated that the cold is bearable when the body have the time to adjust to it and as long as you keep moving. Others find it harder since the body get stiffer and it gets harder to move for example fingers.

The lighting also depended on the time of day and season. It is much darker on the sites during the winter and therefore even more important with proper lighting. Many of the P&H installers had to move the floor lamps as they changed working area. Some P&H installers were more negligent with this than others. The light was mostly focused on the working area leaving the space around it much darker. This put strain on the eyes since they had to adjust to the contrast of light and dark. A larger site with more stakeholders tended to be overall noisier but also having more sudden peaks. Depending on if the visit was during break or active work there was a huge difference in noise level.

All three systems were found at the sites and often a site would use more than one system depending on the situation. The most common was system 2 and this might have to do with cost and tradition but also the fact that system 2, unlike system 3, allows for height adjustment after the pipes are put in place. The pipe rings of system 2 are more user-friendly than the ones used in system 1. System 1 was rarely seen during the observations.

In the cases when preassembly was done onsite, a workbench was available at all but one site where the installer used a wheelbarrow or sat on the floor, see figures 6.7-6.8. In order to visit some sites a small safety course had to be taken or a safety pamphlet read. The cleanliness of the sites varied to some extent and this might have to do with the development phase of the site as some phases are more hectic than others.

Figure 6.7 Wheelbarrow as workbench, construction site 3

Figure 6.8 Workbench, construction site 4

6.2 Telephone survey

Almost all participants of the telephone survey responded that they use all three systems for pipe installation defined in this project. Many factors such as the amount of pipes being installed, if it is a new construction or repair work and the amount of space available for the installation affects which system gets chosen. The telephone survey showed that the most common system for pipe installation was system 2. Of those replying that they often use system 2, a majority replied that they use it most of the time. The second most common system in the telephone study was system 1.

The results from the telephone survey showed that the possibility to preassemble components before installing them in ceilings varied a lot from one time to another. Factors such as availability of detailed blueprints, differences in height or presence of many turns and bends affect the possibility to preassemble. Most participants replied that they could either preassembly quite often or not at all. The possibility to preassemble is connected to the type of work usually performed. Some of the companies contacted often do service work. In these cases the amount of installed pipes is often small and the surroundings less predictable, usually with narrower and more crowded workspaces. This makes the possibility to preassemble quite small since lengths of and distances between components vary much. For those companies that usually work with new construction the possibility to preassemble is larger. Preassembly works well in new constructions since there is often a large amount of pipes to be installed. It is also easier to plan the work beforehand since there are less prior installations (e.g. ventilation systems) in the way of the P&H installer when working. When preassembly is possible it is usually preferred since it can save a lot of time and effort.

MSD is rather common amongst the participants and their colleagues. The shoulders with 30% was the most troublesome area followed by the back 22%, Neck 14%, hand/wrist/fingers 10% and knees 10%. This result can be compared to statistical results from the study conducted by SWEA in 2012, see chapter 2.2.4.

In this study the back was most troublesome 14,9 ±4,6% followed by the shoulder and arm 9,4 ±3,9. It is impossible to say why the shoulders get a higher percentage than the back in the telephone survey compared to the SWEA study. Since the participants of the telephone study are so few, individual or regional factors can affect the results. The back and shoulders are the most exposed body parts in both studies, probably because these body parts are extra sensitive to strain due to the factors presented in chapter 2.2.4. An interesting factor was that the neck was stated to be troublesome in 14% of the cases in the telephone survey while only reaching 3,7 ±2,5% in the SWEA study.

The results for other factors influencing the work situation of P&H installers shows that a majority, 20 out of 30, of the participants does not have a piecework salary. Many participants answered that a piecework salary was not applicable to their type of work since they were either doing service work or small scale construction. This result is therefore not completely representative for the target group of this project as focus lay on installation of piperun, which is usually performed at larger construction sites. Many of the participants of the survey states that their employer focuses on work environment issues. However factors such as safety in the work place and if incidents are addressed appropriately are mentioned as examples of how the employer handle work environment. If the question was limited to only concern work environment related to ergonomics and availability of aiding tools the results would perhaps be different. As can be seen in the results, many participants found it hard to answer the question if ergonomics and preferences of the employees affect the decision of which system for pipe installation to purchase. Many felt that the employer listened to their opinion about the systems but in the end other factors such as economy had a greater impact.

6.3 Work Environment study

The results for vibrations, accident risks and dust were all rather unanimous and considered satisfactory or within the normal zone. Many construction sites used tools of similar standard and the results for vibrations therefore do not vary much between the different construction sites. SWEA have strict regulations on what the employers must do in terms of preventing accidents. This means that many construction sites have similar regulations and guidelines and the results for this category should therefore be similar between the construction sites.

Some participants defined the categories of climate and working postures/ loads/ space as furthest into the unsatisfactory zone. As mentioned in chapter 2.2.2 and 2.2.5 the working postures and work environment of P&H installers vary a lot depending on the type of work performed and the circumstances of the construction site. This can explain the variations in answers from the participants. Individual factors such as sensitivity to heat/cold and the physique of the body can influence how satisfactory or unsatisfactory a participant defines these categories. Statistics from 2011 [38] shows that construction workers are exposed to a cold climate or work in a twisted working posture over 40% of their work time and repeatedly lift over 15kg over 30% of the time. This could explain why half of the participants of the Work Environment study find their working climate and working postures/ loads/ space unsatisfactory.

An example of a working posture that can be viewed as unsatisfactory is presented in figure 6.9. Instead of working at a workbench at a suitable height, the P&H installer in question was performing preassembly of components kneeling on the floor, which put a lot of pressure on the knees and can lead to injuries.

Figure 6.9 Preassembly performed on the floor by an P&H installer

Both the participants and the observers found the lighting conditions of two construction sites unsatisfactory. This was because it was rather dark in some areas of the construction sites and the portable lights provided were to few or not used enough due to too far distances between power outlets. Portable lights used were sometimes even blinding and, as can be seen in figure 6.10, the P&H installer sometimes covered the light source and cast a shadow over the work area.

Figure 6.10 P&H installer covers the light source

As mentioned in chapter 2.2.5 a good work environment is very important in order to prevent disorders and accidents. It is therefore not acceptable that about half of the participants of the study find the working conditions regarding noise, lighting conditions, climate and working postures/ loads/ space unsatisfactory. It is important that the employer provides sufficient equipment such as heat fans, portable lights, aids and tools. Furthermore the material used (e.g. systems for pipe installation) need to be as ergonomically correct as possible in order to provide better working postures.

It is clear from the Work Environment study that some categories such as vibrations, accident risks and dust are found acceptable by most participants. Others factors such as noise, lighting conditions, climate and working postures/ loads/ motion need improvements in order for all participants to be satisfied.

6.4 Questionnaire study

Only a small part of the total results gave any value to the project. This had to do with the fact that some questions were not answered and that some answers contradicted each other making it hard to draw any conclusions. Therefore the decision was made not to use a large part of the results, although some conclusions could be made from the remaining results.

Table 6.1 shows that 60% participants had MSD and all 60% with MSD beleived that their MSD was work-related. All of the participants with MSD had two or more MSDs. One of the more detailed questions asked in the questionnnaire was if the participant thought their MSD to be connected to a certain working posture or task. This question got a poor respons rate makin it difficult to draw connections between postures/ tasks and MSD.

Table 6.1 Correlation between MSD and work, Questionnaire study

	Have MSD	**Number of MSD/affected person**	**Believe MSD is work related**
Participant 1	Yes	4	Yes
Participant 2	Yes	3	Yes
Participant 3	Yes	2	Yes
Participant 4	Yes	2	Yes
Participant 5	No	0	-
Participant 6	No	0	-
Participant 7	No	0	-
Participant 8	No	0	-
Participant 9	Yes	3	Yes
Participant 10	Yes	2	Yes
Average	**60%**	**2.7**	**100%**

As can be seen in table 6.2, 60% of the participants used tobacco and of those who used tobacco, 67% had MSD. Of the participants that were not using tobacco, 75% experienced MSD. 90% of all the participants were physically active during their spare time and out of those 90%, 56% had MSD. Out off the 56% participants that were physically active and had MSD, 60% also used tobacco. The conclusion from this is that the participants using tobacco had a high tendency to also get MSD but so did the ones not using tobacco. A sound lifestyle with healthy habits (e.g not using any form of tobacco) has been shown to prevent MSD as mentioned in chapter 2.2.7.1. This study has however not been able to confirm that tobacco increas the risk of getting MSD. Out of the participants with MSD, 83% were physically active during their spare time. Therefore the conslusion could be made that being physically active had not prevented MSD in these cases. As mentioned in chapter 2.2.7.1, it is not always possible to compensate a bad working environment with a good physique.

Table.6.2 Correlation between lifestyle and MSD, Questionnaire study

	Use tobacco	Physicaly active (spare time)	Have MSD
Participant 1	No	Yes	Yes
Participant 2	No	Yes	Yes
Participant 3	No	Yes	Yes
Participant 4	Yes	Yes	Yes
Participant 5	Yes	Yes	No
Participant 6	Yes	Yes	No
Participant 7	Yes	Yes	No
Participant 8	No	Yes	No
Participant 9	Yes	Yes	Yes
Participant 10	Yes	No	Yes
Average	**60%**	**90%**	**60%**

Participant 5 have been removed from the result of table 6.3 since no information on age or professional experience was provided. As can be read from table 6.3, 67% of the participants with MSD were over the age of 44 and had at least 25 year in the trade. 33% of the participants with MSD were 26-30 years of age with 6-11 years in the trade. Based on the information provided in table 6.3, a conclusion can be made that MSD got more common with age and number of years in the trade. This conclusion corresponds to the information in chapter 2.2.7.2.

Table 6.3 Correlation between age, years in trade and MSD, Questionnaire study

	Age	Year in trade	Number of MSD/affected person
Participant 1	30	11	4
Participant 2	44	25	3
Participant 3	64	24	2
Participant 4	26	6	2
Participant 6	30	12	0
Participant 7	19	0	0
Participant 8	22	3,5	0
Participant 9	56	38	3
Participant 10	59	42	2
Average	**49**	**24.5**	**2.7**

6.5 Posture and Time study

The lighting conditions were, compared to the results from the Work Environment study, better during the test than at actual construction sites. Lighting conditions will as discussed in chapter 2.2.5 affect how well an individual can see the working area and therefore the possibility of a small tension arising in the muscles. The latter also applies to the individual's line of vision in general, see chapter 2.2.7.3. In all systems the participant were not able to see the working area at all times. For example when fastening the screws on the pipe rings above the pipes in system 1 the participant had a more difficult time seeing the working area, see figure 6.11. The corresponding task in system 2 and 3 were within the line of vision since the screws were placed on the sides of the pipes, see figure 6.12.

Figure 6.11 Screws on top of the pipe, system 1

Figure 6.12 Screw reachable from below, system 3

The participants used many types of grips when they installed the different systems. One grip known as the pinch grip is a grip that should not be used for heavy or long lasting tasks, see chapter 2.2.3 For the task of preassembly in system 1 and 2 the type of grip was more frequently used than during system 3. The grip was used in all three systems but due to the fact that the connector was attached in system 1 and 2 by screwing it on the takjärn with screws and bolts (see figure 6.13) the pinch grip appeared at longer intervals unlike system 3 where the connector was attached by clicking it on the rail of the channel (see figure 6.13),

Figure 6.13 Pinch grip, system 1

Figure 6.14 Pinch grip system 3

The pinch grip was also used more in system 1 than in the other systems when closing the pipe rings (see figure 6.15). In order to close the pipe rings, in system 1, the grip had to be used for a longer time than in systems 2 and 3 where the corresponding task was executed by quickly clicking the pipe rings shut (see figure 6.16).

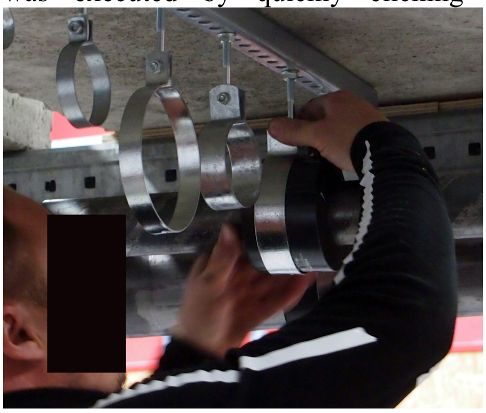


Figure 6.15 Pinch grip, system 1

Figure 6.16 Pinch grip, system 3

The task of fixating pipes in system 1 was performed by fastening the screws and bolts manually with a pinch grip at first followed by tightening with a screwdriver. The corresponding task was performed in system 2 and 3 by fastening the screws with only a screwdriver (see figure 6.17), therefore not using the pinch grip.

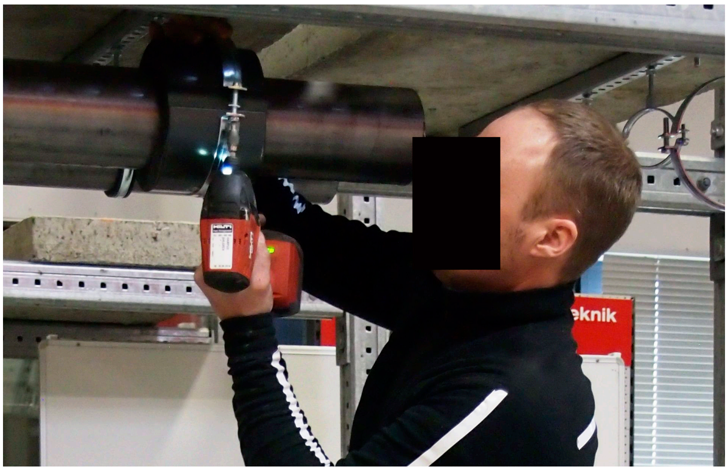


Figure 6.17 Fastening screws, system 2

Both participants found system 1 to be complicated because of all the loose screws and bolts required in installation process. Attaching the pipe rings to the connectors with screws and bolts add extra operations to the installations compared to system 2 and 3 where the insolated pipe rings are screwed on directly to the connectors. For system 2 and 3 the screws needed to secure the pipe rings around the pipes are already in place. For system 1 they also dropped screws or bolts on the floor in more than one occasion, which is not good from a productivity point of view.

Furthermore both participants stated that it was easier to slide the pipes into place in system 3 compared to system 2. This was because the insulation in the pipe rings of system 3 had a hard part in the middle for the pipes to slide on whereas the insulation in system 2 was only made of rubber and sometimes could slide of the pipe rings when the pipes was inserted. Both participants found the possibility in system 1 and 2 to do height adjustment after the pipes were installed desirable.

Participant A marked the exertion as being the same for all three systems. Participant B marked different results and found system 2 to require less exertion while system 3 was just easier than system 1.

The participants' opinions showed that system 1 might not be much harder to install than system 2 and 3 in terms of exertion. However system 1 felt more complicated to install due to the numerous operations required. The opinions of the participants on system 2 and 3 were more even, although system 2 received the lowest exertion score for one of the participants.

6.5.1 Hand Arm Risk Assessment (HARM)

Due to differences in work pattern, the participants' shows large variations in HARM score (see figure 6.18). For for example the task of Mounting takjärn/channels, participant A receives 9, 9.5 and 9.5 for system 1-3 while participant B receives 14, 14 and 11.5. The main reason for this is that participant B has a higher frequency while hammering the expanding screws into the ceiling.

Participant B also hammers both expanding screws needed to mount the takjärn in sequence without drilling a new hole in between. Participant A drills a hole between hitting the two expanding screws. This results in participant B getting a force score of 6 instead of 3.5, which is the score of participant A. This small difference in work pattern results in a quite large disparity in HARM score indicating that it is difficult to draw any generalizing conclusions as of which system is better from an ergonomic point of view, since the study is quite small.

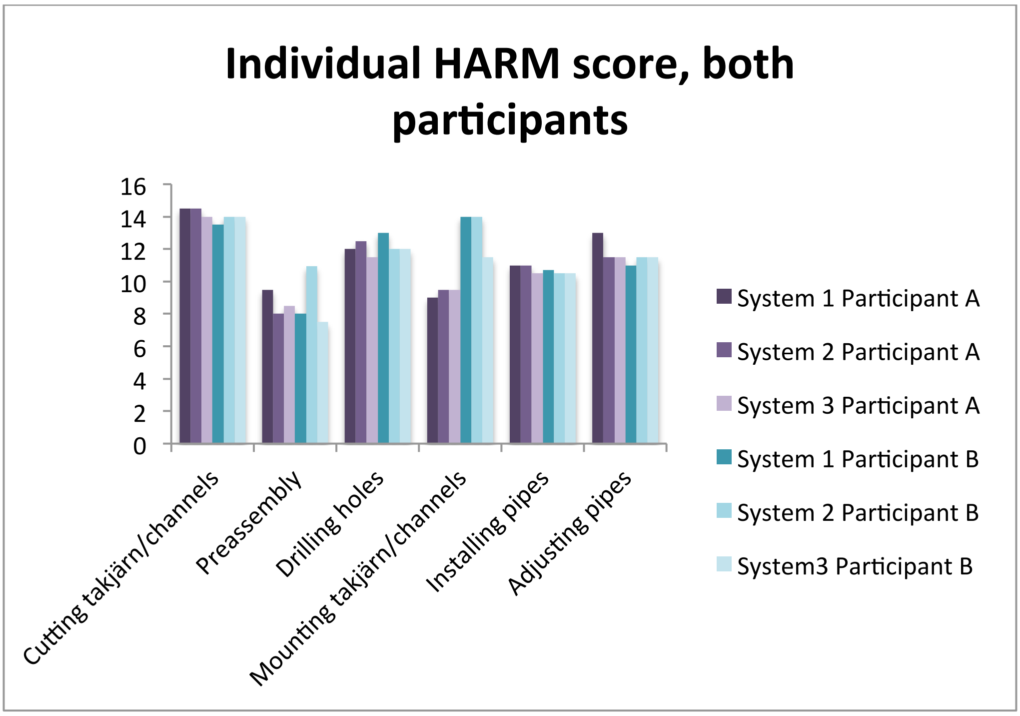


Figure 6.18 HARM score for each participant, task and system. The purple bars represents the HARM scores of participant A and the turquoise the scores of participant B.

Another score that stands out is the score for the task of preassembly for participant B in system 2. This task received a time score of 1.46, which compares to a time score of 1-1.07 for all the other tasks. Since the other scores, such as posture or force scores, received in the HARM analysis are multiplied by the time score this of course has a significant impact on the total HARM score.

Figure 6.19 shows the average HARM scores for the three systems of pipe installation. Tasks including vibrating tools such as cutting and drilling receive the highest HARM score. This is not surprising since the vibration value of the saw and cordless rotary hammer gives 4 and 2 extra HARM points respectively. Preassembly is the least strenuous task for all systems according to HARM, this is also logical since this task is carried out at a work station therefore enabling the participants to work in a more natural way, not having to bend the neck backwards or lifting the arms above shoulder height.

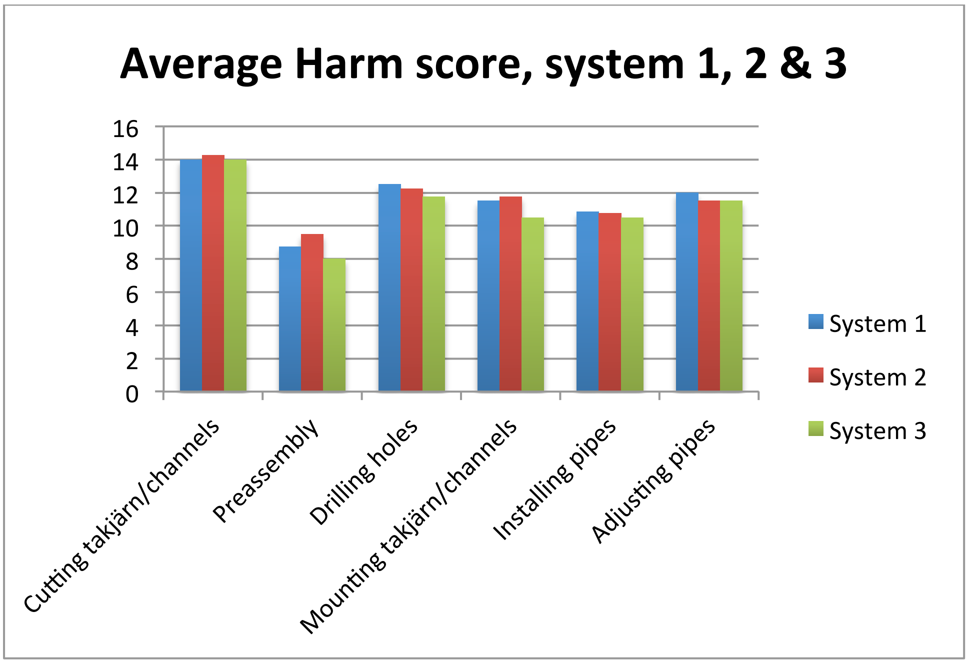


Figure 6.19 Average HARM score for the participants per task and system

It is hard to draw any conclusions as of which system has the most beneficial working postures. The task of cutting shows only a small variation in HARM score, which is what can be expected since this task is carried out the same for all three systems. The task of drilling on the other hand is also carried out the same through all systems but shows a larger variation in HARM score indicating that individual factors influences the scores noticeably.

The tasks that vary the most in HARM score between the systems are preassembly and installation of takjärn/channels. As mentioned before the scores in these tasks vary a lot due to individual factors and the design of the HARM method. It is therefore impossible to draw any generalizing conclusions that system 3 is better than the other two for this task.

6.5.2 Rapid Entire Body Analysis (REBA)

Most of the REBA results lie within the action zone 2-3 indicating a medium to high risk. As mentioned in chapter 2.3.6 a REBA score of 4-7 means a medium risk and the recommended action of further investigation and change soon. A REBA score of 8-10 means a high risk and the recommended action is to investigate and implement change now. The result is not surprising as the recommendation is to avoid work above shoulder height in order to prevent injuries [13].

Figure 6.20 shows the average REBA score for the participants for each task. All three systems are presented at once as to easier compare the results. The task of fastening with a wrench does not exist in system 3 and is therefore not presented on the green line.

As can be calculated from figure 6.20, system 1 got the total REBA score of 42.5 and system 2 with a score of 40.5 (not including the task of fastening with a wrench). System 3 got the total REBA score of 38. Based on this information system 3 is the best system from an ergonomic standpoint. However the results vary much between the two participants, see figures 5.22-5.24 and the average score might therefore be misleading. More than one posture should have been analysed for each task to give more reliable results.

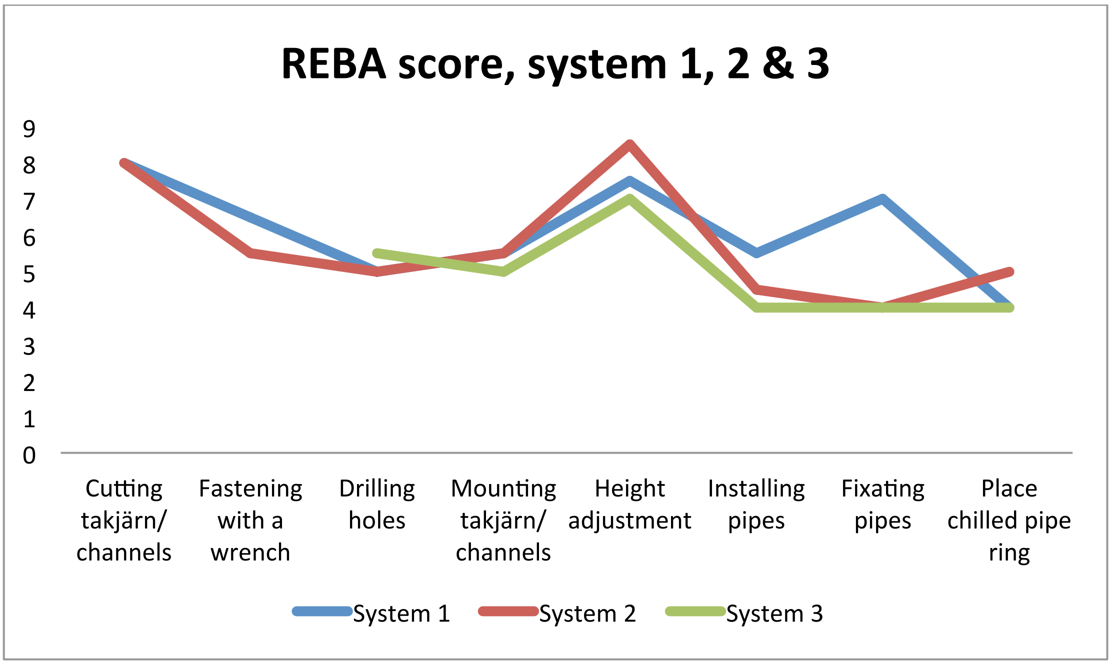


Figure 6.20 The average REBA scores for the participant for each task and system

The overall results do not vary too much between the systems; they seem to be following the same pattern. The result shows however that the biggest variation between the systems is for the task of fixating pipes, described later on, where system 1 scores higher than the other two systems. This task is more complex in system 1 as it is harder to reach the screws. From the result it is evident that cutting takjärn/ channels is the most strenuous task for all the systems, closely followed by the task of height adjustment. Cutting is a strenuous task due to the weight, vibration and force needed to operate the saw. The task of height adjustment is strenuous due to having to lift heavy pipes.

For the task of fixating pipes, system 1 get a very high REBA score compared to the other two systems. The result could be due to the fact that participant B had a bad posture at the moment the picture was taken but also because the task is more extensive in system 1. Figure 6.21 and 6.22 show that the participant have a bent neck, standing on his toes (creating an unstable base) and have the arms raised well over the head. In the right hand a small impact driver is held at an awkward angel thus creating a weight far from the body and the wrist is both bent and twisted.

All of these factors add extra points to the REBA score. The corresponding tasks in the other two systems got lower scores as the participant had a better posture at the time.


Figure 6.21, 6.22 Two angles of participant B fixating a pipe

The second part of the REBA analysis was a further investigation of the three tasks: mounting takjärn/channels, fixating pipes and height adjustment. The five selected postures gave an average REBA score for each of the chosen tasks.

Figure 6.23 show the average REBA score for the five chosen postures for the task of mounting takjärn/ channels. Since this task is the same for system 1 and 2 these are presented in the same column. The REBA score for the participants for system 1 and 2 are presented in the first two columns. The last two columns present the scores for system 3.

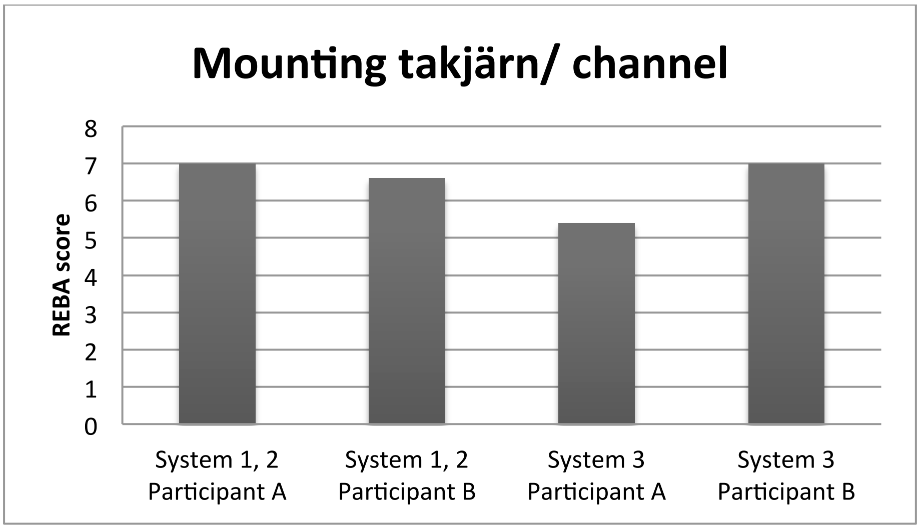


Figure 6.23 Average REBA scores per participant and system for the task of mounting takjärn/ channels

Figure 6.24 show the average REBA score for the five chosen postures of the task fixating pipes. The task is the same for system 2 and 3 and is therefore presented in the same column. The REBA score for the participants for system 1 is presented in the first two columns. The last two columns present the score for systems 2 and 3.

It is clear from figure 6.24 that both participants got lower REBA scores for systems 2 and 3 than for system 1. This could be due to the fact that in order to fixate the pipes in system 1, the participants had to take many awkward angles to reach the screws and bolts on top of the pipes, as can be seen in figure 6.25. Bent or twisted wrist, neck and/or trunk add points to the REBA score in comparison to a straight upper body.

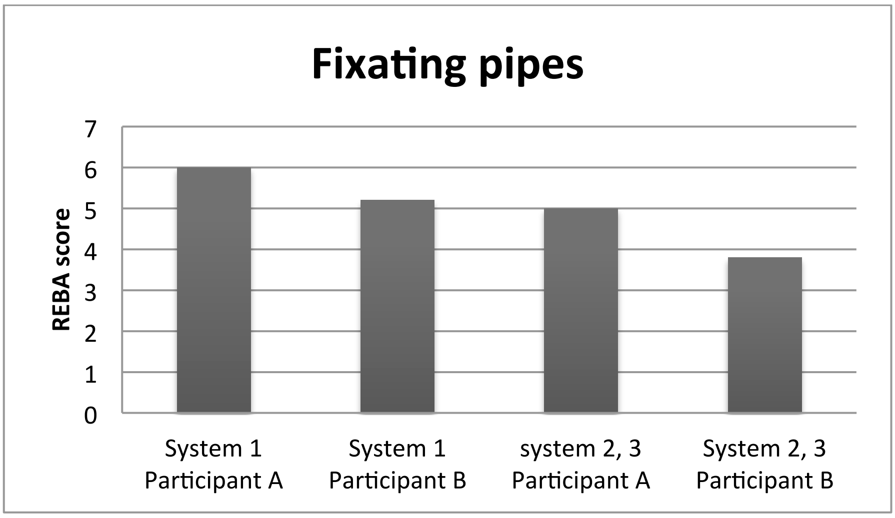


Figure 6.24 Average REBA scores per participant and system for the task of fixating pipes

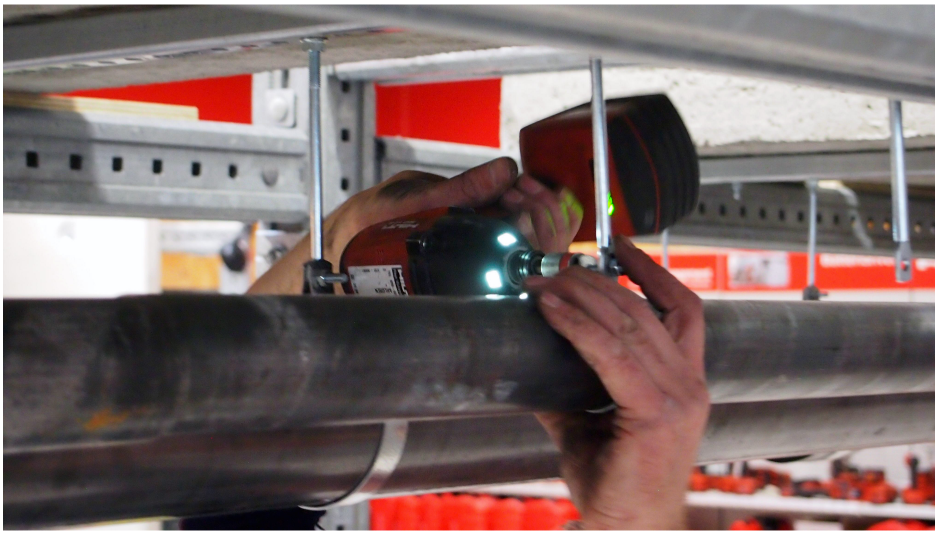


Figure 6.25 The wrist at an awkward angle during the task of fixating pipes

The average REBA score for the five chosen postures of the task height adjustment are shown in figure 6.26 Again the task is the same for system 1 and 2 and the results are presented in the same column. The first two columns present the average score for systems 1 and 2 and the last two columns present the score for system 3.

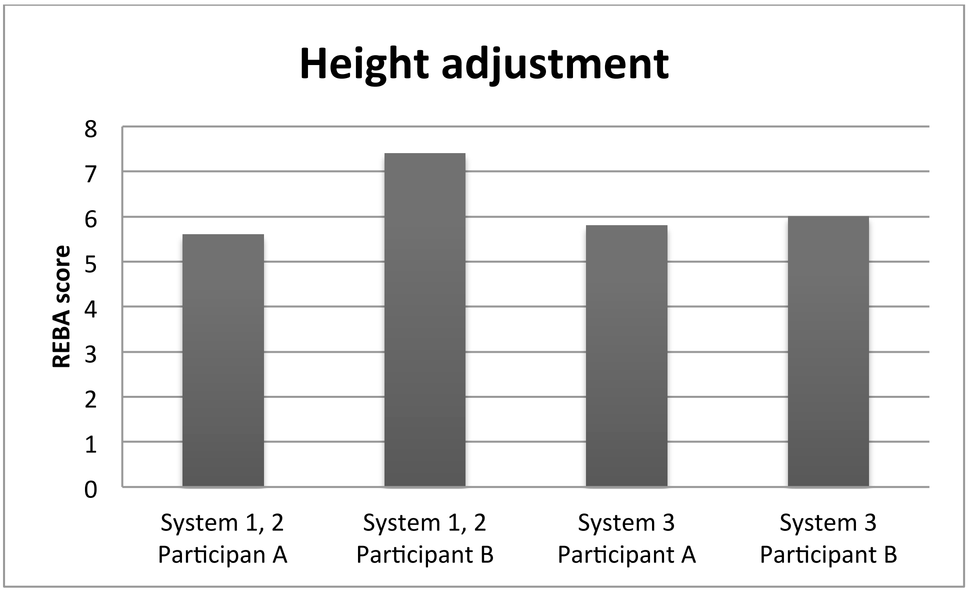


Figure 6.26 Average REBA scores per participant and system for the task of height adjustment

No tendency can be seen from the results for the task of height adjustment except that participant B get higher REBA scores for all three systems than participant A. This could be due to participant B leaning more backwards than participant A, which adds extra points to the REBA score (see figures 6.27-6.28).

Participant A was standing on a stool and took advantage of the space between the concrete blocks, which would not be possible in an actual environment. This means that participant A was standing straight and with a straight neck and that will bring the score down (see figures 6.29-6.30). This proves that individual prerequisites (e.g. height of the participants), work environment (e.g. different aids) and way of working is important.

Figure 6.27, 6.28 Participant B leans backwards

Figure 6.29, 6.30 Participant A standing on a stool

6.5.3 Time study

The results from the Time study shows that for both participants, system 1 took the longest time to install. Participant A installed system 2, 30 seconds faster than system 3 while participant B installed system 3, 90 seconds faster than system 2. For system 1, the task of preassembly took longer time for participant A than participant B while the opposite was true for the task of installation pipes. The reason for this is differences in work pattern between the participants. Participant A preassembled everything including the pipe rings while participant B only preassembled the takjärn/channels and connectors, collecting the pipe rings while installing the pipes.

System 3 has the shortest installation times for the tasks preassembly, installation of takjärn/channels and installating pipes. It is good from an ergonomic standpoint that the installation times of installing takjärn/channels and pipes are shortened since these tasks are performed above shoulder height. The task of installing pipes often includes heavy lifting, which makes it even more strenuous, being able to reduce the installation times for this task is thereby highly recommended. It is of course good that less strenuous tasks such as preassembly is shortened as well although it is important from an ergonomic stand point to know what tasks are performed instead.

If the installation time of a system is shortened over all, more installations can be performed during a workday. This could expose the P&H installer to the same amount or even a greater amount of strain since more pipe installations also means putting up more pipes which is a very strenuous task.

The task of adjusting pipes takes, for participant B, longer time for system 3 than system 2. For participant A the adjusting of pipes takes longer for system 3 than both the other systems. For system 3, height adjustment of the connectors needs to be done with the aid of a laser-measuring tool, prior to installing the pipes. This means that the loads handled by the participants during this task is less than for the corresponding task for system 1 and 2 thereby creating a more ergonomic working posture. However height adjustment could be done prior to installing the pipes for these systems as well only traditionally that is never done since it would require a change of work pattern as well as investment in a laser-measuring tool.

7 Discussion

In this chapter the methods, results and aims of the project are discussed

7.1 Methods

7.1.1 Observation

7.1.1.1 Participant observation

The objective with this study was to get a better understanding of the process, investigate differences between the systems and to locate problem areas and/or actions to further investigate. It was a very efficient way to get an understanding for how the daily work performed by P&H installers affect the body and what postures or tasks are the most strenuous.

Only system 1 and 3 were tested during this occasion. Since system 2 contains a mixture of tasks performed in either system 1 or 3 there was no need to install system 2. Also the key interest for the study was to explore the extremes of the systems, being the more traditional system 1 and the modern system 3. The participant observation gave many valuable insights about the two systems and was well placed in the beginning of the project.

7.1.1.2 Construction sites

The purpose of the study was to further investigate working postures, examine working conditions and become aware of new aspects. Unfortunately it was difficult, but not impossible, to study installation of piperun in ceilings in action. Many of the P&H installers had either just completed this part of the work or were going to start at a time that did not fit the time frame of this project. Installation of piperun in ceilings was seen in action at four sites out of five. Many questions were asked about how installation of piperun in ceilings was done and when possible, finished installations were observed and documented. The observation gave good insight into the daily routine of an P&H installer. Further observations of on-going installations would have been preferred.

7.1.2 Telephone survey

The telephone survey was conducted to get a better understanding of the P&H industry and the systems being used for pipe installation. It served as a complement to the observations of P&H installation, as to reach a lager number of participants. Performing interviews by telephone was a time efficient and facile way to collect information from a larger group. However the interviewer misses the opportunity to observe signals through body language and some information can therefore be lost. The distance between the interviewer and the participant could on the other hand make the participant feel more anonymous and therefore being more willing to give truthful answers.

The selection of participants in the telephone survey differed from the other studies. The survey was executed early on in the thesis project and all companies contacted were not representative for the chosen target group. This made it difficult to draw generalizing conclusions in relation to the other studies since it was impossible to know which answers in the telephone survey that was given by participants that could represent the target group. No information about the type of work performed by the contacted participants was available upon calling. Therefore answers might differ depending on the size of the company, if they work with new construction or service work and even of past experiences of the individuals participating in the interviews. In retrospect it would have been good to start with some general questions concerning these aspects in order to get a better understanding of the participants background when analysing the results.

For practical reasons the participants in the telephone survey were chosen from Hilti's list of customers. This could have influenced the results since no companies without connection to Hilti were selected. However, Hilti has a large share of the market for tools and other equipment for construction and installation. Hiltis customer list should therefore cover many applicable companies for the survey and since all companies were not customers of the Installation BU, which includes components for pipe installation, the selection can be seen as representative.

Many participants found it hard to specify which system they use for pipe installation since many different systems are used depending on the work in question. They were then asked to define which system they use the most and estimate a percentage of how often it was used. In order to present the results in a good way, the observers categorized the answers of how much or often something occurred based on the estimations of the participants. This is not an exact method and no exact conclusions could therefore be made of which system is most frequent. However tendencies can be seen and since the purpose of this investigation was to get an understanding of the industry and not an exact mapping of how often certain systems are being used, the data has value.

7.1.3 Work environment study

The zone limits used to define how satisfactory a category is were based on "Se om miljön" which focuses on work in a workshop or factory and not specifically towards the construction industry. However, the conditions of these workplaces could be considered similar to those in a construction site even though some aspects such as variations in climate that are regularly present in for example a construction site would not be as common in a workshop. The target of this investigation was not to suggest changes in the workplace but merely pinpoint which areas that could be considered troublesome by the installer or observer and would therefore not affect the study.

The focus of the Work Environment study was on environmental conditions that could influence the P&H installers when installing piperun above shoulder level. Therefore categories such as factors affecting the skin, chemicals and fire hazards have been disregarded since they do not directly apply for installation of piperun. Psychosocial factors such as work content and freedom of action are also important when evaluating working conditions. These were excluded in the study, as it has to do with the experience of the total working situation and would be hard to apply on a specific situation such as installation of piperun.

Measuring noise and lighting conditions in a proficient way proved to be more difficult than anticipated. Measurements had to be taken close to the participants working area in order to get reliable results. Since they often worked at a high level this was not possible. Noise levels vary much throughout the workday with many sudden peaks occurring. Therefore measurements would need to be taken over several hours in order to get a representative result. The amount of time needed for longer recordings was not provided during visits to the different construction sites. Instead of using measurements that was not collected in a controlled and sufficient way a decision was made to base the survey only on the opinions of the participants and observers. If the purpose of the study had been to get a full insight of the work environment at the observed construction sites, this would not be advisable. The main target of this study was however to find out how the participants felt about their workplaces in general. P&H installers frequently change construction sites when their work is completed. Taking this into consideration, the actual values of noise level and lighting conditions at the particular sites visited for this study was not as important as the participants perception of these factors. Therefore the change of plans was acceptable.

7.1.4 Questionnaire study

Questionnaires were used to gather data on work related musculoskeletal disorders. The purpose with the questionnaires was also to find out if the test persons participating in the Posture and Time study could be considered to represent the whole target group. By letting the participants in the Posture and Time study answer the same questionnaires as the P&H installers from the four construction sites, a comparison between the two could be made.

As mentioned in chapter 6.4, some of the results had to be disregarded due to misleading or missing answers. The participants who left unchecked boxes or inconsequent answers might be less interested in answering the questionnaire and therefore not reading it properly or just rushing through it. It could also be due to the extent of the questionnaire consisting of around 70 questions. Even though the structure was such that the same types of questions were repeated, only covering a different body region, it might have seemed overwhelming. The questionnaire was too comprehensive for such a small group of participants for the entire questionnaire to bring value to the overall project. A smaller and less extensive questionnaire would have sufficed.

7.1.5 Hierarchical task analysis (HTA)

The purpose of the HTA was to define a common work scenario for P&H installers that could be used during the Posture and Time study. The HTA:s for the three systems were shown to three P&H installers that all agreed with the presented sequence of tasks. Constructing the three HTA:s helped preparing the Posture and Time study. For example; by studying the HTA:s the task of going through all material that was needed became easier. The decision of where the material should be placed during the test and where to place the cameras were helped by studying the HTA:s and trying to figure out the motion pattern of the participating P&H installers.

7.1.6 Posture and Time study

Since the study was performed in the demonstration room at Hilti some adjustments compared to an actual piperun installation had to be made. The test rig was only six meters long resulting in the use of very short pipes, only two meters long[1] since it was important to fit in more than two installations of takjärn/channels within the length of the rig. It would also have been impossible for one participant to install a full length of pipe (six meters long) of the larger dimension Ø100, as it would be to heavy to handle. Even with the two-meter long pipes the installers sometimes needed assistance in getting the larger dimensioned pipes in place. The fact that the pipe lengths were shorter than normal could have influenced the motion patterns of the participants. During the study, the participants often held the pipes in the middle balancing them. With longer pipes P&H installers would normally use the aid of a lifting device or ask for help from a colleague thereby carrying one end of the pipe getting a more stable grip. This is a factor that can affect the results of the posture analysis since the position of the body has a great influence on the scores as well as the weight handled. The changes in movement pattern would probably be most noticeable when handling the pipes on the ground. When installing them in the ceiling the manoeuvres would be similar to those used by the participants in the study as another P&H installer would help stabilizing the pipe and taking some of the load from the first P&H installer.

[1] The pipes are delivered at lengths of six meters.

The climate conditions of the study also varied from those usually found at construction sites. The temperature of 18° C required no extra layers of clothing, which could influence the mobility of the participants, in order to keep warm. Temperatures below freezing would probably affect the installation time of system 1 the most since this system contains more operations requiring finer motor skills. With lower temperatures, the joints and muscles stiffen. The temperature was not warm enough for the participants to be overheated, which could slow down the work pace. Overheating would likely have affected all three systems alike. Heat affects the body by making it slow and tired, which affects all tasks in the same way. Except for the factors mentioned above, both participants found the study to be realistic and representative for how work would be carried out in a construction site.

All three different systems were installed during one day and therefore the installation order of the systems could have influenced the results. The schedule during the test days was very tight resulting in the participants being required to start with the installation of system 1 right away without prior warm up. This could be unfavourable for system 1 since the body usually works better after getting warmed up. Furthermore the break time between the different systems was only 30 min, which is probably not enough to feel completely rested before starting an installation of the next system. This could lead to the participants feeling more tired when installing system 2 and 3 and these might therefore take a relatively longer time to install. The layout of the pipe installation was identical between the systems and the participants might have “learned” how to work efficiently as the day progressed. It is impossible to know how these aspects affect the results of the study. Since only two days were available for the study the decision was made to install the systems in identical order as not to include any more variables when analysing the results. To get more generalizing results it would be necessary to expand the study so that the systems could be installed either one each day or several times during several days varying the installation order of the systems.

Each P&H installer has his own way of working when it comes to the order in which to perform different operations and how to use tools and other aids. This posed a problem when it came to comparing the work postures of the two individuals participating in the Posture and Time study. Either the working pattern could be controlled, forcing the participants to adjust their working pattern to a set manuscript or the participants could be given the freedom to work in the way they found comfortable. In the Posture and Time study the participants were free to work in their individual ways. This meant that the results from the Posture and Time study were harder to compare to one another since small differences in work pattern sometimes caused significant variation in scores between the participants. The reason for this decision was that forcing the participants to follow a pattern not natural to them could cause unreliable results as well since it is hard to adapt to a new way of working right away without falling back into old habits. With this set up the participants felt comfortable working and it is easy to detect when differences in working pattern occur. In order to get more reliable results it would be advisable to do the study in a more controlled way giving the participants time to practise this standardized work pattern beforehand which will greatly increase the time needed to perform the test.

Borg's RPE scale was used when asking the participants to evaluate the different systems after each installation. It would probably been better to use the Borg CR-10 scale as this scale focuses more on sensory intensity than exertion related to physical aspects such as heart rate. Since this was a very small part of the Posture and Time study no time was spent researching this matter and the Borg CR-10 scale was not discovered until afterwards.

HARM was chosen as the main method for the posture and time study since it was thought to give thorough analysis the upper body positions as well as including important aspects such as load, duration and frequency of the work performed. However, it is important to take the whole body into consideration and REBA was therefore used as a complementary study. Both methods are easy to use without prior education, which was a necessity. Another important factor was that they did not require the involvement of the participants during the analysis. Other methods where the participant analyse the work postures together with the observer would possibly have provided valuable information about the participant's perception of the different systems installed. This was not possible for this study. The participants were only available for one day each and therefore the time for the participants to both install and evaluate systems and postures was not enough.

7.1.6.1 Hand Arm Risk assessment Method (HARM)

HARM is not suitable for loads exceeding 6kg/60N for each hand. This causes a problem since both the saw and cordless rotary hammer exceeds this force when the feed force needed to operate the machine is added to the weight of the machine. The two larger pipe dimensions exceed the weight limit as well, weighting 7.80kg and 19.80kg. However the loads mentioned are seldom handled with only one hand therefore making the weight per hand staying under the 6kg/60N limit with the exception of the largest pipe. When handling the pipes, one end was often attached to a pipe ring or assistance in holding the pipes was provided. This lessens the weight handled by the participant.

The observers had a predetermined understanding of the foundations of how to judge the film sequences and kept an open communication throughout the process. This was to eliminate variations in the judging when following HARM. Even so, judging a posture held by a participant was difficult since many postures were in the borderline of being considered good or bad. The observers aided each other in these cases to keep the results from varying depending on the observer. Furthermore, the participants did not always carry out the tasks predefined by the observers separately leading to difficulties when deciding exactly were one task ended and another started.

7.1.6.2 Rapid Entire Body Analysis (REBA)

The purpose with the REBA analysis was to compare and evaluate all three systems based on analysed postures for corresponding tasks occurring within the systems. Since only two participants took part in this study it was hard to draw conclusions from the results.

This was partly due to the fact that both participants had their own way of working but also because a much larger group of participants was needed to draw generalizing conclusions and find connections. As the participants both had different ways of working (e.g. different working postures) more emphasis was put on individual differences rather than the actual differences between the systems.

Both observers have analysed the postures with a predetermined understanding of the premises for how to judge the postures. In addition there was a continuous communication throughout the process in order to make sure that both observers assessed the postures as equally as possible. Even so there is no guarantee that the postures have been judged completely the same. One of the observers might have been harder in judging the postures than the other and it can be hard to stay consistent. Another difficulty was the subjectivity when judging the postures. Some borderline cases were hard to judge (e.g. if a back is bent 17° or 20°) and since each decision will add or reduce one extra point to the REBA score this will have had a great effect on the end result. This further suggests that to draw any generalizing conclusions a much larger investigation is needed where individual variations can be evened out.

The analysed postures all lie within the medium- to high-risk categories. Based on information mentioned in chapter 2.2.1 and 2.2.2 most of the analysed postures would fall under the categories of postures that might lead to work-related MSD.

7.1.6.3 Time study

Some trouble with the material used in the Time study (e.g. pipe rings that would not fit around the pipes correctly) resulted in participant A spending time on trying to fix these problems. Because the decision was made to eliminate these faulty parts from the study, the times of participant A had to be adjusted after the test. The time spent by participant A on trying to fix the problems was therefore removed.

7.1.7 Structure of methods

Several methods have been used during this thesis project. The purpose of this was partly to be able to triangulate the results but also an opportunity for the observers to gain knowledge and experience from using many methods. However some methods could in retrospect have been excluded or performed in a different way. The results from the Telephone survey might not be necessary for the thesis project since the participants did not exactly match the target group of the other studies. It was nevertheless a good way for the observers to start the project and get valuable insights into the field of P&H installation and the people who work in it.

The Work Environment study perhaps put a bit much emphasis on work environment factors in relation to what was needed for an evaluation of the three systems. Nonetheless the Work Environment study gave valuable input, in addition to the information provided by observations and interviews, on the conditions of P&H installation. This input was of great help when analyzing if the results from the Posture and Time study could be applied to realistic conditions.

The questionnaires turned out to be too extensive since some of the results were not even used. Perhaps it would have been better to save the time spent on creating the questionnaire since data on MSD and other work related disorders could be found from previously published studies. The questionnaire should have been smaller with fewer questions that would be easier to fill in quickly. It would also have been preferable if the questionnaires were answered by a larger number of participants.

The HARM and REBA methods turned out not to be detailed enough in order to make conclusion of which system for pipe installation that was most ergonomic. Methods such as EMG and Inclinometry would perhaps be better in detecting small differences in working postures between the three systems. Combined with several interviews with P&H installers about their opinion of the systems, both objective and subjective data could be collected. However EMG and Inclinometry create a vast amount of data that requires a lot of time and knowledge to analyse. These methods were disregarded for this thesis project since the time frame of the project made it impossible to analyse the data without the aid of someone more experienced with this type of analysis.

7.2 Results

7.2.1 Observation

During the observations at construction sites, the whole process of installing piperun in ceiling was rarely seen. Information provided by P&H installers, in combination with seeing parts of piperun installation being performed, have therefore served as a base when understanding how the work is executed. Being able to see the whole process directly would of course create the best understanding for the process. However with the aid of many helpful P&H installers a good understanding was reached.

7.2.2 Telephone survey

The results from the Telephone survey shows that system 2 is most frequently used among the participants. This result correlates well to the result from the observations performed at construction sites, indicating that system 2 is very common in these types of constructions. System 1 was defined as being the second most common system during the Telephone survey. This does not correspond to the results from the observations since system 1 was almost never seen. An explanation of this can be that all construction sites visited were new constructions. As mentioned in chapter 4.3, some of the companies participating in the telephone survey perform service work. The use of system 1 could be more prevalent in these applications since these types of work are smaller both in size and budget and it is harder to plan the work in advance.

The results for troublesome areas put the neck in third place from the top with 14% while only 3,7 ±2,5% of the participants in the SWEA study claimed to have neck problems. This could be because work over shoulder height was discussed during the telephone survey therefore putting a lot of focus on the problems that could be occurring during this type of work (i.e. keeping the neck bent for a long time).

This could have increased the participants' memories of having or having heard of someone complaining of having neck disorders and therefore resulting in a higher percentage for this area. The fact that the percentages are over all much higher in the telephone survey than the SWEA study is due to the design of the survey. Participants were asked to state if they or a colleague have had troubles in any body parts whereas the participants in the SWEA study were only representing themselves. The exact percentage presented in the telephone study was therefore not as interesting as which areas were found most troublesome.

The number of participants in the Telephone survey was to small to draw any generalizing conclusions. However many of the results were similar to those found in statistical data as well as interviews and observations. It is therefore likely that the results well represent the views of P&H installers installing piperun in new construction. Some of the results were as previously mentioned probably not representative for this group since they can be related to other types of work (e.g. service work) than installation of piperun.

7.2.3 Work environment study

The purpose of the study was partly to get an understanding of the work conditions in the P&H industry but most importantly to find out how P&H installers feel about their own work environment. The opinions of the observers were often in line with the opinions of the participants. For the noise category however, there was a clear difference in opinion between the participants and observers. An explanation for this could be that the observers were only visiting the construction sites for a limited time of the workday. Depending on the tasks carried out during that moment the noise level might have been higher or lower than the average level during a normal workday.

In three cases (two regarding climate and one regarding accident risks) the participant did not provide an answer distinct enough to be interpreted into a zone. The opinions in these three cases have therefore been left out, see appendix I. The lower return rate of these questions makes the results less reliable. However, the conclusion drawn from the data that the opinions are very spread regarding the work climate and unanimous for accidents risks would probably not be affected much depending on the answer of a few individuals.

The participants of this study were only 11 in total and from four different construction sites. 11 participants are not enough to make any generalizing conclusions of how P&H installers as a group feel about their working environment. It can however give a notion of the overall opinion. It was visible from the results that some categories such as noise, lighting conditions, climate and working postures/ loads/ space need to be addressed more in order to make the working environment more pleasant for all P&H installers.

7.2.4 Questionnaire study

It was difficult to analyse the results from the questionnaire study since many of the participant did not answer all questions completely. The answers to the more detailed questions got a low response rate and were disregarded while the more general question got a high response rate. In the cases where the Work Environment study and the Questionnaire study were performed during the same visit, the probability of the participant becoming less motivated in answering the questionnaire truthfully, increased. Some of the participants skipped questions leaving an unchecked box. This could be due to the extent of the questionnaire (i.e. number of questions) or because it was too tiresome to participate in both studies during such a short timespan, see table 5.1.

70% of all participants had left at least one question unanswered leading to that much of the results were disregarded. 70% of the participants missed one of the questions asking for a short description on the task the participant was doing at the time of the study. This question was placed at the very beginning together with questions concerning the construction site, name, age, date etc. Either this question was missed due to its early appearance and context or because it seemed too exhaustive to write a description of the task.

Many answered the first part of the question “ Do you use any type of tobacco? If yes, how often?” but left out the second part. If an answer was given, it could be an answer like “every day”. This question should have been defined more clearly since answers like “2 times a day or once a week” was the preferred type of answer. If the second part of the question was an independent question it is possible that it would have gotten more answers. Another example of unanswered questions could be a checked box on work-related MSD in the wrist but not defined weather this disorder was caused by an accident at work or by the work performed. Another example was that MSD in the left lower arm could be checked but when asked where the most troublesome area was, the right lower arm was checked, contradicting the previous answer.

It would have been advisable to check all questionnaires directly after collecting them so that missed answers could be added right away. The questionnaires were not assessed until later. Collecting missing or unclear answers at another occasion was considered to take too much time from other more important aspects of the thesis project.

7.2.5 Hierarchial Task Analysis

As mentioned before it proved difficult to create an HTA of installation of piperun that was representative for all P&H installers due to individual preferences in for example working pattern. Three P&H installers overviewed the HTA:s and found them to be representative giving the HTA:s enough credibility to be used during when planning the Posture and Time study.

7.2.6 Posture and Time study

During the Posture and Time study there were some troubles with the installation material. Even though having followed the recommendations provided by the retailer some of the components did not fit well together. This was mostly noticeable for the medium sized pipe, Ø50 millimeters, in system 1 were the pipe ring simply would not fit over the insulation of the chilled pipe rings. The decision was made to remove this row of pipes from the installation of all three systems in order to be able to compare the results. Furthermore the pipe rings with insulation used for system 2 turned out to be a little bit too small for the largest pipe dimension, Ø100 millimeters. Therefore the rubber insulation was removed from these pipe rings as to make it possible to close them. These lapses in material have had an affect on the results of the Posture and Time study. Possibly the installation time of system 2 became shorter since the friction between the pipe and pipe ring was reduced when the rubber insulation was removed.

Based on the results from both the participant and construction sites observations and the interviews a larger difference in HARM/REBA score was expected between the three systems than the actual outcome. System 1 was expected to be noticeably worse than the other two since many P&H installers described this system as containing to many operations and small parts that are tricky to install without dropping any to the floor.

7.2.6.1 Hand Arm Risk assessment Method (HARM)

The fact that both participants received a score below 25 during the HARM analysis and therefore ended up in the green zone does not mean that they are not at risk for MSD. In an attempt to see differences in working postures for separate tasks during the installation of the three systems, the work was divided into smaller segments. This resulted in very low time scores for each segment even though the actual time spent performing a task was recalculated to a standard 8h workday. If the whole pipe installation were to be analysed at once using HARM the time score would be considerably higher. Many of the tasks include working postures where the arms are held above shoulder height for a large proportion of the time. These postures would therefore be given high scores for the whole task of pipe installation which combined with the higher time score would give a higher and more representative total HARM score. However it would have been impossible to see which tasks during installation of pipes that could be considered most strenuous.

7.2.6.2 Rapid Entire Body Analysis (REBA)

A variation of five postures per task was not enough to capture the differences between the good and the bad postures. In order to minimize the fluctuations between good and bad postures even more postures of one and the same task should be evaluated. The reliability increases with the number of evaluated postures as more fluctuations are covered.

The reliability of the results from the REBA analysis can be questioned, as there are valid contradictions amongst them. The difference between system 1 and 2 (2 getting the higher REBA score) for the task of height adjustment should not be as huge since this task was the same for both systems, see figure 6.26. System 3 got the highest score for the task of drilling holes which is questionable since this task was the same in systems 1 and 2 with the only difference that the drill head had a smaller diameter in system 3, see figure 7.1 A smaller drill head should make the task easier as the resistance is smaller. The task of cutting takjärn was the same for both system 1 and 2 and both got a REBA score of 8, see figure 7.2. The corresponding task in system 3 was cutting channels and got a REBA score of 8,5. These results were solely based on the participant's postures at the time of the cutting. The channels have a smaller cross section than the takjärn and should be as easy or easier to cut, not harder as the results showed.

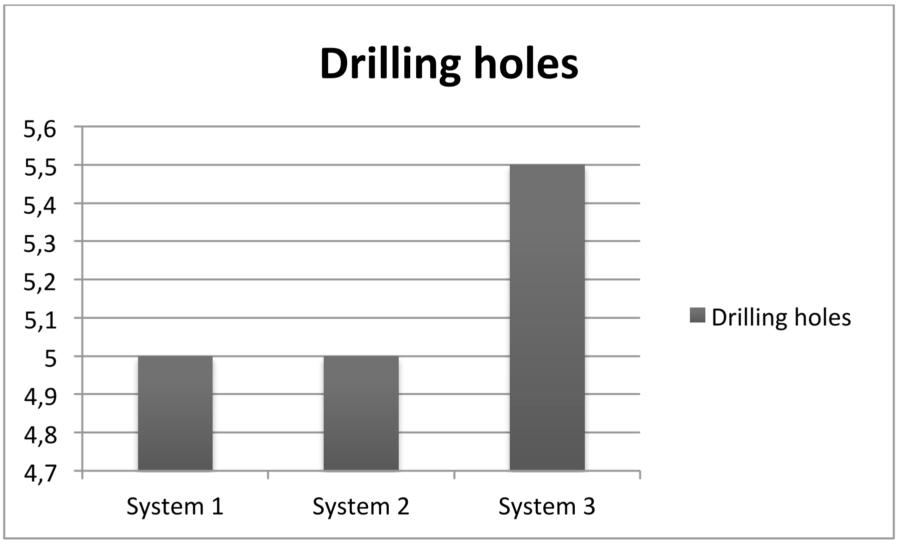


Figure 7.1 The participants average REBA score per system

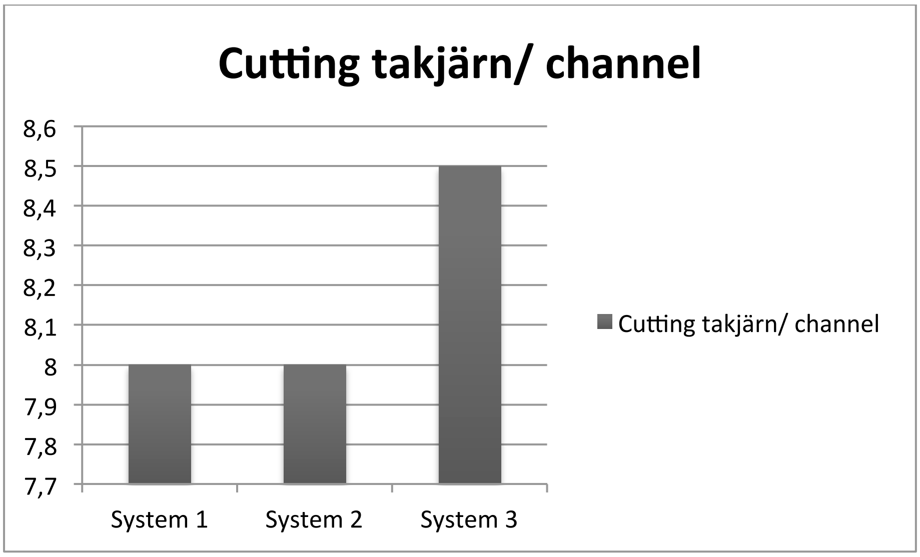


Figure 7.2 The participants average REBA score per system

7.2.6.3 Time study

As mentioned before, the pipe rings with insulation used for system 2 turned out to be a little bit too small for the largest pipe dimension, Ø100 millimeters. This meant that the participants had to remove the rubber insulation of the pipe rings in order to fasten them around the pipes. By doing so it perhaps got a bit easier to put the largest pipes in place since these could glide into the pipe rings without getting stuck on the rubber insulation. This could have affected the total installation time of system 2 making the installation time shorter in comparison to the other systems than it should be.

The difference in experience between the participants of the Posture and Time study could also have affected the installation times. Although both participants were experienced P&H installers, participant A did not have much prior experience from installing system 3. It is therefore possible that with more training participant A could install system 3 even faster. In general, the difference in installation times for system 2 and 3 was more noticeable for participant B who had more equal experience from installing both systems.

7.2.7 The total result

The studies conducted during this thesis project were all small scale. It is therefore impossible to draw conclusions that could apply to P&H installers in general. This thesis project is therefore to be seen as a pilot study of how an investigation of different systems for pipe installation could be done. Furthermore the focus of the project has been installation of piperun in new constructions. All results presented are therefore only applicable to that specific setting.

7.3 Aims

The purpose of this thesis project was to compare different systems for pipe installation based on ergonomic factors and productivity referring to installation time. To further define the project, three questions of issue were raised. In order to answer these questions, literature were researched and observations, interviews and different studies were performed. After analyzing the results all three questions could be answered.

- Can any distinction be made between the different systems for installation based on an ergonomic investigation of observing working postures and loads handled by the P&H installer?

No significant differences between the systems were found using the HARM and REBA analysis. However results from interviews and observations showed that there is a significant difference in perception between system 1 and system 2 and 3. System 1 was found to be trickier to install since it contains more operations and parts than the other systems.

- By conducting a time study of the systems, what conclusions can be drawn on the productivity of the different systems?

The Time study showed that the installation time for system 1 is significantly longer than the installation times for system 2 and 3, which were quite similar. Participant A in the study had little or no prior experience from installing system 3. This participant got a longer installation time for this system than participant B who had prior experience from all three systems. This could indicate that system 3 requires a somewhat shorter installation time than system 2. Since system 1 contains more loose screws and nuts than the other systems the waste of material was larger for this system since the P&H installers sometimes dropped screws and nuts on the floor. The productivity of system 2 and 3 is therefore better from an installation time point of view.

- By exploring the relationship between productivity and work conditions, can any conclusions be drawn on weather one of the two can be improved without impairing the other?

Research from previously published studies showed that improved working conditions often have a positive impact on quality and productivity. When a person is content with the work situation and do not feel any unnecessary strain the individual is more willing to spend time on fine tuning or quality control of the work performed. It is beneficial if the installation time of a system is short since the P&H installer then is exposed to strenuous working postures for a shorter amount of time. Interviews with persons working in the field of occupational and environmental medicine emphasized the importance of using the spare time in a deliberate way. If a system takes less time to install, more times is available for performing other tasks. The nature of these tasks is important from an ergonomic standpoint.

If the same type of work is performed (i.e. the same postures held) the shorter installation time is not beneficial. However if tasks requiring other working postures are performed, the muscles engaged in the first task are able to recover. Productivity can be improved without impairing working conditions if work rotation is used.

- Can any conclusions be drawn on weather individual prerequisites prevent or induce work-related disorders?

From previously published studies it can be said that a healthy lifestyle affect both work performance and spare time. A good physique can aid but not guarantee in preventing MSD. It is very important to adapt the work environment to the individual. Many factor such as physique, size, age and eyesight affect what requirements need to be put on the work environment. Both studies conducted in this project and published studies show than the use of tobacco can increase the risk of getting MSD.

8 Conclusion

In this chapter the conclusion of the thesis is presented

From observing and interviewing P&H installers at different construction sites it can be said that it is difficult to draw any generalizing conclusions on the working conditions and working patterns. The working conditions of the P&H industry varies from site to site depending on the weather, season, employer and what material the employer chose to invest in, colleagues etc. What can be said about the P&H industry is that it is a demanding workplace often exposed to external factors such as a harsh climate. The work often requires bad working postures, which might eventually lead to MSD. Much of the working conditions such as good lighting, standing in as good working postures as possible and follow regulations depends on the individual. It is however the employers responsibility to provide the means for the employee to create a good work environment. For example, the employer should provide hearing protection but it is the employee's responsibility to use them.

One conclusion that could be drawn from the Questionnaire study is that MSD gets more common with age, which also is reported in other published studies.

It is hard to draw any generalizing conclusions based on the results from the HARM and REBA analysis. There were no great differences or clear tendencies between the three analyzed systems. Instead the variation between the participants' individual scores was evident and a distinct difference between good and bad postures could be read from the results. The conclusion drawn from this is therefore that even though no system could be said to be better from an ergonomic point of view the importance of how an individual work in terms of work pace and working positions have a great affect on the overall ergonomics.

The results from the Time study showed that system 2 and 3 took a shorter time (approximately 2/3) to install than system 1. System 2 was the quickest for one of the participants and system 3 for the other. This has likely to do with which system the participant was most familiar. A system with a short installation time is preferable as it saves time and in some cases money. Depending on how the time spared is spent, a shorter installation time can either improve or impair the ergonomic situation. Work rotation is preferable since it is important for engaged muscle groups to obtain rest.

9 Recommendations

Recommendations for further investigation on this subject are presented in this chapter

This project was a pilot study conduced to find out what areas to focus on and what methods to use in a more extensive study on the subject. The recommendations presented here are based on the results from the project.

A questionnaire on work-related disorder should be sent out to a larger group of participants. The questionnaires could be sent out electronically in order to reach more participants. This might affect the response rate as the examiners will not be able to control the answer rate. Since a much larger group can be contacted the response rate might still be sufficient. The questionnaire should be tested on a small group at first as to see if the questions are easy to understand and if the questionnaire seems too extensive. The purpose of the questionnaire is to be able to draw connections between disorders and work and also to localize which areas of the body that are most exposed to MSD.

A more extensive study of a test such as the Posture and Time study is recommended to draw conclusions and get reliable results. The recommendation is however to change the methods of analysis. With the methods of EMG and Inclinometry, the chosen muscle groups (the areas that are most prone to MSD located through the questionnaire study) could be closely monitored. Instead of using subjective analysis methods to study large parts of the body, the recommendation is to limit the study by using objective analysis methods to study certain exposed muscle groups. This will hopefully give objective data on the difference between the systems from an ergonomic perspective. Since the findings of this project clearly shows that the individual factors play an important role for the results from various studies, a larger group of participants is recommended.

The recommendation for Hilti in the present is to introduce a course on ergonomics and working postures. The results from this project clearly states that individual postures are very important in preventing MSD and that many P&H installers do not work in the best possible working postures for different tasks they perform. This could either be due to negligence or ignorance. By offering a course on how to work in the best way as to avoid injuries and MSD, Hilti could get a new advantage point while gaining more trust from their customers.

Furthermore there are many installers that complain about not being able to adjust the height with system 3 compared to system 1 and 2. This seems to depend on the installers' unfamiliarity with the system and not knowing how to use it properly. Therefore the recommendation is for Hilti to further work on educating their customers on how to use their system in the most efficient way.

When evaluating the productivity of the systems from an ergonomic point of view the experimenter should keep in mind what the effects are. What happens with the time gained by installing one of the faster systems? Is the time used for other strenuous tasks (using the same muscle groups) or rest? Is work rotation used and if not, should it be?

To sum it up, the recommendations are:

- Questionnaires with a larger group of participants to find the most exposed areas of the body.
- More tests like the one in Posture and Time study with more participants. An objective analysis with focus on the most exposed areas of the body instead of a subjective analysis of the entire body. Methods for analysis: EMG and Inclinometry.
- Further demonstration on how system 3 should be used to gain the benefits of system 3.
- Introduce a course on how to work in an ergonomically beneficial way with good working postures. Suggestions of topics for such a course are presented below.

Suggestion of topics for a course on working postures:

- Avoid extreme positions (i.e. keeping body parts fully extended or bent) often or for a longer amount of time.
- Avoid combinations of strenuous positions such as bending and twisting the neck at the same time.
- Apply a variation of different postures when working so that the same muscles are not activated all the time.
- Plant both feet on the ground in order to hold a stable base.
- Apply suitable lifting techniques when manually handling heavy loads (e.g. keep the load close to the body and lift using the legs).
- Use proper tools and available aids when possible (e.g. tools with low vibration value and lifts with enough working space).

10 References

[1] Ergonomi I byggbranschen – förebygg de belastningsergonomiska riskerna (Electronic) http://www.av.se/dokument/publikationer/adi/adi_616.pdf, 2013-02-12

[2] Byggherrens ansvar (Electronic) http://www.boverket.se/Bygga--forvalta/Bygglov-och-anmalan/Byggherre-och-agare/ 2013-06-14

[3] About the Swedish Work Environment Authorities (Electronic) http://www.av.se/omoss/, 2013-03-27

[4] About piecework salary (Electronic) http://www.ne.se/ackordsl%C3%B6n, 2013-02-26

[5] Krister Persson, Regionalt skyddsombud, Byggnads, Telephone call, 2013-01-30

[6] Michael Jensen, Företagsrådgivare Skåne, VVS-företagen, Telephone call, 2013-01-29

[7] Johansson, B, Rask, K, Stenberg, M (2010). Piece rates and their effects on health and safety - A literature review. Applied Ergonomics, 41**,** 607-614. Found in [21]

[8] Piecework (Electronic) http://www.vardguiden.se/Sjukdomar-och-rad/Omraden/Sjukdomar-och-besvar/Stress/, 2013-05-16

[9] Definition of Ergonomics (Electronic) http://www.iea.cc/01_what/What%z20is%20Ergonomics.html, 2013-03-04

[10] Rafnsson V, Steingrimsdottir O, Olafsson M, Sveinsdottir T (1989). Musculoskeletal symptoms in the Icelandic population. Nordisk Medicin 104(4):104–107. Andersson I, Ejlertsson G, Leden I, Rosenberg C (1993). Chronic pain in a geographically defined general population: Studies of differences in age, gender, social class, and pain localization. Clin J Pain 9:174– 182. Bassols A, Bosch F, Campillo M, Canellas M, Banos JE. 1999. An epidemiological comparison of pain complaints in the general population of Catalonia (Spain). Pain 83:9–16. Found in [24]

[11] Musculoskeletal disorders (Electronic) http://www.who.int/occupational_health/publications/oehmsd3.pdf, 2013-05-09

[12] Musculoskeletal disorders (Electronic) https://osha.europa.eu/en/topics/msds, 2013-04-29

[13] Belastningsergonomi (2005). Arbetarskyddsstyrelsens författningssamling AFS 1998:1

[14] Arbetsmiljöstatistik (2012). Stockholm. Serie: Arbetsmiljöstatistik ISSN 1652-1110

[15] Hägg, G M (2001). Handintesivt arbete - En belastningsergonomisk kunskapsöversikt gällande människans kapacitet och interaktion med verktyg och arbetsuppgifter. Arbetslivsinstitutets expertgrupp för ergonomisk dokumentation – dokument 3, Arbetslivsinstitutet, Stockholm,

[16] Hand and Grip (Electronic) http://www.hrsdc.gc.ca/eng/labour/publications/health_safety/ergonomics/identify_ergonomics/page03.shtml, 2013-05-16

[17] Mital, A, Kilbom, Å (1992a). Design, selection and use of hand tools to alleviate trauma of the upper extremities: Part I - Guidelines for the practitioner. *Int J Ind Ergon,* 10, 1-5. Found in [14]

[18] Hägg, G M, Ericson, M, Odenrick, P (2010). Fysisk belastning, Bohgard, M, Karlsson, S, Lovén, E, Mikaelsson, L-Å, Måretnsson, L, Osvalder, A-L, Rose, L, Ulfvengren, P (red.) Arbete och teknik på människans villkor. Prevent, Stockholm, Sweden, pp 129-188

[19] Arbetsplatsens utformning (2009). Stockholm, Arbetsmiljöverkets författningssamling AFS 2009:2

[20] Inspektioner ska minska skador av damm på byggarbetsplatserna (Electronic) http://www.av.se/pressrum/pressmeddelanden/2012/37549.aspx, 2012-06-04

[21] Buller (2005). Solna. Arbetsmiljöverkets författarsamling AFS 2005:16

[22] Brännmark, M, Eklund, J, Håkansson, M, Vogel, K (2012). Kunskapsöversikt Belastningsergonomiska studier utifrån ett produktions- och systemperspektiv - interventioner, verksamhetseffekter och konsekvenser. Rapport 2012:1 Skolan för teknik och hälsa, avdelningen för Ergonomi vid Kungliga Tekniska Högskolan och Helix vid Linköpings universitet, Stockholm, Linköping.

[23] Axelsson, J R C (2000) Quality and ergonomics – towards successful integration. Doctoral thesis. Linköping University. Found in: [21].

[24] Inger Arvidsson, Dr Med Sci, Arbets- och miljömedicin, Lund, Personal conversation 2013-02-19

[25] Holmström, E, Engholm, G (2003). Musculoskeletal Disorders in Relation to Age and Occupation in Swedish Construction Workers. American Journal of Industrial Medicine 44, 377–384

[26] Hemphälä, H (2008). En god visuell arbetsmiljö – ögonbesvär, muskuloskeletala besvär och produktivitet hos brevbärare. LiU-Tek-Lic-2008:8. Avdelningen för industriell arbetsvetenskap, Institutionen för ekonomisk och industriell utveckling, Linköping University, Linköping

[27] Stanton, N, Hedge, A, Brookhuis, K, Salas, E, Hendrick, H (2005). The handbook of human factors and ergonomics methods. CRC Press, Boca Raton, USA

[28] Höst, M, Regnell, B, Runesson, P (2006). Att genomföra examensarbete. Studentlitteratur, Lund, Sweden

[29] Sveriges Verkstadsförening (1990). Arbetsmaterial - Se om miljön. Informako AB, Stockholm, Sweden

[30] Hierarchial Task Analysis /Electronic) http://classweb.gmu.edu/ndabbagh/Resources/Resources2/hierarchical_analysis.htm, 2013-05-17

[31] Osvalder, A-L, Rose, L, Karlsson, S (2009). Methods, Bohgard, M, Karlsson, S, Lovén, E, Mikaelsson, L-Å, Måretnsson, L, Osvalder, A-L, Rose, L, Ulfvengren, P (editors) Work and technology on human terms. Prevent, Stockholm, Sweden, pp 463-566

[32] Douwes, M, de Kraker, H (2012). HARM overview and its application: some practical examples. Work 41, 4004-4009

[33] Hignett, S, McAtamney, L (2000). Rapid Entire Body Assessment (REBA). Applied Ergonomics 31, 201-205

[34] Statistiska Centralbyråns yrkesregister, Yrkeskod SSYK 7135 VVS montörer m.fl. Statistik service, Telephonecall, 2013-05-08

[35] The occupational structure in Sweden 2011 – Occupational statistics based on the Swedish occupational register (Electronic) http://www.scb.se/Statistik/AM/AM0208/2011A01/AM0208_2011A01_SM_AM33SM1301.pdf, 2013-05-29

[36] Picture: Bodymap (Electronic) http://www.sciencedirect.com/science/article/pii/S000368701200186X, 2013-03-22

[37] Picture Borg RPE scale (Electronic) http://www.vavaveteran.co.uk/borg-me-and-rpe/, 2013-03-22

[38] Byggverksamhet (2011). Stockholm, Arbetsmiljöverket, Korta arbetsskadefakta, Nr 2

Appendix A: HARM Score sheet

HARM: Hand Arm Riskbedömningsmetod

Bedömningsmall — Version 2008

Arbetsuppgift – arbetstagare (initialer)	Datum
Arbetsställe - avdelning	Bedömning utförd av

Steg 1: Bestämning av tidspoäng

Steg 1A: Den sammanlagda tiden som uppgiften förekommer i snitt under en arbetsdag (alla perioder tillsammans). Ange tiden enbart för de dagar uppgiften förekommer (max en decimal)	…. timme - 0,5 = …….
Steg 1B: Hur många dagar/vecka förekommer uppgiften?	
- 1 eller 2 dagar/vecka: dra bort 1 poäng	- 1
- 3 eller flera dagar: poängen kvarstår	- 0
Steg 1C: Minst 7,5 min. paus* per 1,5 timme?	
- om ja: dra bort 1 poäng	-1
- om nej: poängen kvarstår	-0

*Läs i handledningen vad som räknas som paus

Steg 1D: Beräkna tidspoängen Om poängen <1, sätt 1 …….

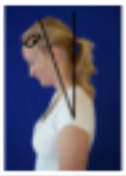
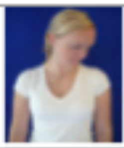
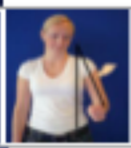
Steg 2: Den mest aktiva handen ringa in **höger/vänster/båda**

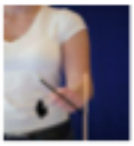
Steg 3: Bestämning av kraftpoäng

Steg 3A		**Steg 3B**			**Steg 3C**		
Ange den mest aktiva handen (H,V,B)		**Hur länge varar kraften i sek/min. (för varje rörelse/moment)**			**Antal kraftansträngningar/ minut (frekvens)**		
Kraft	**Beskrivning och exempel**	**< 4**	**4 - 30**	**31 - 60**	**< 4**	**4 - 30**	**> 30**
liten Vikt<100g Kraft<1 N	Litet tryck med fingrar (t.ex. hålla en blyertspenna med 2 eller 3 fingrar), sortera, trycka lätt med fingrar	0	1,5	3	1	2,5	4
Medel V 100 – 1000 g K 1-10N	Hålla litet motordrivet verktyg med fingrar/hand. Ta/gripa, hålla delar, montera, trycka hårt	0	2,5	4	1	2,5	4
Större V 1-3 kg K 10-30N	Stadigt grepp med handen (användning av kniv/tång, hantering av delar el. verktyg, genomförande av tyngre delar (t.ex. kassaarbete)	0	3,5	6	2	3,5	6
Stor V 3-6 kg K 30-60N	Mycket kraft med armen, (tunga verktyg, tung manöver)	0	4,5	7	2	4,5	7
"peak"	Slå med handflata eller knytnäve	-	-	-	3	5	8

Steg 3D Kraftpoäng = högsta inringade värdet = ……

Obs! Om belastningen överstiger 6 kg bedöms den med annan metod (t ex för skjut/dra eller manuell hantering)

Steg 4A Arbetsställningspoäng för HUVUD/NACKE och SKULDRA/ÖVERARM		Procentandel som arbetsställningen före-kommer av den totala tiden som uppgiften pågår **0 – 10 %**	**10 – 50 %**	**> 50 %**
Huvudet mer framåtböjt än på första bild ELLER bakåtböjt  	Huvudet mer sidoböjt än på första bild ELLER vridet  	0	1,5	3
Huvudet **både framåtböjt och vridet**		0	2	4
Huvudet **både bakåtböjt och vridet**		0	3	4
(Mycket) Framskjutet huvud/haka		0	1,5	3
Överarmen längre framåt, åt sidan eller bakåtlyft än på bilderna och **utan** stöd	 	0	2,5	3,5
(Starkt) uppdragna axlar		0	3	4
Poäng för arbetsställning nacke/skuldra = högsta poäng =		……		

Steg 4B Arbetsställningspoäng UNDERARM/HANDLED	Procentandel som arbetsställningen förekommer av den totala tiden som uppgiften pågår 0 – 10 %	10 – 50 %	> 50 %
Maximalt böjd eller sträckt.  	0	1	2
Underarmen är (i pilens riktning) mer vriden än på nedanstående bilder  	0	1	2
Handen tydligt böjd i sidled från handleden, nära ytterläge - ställningen i handleden ligger mellan lägena på respektive bild. Rörelsen är i riktning mot tummen eller lillfingret.  	0	1,5	3
Handen är tydligt böjd från handleden, nära ytterläge - ställningen i handlederna ligger mellan ställningarna på respektive bild.  	0	1,5	3
Poäng för arbetsställning underarm/handled = högsta poäng =	......		

Steg 5 Vibrationspoäng

Används vibrerande verktyg vid uppgiften?

- Om Nej, fyll i en "0" på vibrationspoängen på den grå raden under tabell 5A och gå vidare till steg 6.
- Om Ja, är verktyget accelerationsvärdet känt?
  - Nej, gå till 5A
  - Ja, gå till 5B

Steg 5A Accelerationsvärdet är inte känt

Vilken av nedanstående förhållanden stämmer bäst? Ringa in passande poäng och för ned till den grå raden under tabellen.	Exponeringstid inom arbetsuppgiften	
Beskrivning	0-4 timmar	4-8 timmar
Vibrationer inte eller knappast kännbara eller synliga för operatör och observatör	0	0
Vibrationer inte synliga, men kännbara av operatör och observatör (kittlar)	2	2
Vibrationer synliga (lite) i underarm och hand, tydligt kännbara av operatör och observatör	2	4
Händer, armar och skuldror vibrerar tydligt synbart, vibrationer också tydligt kännbara.	4	4
Vibrationspoäng: ta med det inringade talet	.....	.....

Steg 5B Accelerationsvärdet är känt

Vilken av nedanstående förhållanden stämmer bäst? Ringa in den poäng som stämmer och för ned till den grå raden under tabellen.	Exponeringstid inom uppgiften	
Accelerationsvärdet	0-4 timmar	4-8 timmar
< 2,5 m/s²	0	0
≤ 2,5 – 5 m/s²	2	2
≤ 5 – 10 m/s²	2	4
> 10 m/s²	4	4
Vibrationspoäng: ta med det inringade talet	.....	.....

Steg 6 Andra faktorer:

Ange för varje faktor om den stämmer med de aktuella förhållandena	**Ringa in**
Fasta tider för raster o pauser (motsats till att själv kunna bestämma när man tar paus)?	Ja / nej
Ogynnsamt klimat (t.ex. kyla, drag) ?	Ja / nej
Svårt att koncentrera sig (enbart vid koncentrationskrävande arbete)	Ja / nej
Dålig kontakt med verktyg och material, t.ex. genom handskar?	Ja / nej
Precisionskrävande arbete?	Ja / nej

Poäng andra faktorer	**Ringa in**
0 "Ja" – svar ger poängtalet	0
1 "Ja" – svar ger poängtalet	1
2 eller fler "ja" – svar ger poängtalet	2

Steg 7 Total riskpoäng:

Notera poängen från steg 3 - 6 (A)		Poäng
Kraftpoäng	(steg 3)	....
Poäng arbetsställning nacke/skuldra	(steg 4A)	....
Poäng arbetsställning underarm/handled	(steg 4B)	....
Vibrationspoäng	(steg 5)	....
Poäng andra faktorer	(steg 6)	.... +
Summera poäng (A)		....
Tidspoäng (steg 1) (T)		 x
Beräkna riskpoäng (A x T)		....

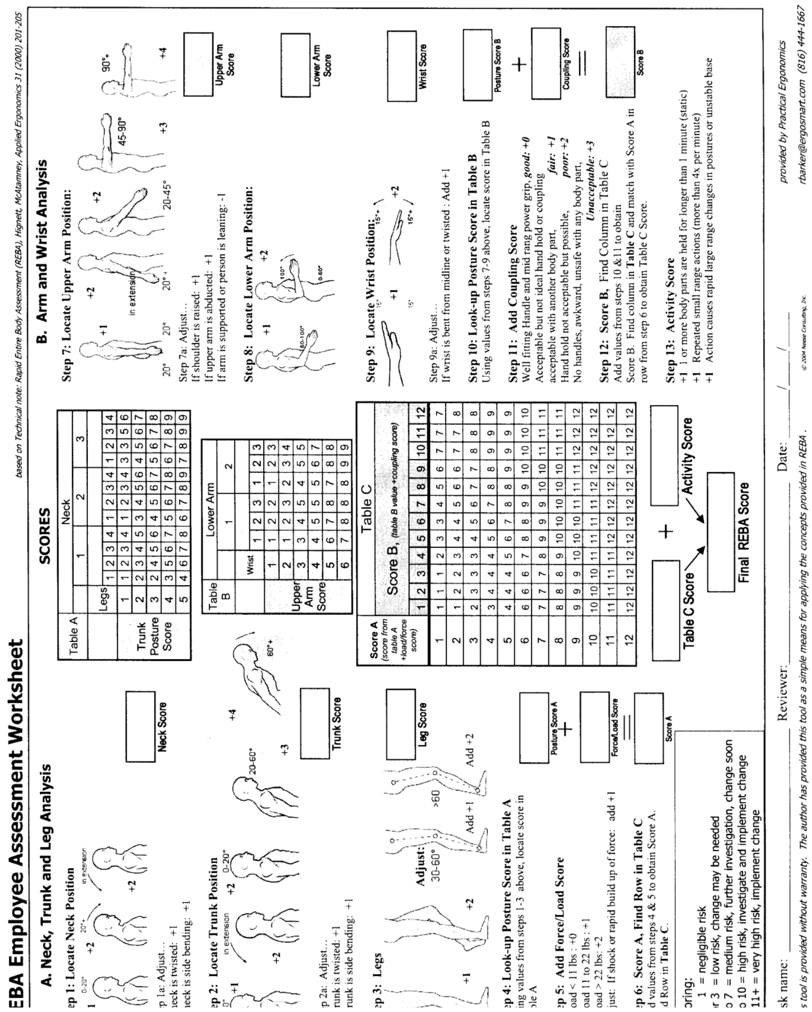
...

Steg 8. Riskbedömning

Bedöm risk med hjälp av nedanstående tabell:

Total poäng	Risk	
< 25	GRÖN	Ingen förhöjd risk för belastningsrelaterade besvär i arm, nacke eller skuldra för majoriteten av arbetstagarna.
25 - 50	GUL	Risk för besvär i arm, nacke eller skuldra för en del av arbetstagarna. För att skydda arbetstagarna är det viktigt att vidta åtgärder för att minska risken.
≥ 50	RÖD	Hög risk för belastningsbesvär i arm, nacke eller skuldra för en stor del av arbetstagarna. Vidta åtgärder omgående.
UTTALADE BESVÄR		Om någon arbetstagare har besvär och misstanke finns om samband med arbetsuppgiften är det ALLTID viktigt att undersöka orsaken och vidta åtgärder.

Appendix B: REBA Score sheet



Appendix B: REBA Score sheet

Appendix C: Questions, Telephone survey

- Does your company use piecework as form of salary? Why/ why not?
- Which systems do you use for pipe installation?

    1, Takjärn and pipe ring?

    2, Takjärn and pipe ring with insulation?

    3, Channels and pipe ring with insulation?

    4, An assortment of different systems? If so, which do you use most often and how often is that system used?

  Why do you use that system and from which supplier do you purchase?

- To what extent do you preassemble pipe rings and connectors before installation?
- How common are MSD related to work above shoulder height/level? Which areas are most troublesome?
- How active does your employer work with working environment issues?
- Does ergonomic factors play a part when choosing which installation system to purchase? Can the employees affect the decision?

Appendix D: Questions, Work Environment study

Workplace:
Size and type of workplace:
Size of employer:
Piecework:
Season (climate protection):

Name:
Phone:
Gender:
Age:
Position:
Years in business:

Noise

- What is your opinion regarding the noise?
- What makes most noise / sound?
- Can you talk to your colleagues in a normal way?
- How often do you use ear protection during a work day?
- Do you have any additional comments?

Climate

- What is your opinion about the climate of the workplace (temperature, humidity, wind)?
- Can you preform your work tasks in a normal way in relation to the climate?
- Do you have any additional comments?

Vibration

- What is your opinion regarding vibrations?
- Which machine vibrates the most?
- How often / during how much time per day are you exposed to vibrations?
- Do you have any additional comments?

Lighting conditions

• What is your opinion regarding the lighting conditions?

• Do you have enough lighting in order to perform work tasks in a normal way?

• Does the light vary during different tasks?

• Do you have any additional comments?

Dust

• What is your opinion regarding dust?

• How often are you exposed to dust?

• Do you use any protection against dust?

• Can you perform your duties in a normal way?

• Do you have any additional comments?

Accident risks

• What is your opinion regarding the risk of accidents?

• Do you use any protective gear?

• Do you have any additional comments?

Working postures, Workloads, Lack of space

• What is your opinion regarding working postures?

• Can you adjust your working posture and workspace according to your physical prerequisites?

• Does heavy lifting occur during a typical workday? How often, how heavy?

• Are the tasks performed varied (repetitive)?

• Do you have the space you need to perform your duties in a normal way?

• Do you have any additional comments?

Appendix E: Definition of zones, Work Environment study

Noise

Target zone: The noise level is not bothersome. Conversations can be held in a normal voice when standing at least two meters apart.

Normal zone: Somewhat disturbing and irritating noise may occur at times. Conversations can be held in a normal voice when standing about one meter apart.

Action zone: Oppressive noise. Conversations must be held with a raised voice when standing about one metre apart. Short periods of loud noise occur in an otherwise quiet environment.

Climate

Target zone: The climate is fully satisfactory. The conditions for heat balance are completely fulfilled. No occurrence of climate asymmetries or unwanted air movement.

Normal zone: The climate conditions are considered satisfactory. Occurrence of climate asymmetries or unwanted air movement is limited.

Action zone: The conditions to maintain body heat balance are not met. Cooling or heating of the body cannot be compensated for with altered activity or clothing.

Vibrations

Target zone: The exposure time is shorter than the specified exposure time for each vibration class.

Normal zone: Exposure time is equal to that specified for each vibration class.

Action zone: The exposure time is longer than the time specified for each vibration class. (Corresponding to one to two classes).

Lighting conditions

Target zone: Fully adequate lighting conditions. The lighting is satisfactory and glare does not occur. No requirement for remote or near vision.

Normal zone: The luminance conditions are acceptable and glare occurs only to a minor extent. The illuminance is satisfactory. Objects are within the optimal field of view.

Action zone: The lighting is unsatisfactory with poor luminance. Glare exists during most of the day or bright glare exists during certain periods. Near, depth or remote vision is required.

Dust

Target zone: Conditions considered satisfactory. The employee is exposed to dust only to a very small extent.

Normal zone: Conditions considered acceptable. The employee is exposed to dust to some extent.

Action zone: Conditions considered unsatisfactory. The employee is exposed dust to a large extent.

Accident risks

Target zone: No obvious risks are present. Safety Instructions are available. Personal protective equipment other than gloves, hearing protection, safety shoes and high-visibility vest need not to be used. The employee does not need to be particularly alert to potential dangers. Incidents are monitored.

Normal zone: Risk of injury is small during ordinary work tasks. The employees need only occasionally to be especially attentive towards risks. Safety instructions are available. Regulations are met for safety and prevention of accidents. The workplace is designed to facilitate the maintaining of a neat working environment.

Action zone: The personal safety is not acceptable. Risks that have arisen in previous accidents / incidents have not been resolved. Disorganised conditions in the workplace stipulate substantial risk of injury (see example). Safety instructions are necessary but missing.

Working postures / Work loads / Lack of space

Target zone: Variation and changes in work postures and movement patterns occur. Work is usually performed within a comfortable range of motion. Individual adjustment of the workplace is possible. Static muscle work does not occur. Good space provided for knees and feet. The need for pauses are well met. Good seating facilities are available. Good floor surfaces.

Normal zone: Occasional heavy lifting may occur. Variation and changes in work postures and movement patterns are possible. Less suitable work postures and movements patterns may occur. Seating facilities are available. Space and floor surfaces are acceptable. Work at or above shoulder level occurs occasionally. Good grip conditions for lifting and handling tools.

Action zone: Occasional heavy lifting is required. Work in bent forward or twisted postures occurs more than 20% of the time. Fixed postures are held frequently or a total of more than 20% of the time. Work with the arms vertically away from the body often occurs. Head, neck, arms held briefly but regularly fixed in the near extreme positions. Work with the arms at or above shoulder height is performed more than 10% of the time. Unilateral, repetitive tasks are commonly preformed. Troublesome overhand grip occurs, as well as frequent rotation of the forearms and hands. Available seating facilities are limited. Space and floor surfaces are less than well.

Appendix F: Questionnaire

Studie: Arbetsrelaterade belastningbesvär

Denna studie kommer att ingå i ett examensarbete som utförs i samarbete med Lunds Tekniska Högskola och Hilti AB. Syftet med studien är en kartläggning av eventuella belastningsbesvär relaterade till arbetet av rörmontering ovanför axelhöjd. Resultatet av studien kommer att ingå i slutrapporten som en del i exmensarbetet. **Alla testpersoner kommer att förbli anonyma i rapporten.**

Undersökningen består av 2 delar. Del 1 är tillstörsta del kryssfrågor och görs på egen hand och del 2 består av en kortare intervju. Var god och leta upp oss när du är klar med del 1.
Tveka inte att fråga ifall du har några funderingar.

Tack för din medverkan!
Magdalena Bosson och Veronica Andersson

Formalia

Namn: Arbetsplats: Datum:

Ålder: Företag: Klockslag:

År i branschen: Befattning:

Arbetsmoment (ex. montering av takjärn):

Bakgrund

Är du fysiskt aktiv under fritiden (ex. joggning eller badminton)?

Har du någon hobby där du arbetar med händerna (ex. modellbygge)?

Röker eller snusar du? Om ja, hur ofta?

Känner du dig ofta stressad i arbetet?

Tänk på att följande frågor är avsedda för arbete ovanför axelhöjd!

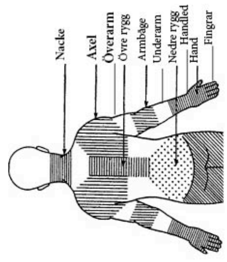
1

NACKE, AXEL, ÖVERARM

Del 1

Har du under det senaste året haft ÅTERKOMMANDE problem i NACKE, AXEL och/ell ÖVERARMEN mer än 3 gånger eller längre än en vecka?

☐ Nej (gå till sida 4)
☐ Ja



Om Ja beskriv typ av besvär och område genom att göra en markering i de rutor som pas nedan. Markera så många som behövs.

	Nacke	Höger axel	Vänster axel	Höger överarm	Vänster överarm
Trötthet	☐	☐	☐	☐	☐
Smärta	☐	☐	☐	☐	☐
Ömhet	☐	☐	☐	☐	☐
Värk	☐	☐	☐	☐	☐
Pirrningar/ stickningar	☐	☐	☐	☐	☐
Stelhet	☐	☐	☐	☐	☐
Kramp	☐	☐	☐	☐	☐
Domningar	☐	☐	☐	☐	☐
Mjölksyra	☐	☐	☐	☐	☐

Under de senaste 7 dagarna har besvären i min nacke, axel och/ eller överarm påverkat produktionshastigheten och/ eller kvalitén av mitt arbete (markera det svar som stämmer

Instämmer inte alls				Instämmer hel
1	2	3	4	5

NACKE, AXEL, ÖVERARM

Tror du besvären är relaterade till en viss arbetsuppgift eller arbetsställning?
☐ Nej ☐ Ja

Om ja, beskriv problemområde och typ av arbetsuppgift.

Område (nacke, axel, överam etc)	Arbetsuppgift/ arbetsställning
______	______
______	______
______	______

Om du har besvär i mer än ett område markera vilket område som är det MEST utsatta (markera endast ETT svar).
☐ Nacke ☐ Höger överarm
☐ Höger axel ☐ Vänster överarm
☐ Vänster axel

I följande stycke om nacke, axel och överarm besvara frågorna utifrån ditt tidigare svar om mest utsatt område.

Upplever du besvären:
☐ Endast under aktivt arbete
☐ Efter kort (15-30 min) vila
☐ Efter lång (>30 min) vila
☐ Kontinuerligt

Hur mycket obehag upplever du i detta område just nu? Markera på en skala från 1-10 den nivå av obehag som stämmer bäst in på dig (0 = inget obehag och 10 = värsta tänkbara obehag).

Inget obehag — Värsta tänkbara obehag
0 1 2 3 4 5 6 7 8 9 10

Har just detta besvär uppkommit pga. av en specifik händelse eller olycka? ☐ Nej ☐ Ja

Har du fått behandling för besväret antingen professionellt eller egenvård? ☐ Nej ☐ Ja

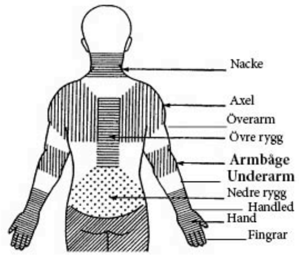
Om ja (markera de svar som stämmer bäst).
☐ Vila ☐ Antiinflammatoriska mediciner
☐ Kyla ☐ Sjukgymnastik
☐ Operation
☐ Annat (beskriv) ______

Har du varit sjukskriven från jobbet på grund av detta besvär? ☐ Nej ☐ Ja

3

ARMBÅGE, UNDERARM

Har du under det senaste året haft ÅTERKOMMANDE problem i ARMBÅGE och/eller i UNDERMEN mer än 3 gånger eller längre än en vecka?
☐ Nej (gå till sida 6)
☐ Ja



Om Ja beskriv typ av besvär och område genom att göra en markering i de rutor som passar i tabellen nedan. Markera så många som behövs.

	Höger armbåge	Vänster armbåge	Höger underarm	Vänster underarm
Trötthet	☐	☐	☐	☐
Smärta	☐	☐	☐	☐
Ömhet	☐	☐	☐	☐
Värk	☐	☐	☐	☐
Pirrningar/ stickningar	☐	☐	☐	☐
Stelhet	☐	☐	☐	☐
Kramp	☐	☐	☐	☐
Domningar	☐	☐	☐	☐
Mjölksyra	☐	☐	☐	☐

Under de senaste 7 dagarna har besvären i min armbåge och/ eller underarm påverkat produktionshastigheten och/ eller kvalitén av mitt arbete (markera det svar som stämmer bäst).

Instämmer inte alls — Instämmer helt
1 2 3 4 5

4

ARMBÅGE, UNDERARM

Tror du besvären är relaterade till en viss arbetsuppgift eller arbetsställning?
☐ Nej ☐ Ja

Om ja, beskriv problemområde och typ av arbetsuppgift.

Område (armbåge, underarm etc)	Arbetsuppgift/ arbetsställning

Om du har besvär i mer än ett område markera vilket område som är det MEST utsatta (markera endast ETT svar).
☐ Höger armbåge ☐ Höger underarm
☐ Vänster armbåge ☐ Vänster underarm

I följande stycke om armbåge och underarm besvara frågorna utifrån ditt tidigare svar om mest utsatt område.

Upplever du besvären:
☐ Endast under aktivt arbete
☐ Efter kort (15-30 min) vila
☐ Efter lång (>30 min) vila
☐ Kontinuerligt

Hur mycket obehag upplever du i detta område just nu? Markera på en skala från 1-10 den nivå av obehag som stämmer bäst in på dig (0 = inget obehag och 10 = värsta tänkbara obehag).

Inget obehag — Värsta tänkbara obehag
0 1 2 3 4 5 6 7 8 9 10

Har just detta besvär uppkommit pga. av en specifik händelse eller olycka? ☐ Nej ☐ Ja

Har du fått behandling för besväret antingen professionellt eller egenvård? ☐ Nej ☐ Ja

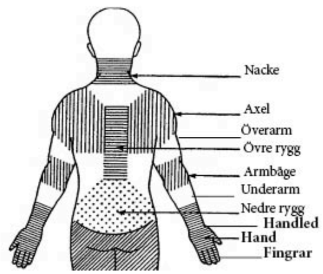
Om ja (markera de svar som stämmer bäst).
☐ Vila ☐ Antiinflammatoriska mediciner
☐ Kyla ☐ Sjukgymnastik
☐ Operation
☐ Annat (beskriv) ____________

Har du varit sjukskriven från jobbet på grund av detta besvär? ☐ Nej ☐ Ja

5

HANDLED, FINGRAR

Har du under det senaste året haft ÅTERKOMMANDE problem i HANDLED och/eller i FINGRARNA mer än 3 gånger eller längre än en vecka?
☐ Nej (gå till sida 8)
☐ Ja



Om Ja beskriv typ av besvär och område genom att göra en markering i de rutor som passar i tabellen nedan. Markera så många som behövs.

	Höger handled	Vänster handled	Fingrar på höger hand	Fingrar på vänster hand
Trötthet	☐	☐	☐	☐
Smärta	☐	☐	☐	☐
Ömhet	☐	☐	☐	☐
Värk	☐	☐	☐	☐
Pirrningar/ stickningar	☐	☐	☐	☐
Stelhet	☐	☐	☐	☐
Kramp	☐	☐	☐	☐
Domningar	☐	☐	☐	☐
Mjölksyra	☐	☐	☐	☐

Under de senaste 7 dagarna har besvären i min handled och/ eller fingrar påverkat produktionshastigheten och/ eller kvalitén av mitt arbete (markera det svar som stämmer bäst).

Instämmer inte alls — Instämmer helt
1 2 3 4 5

6

HANDLED, FINGRAR

Tror du besvären är relaterade till en viss arbetsuppgift eller arbetsställning?
☐ Nej ☐ Ja

Om ja, beskriv problemområde och typ av arbetsuppgift.

Område (handled, fingrar etc)	Arbetsuppgift/ arbetsställning
______________________	______________________
______________________	______________________
______________________	______________________

Om du har besvär i mer än ett område markera vilket område som är det MEST utsatta (markera endast ETT svar).

☐ Höger handled	☐ Fingrar på höger hand
☐ Vänster handled	☐ Fingrar på vänster hand

I följande stycke om handled och fingrar besvara frågorna utifrån ditt tidigare svar om mest utsatt område.

Upplever du besvären:
☐ Endast under aktivt arbete
☐ Efter kort (15-30 min) vila
☐ Efter lång (>30 min) vila
☐ Kontinuerligt

Hur mycket obehag upplever du i detta område just nu? Markera på en skala från 1-10 den nivå av obehag som stämmer bäst in på dig (0 = inget obehag och 10 = värsta tänkbara obehag).

Inget obehag — Värsta tänkbara obehag

0	1	2	3	4	5	6	7	8	9	10

Har just detta besvär uppkommit pga. av en specifik händelse eller olycka? ☐ Nej ☐ Ja

Har du fått behandling för besväret antingen professionellt eller egenvård? ☐ Nej ☐ Ja

Om ja (markera de svar som stämmer bäst).

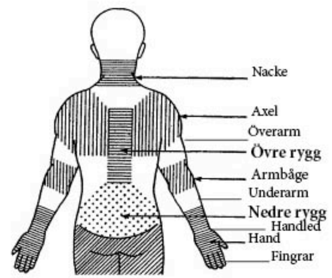
☐ Vila	☐ Antiinflammatoriska mediciner
☐ Kyla	☐ Sjukgymnastik
☐ Operation	
☐ Annat (beskriv) ______________	

Har du varit sjukskriven från jobbet på grund av detta besvär? ☐ Nej ☐ Ja

7

RYGG

Har du under det senaste året haft ÅTERKOMMANDE problem i RYGGEN mer än 3 gånger eller längre än en vecka?
☐ Nej (gå till sida 10)
☐ Ja



Om Ja beskriv typ av besvär och område genom att göra en markering i de rutor som passar i tabellen nedan. Markera så många som behövs.

	Övre delen av ryggen	Nedre delen av ryggen
Trötthet	☐	☐
Smärta	☐	☐
Ömhet	☐	☐
Värk	☐	☐
Pirrningar/ stickningar	☐	☐
Stelhet	☐	☐
Kramp	☐	☐
Domningar	☐	☐
Mjölksyra	☐	☐

Under de senaste 7 dagarna har besvären i min rygg påverkat produktionshastigheten och/ eller kvalitén av mitt arbete (markera det svar som stämmer bäst).

Instämmer inte alls — Instämmer helt

1	2	3	4	5

8

RYGG

Tror du besvären är relaterade till en viss arbetsuppgift eller arbetsställning?
☐ Nej ☐ Ja

Om ja, beskriv problemområde och typ av arbetsuppgift.

Område (övre, nedre del av ryggen etc)	Arbetsuppgift/ arbetsställning

Om du har besvär i mer än ett område markera vilket område som är det MEST utsatta (markera endast ETT svar).
☐ Övre del av ryggen
☐ Nedre delen av ryggen

I följande stycke om rygg besvara frågorna utifrån ditt tidigare svar om mest utsatt område.

Upplever du besvären:
☐ Endast under aktivt arbete
☐ Efter kort (15-30 min) vila
☐ Efter lång (>30 min) vila
☐ Kontinuerligt

Hur mycket obehag upplever du i detta område just nu? Markera på en skala från 1-10 den nivå av obehag som stämmer bäst in på dig (0 = inget obehag och 10 = värsta tänkbara obehag).

Inget obehag — Värsta tänkbara obehag
☐0 ☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7 ☐8 ☐9 ☐10

Har just detta besvär uppkommit pga. av en specifik händelse eller olycka? ☐ Nej ☐ Ja

Har du fått behandling för besväret antingen professionellt eller egenvård? ☐ Nej ☐ Ja

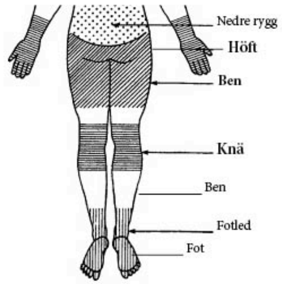
Om ja (markera de svar som stämmer bäst).
☐ Vila ☐ Antiinflammatoriska mediciner
☐ Kyla ☐ Sjukgymnastik
☐ Operation
☐ Annat (beskriv) ____________

Har du varit sjukskriven från jobbet på grund av detta besvär? ☐ Nej ☐ Ja

9

HÖFT, BEN, KNÄN

Har du under det senaste året haft ÅTERKOMMANDE problem i HÖFT, BEN och/eller i KNÄNA mer än 3 gånger eller längre än en vecka?
☐ Nej (gå till sida 12)
☐ Ja



Om Ja beskriv typ av besvär och område genom att göra en markering i de rutor som passar i tabellen nedan. Markera så många som behövs.

	Höft	Höger ben	Vänster ben	Höger knä	Vänster knä
Trötthet	☐	☐	☐	☐	☐
Smärta	☐	☐	☐	☐	☐
Ömhet	☐	☐	☐	☐	☐
Värk	☐	☐	☐	☐	☐
Pirrningar/ stickningar	☐	☐	☐	☐	☐
Stelhet	☐	☐	☐	☐	☐
Kramp	☐	☐	☐	☐	☐
Domningar	☐	☐	☐	☐	☐
Mjölksyra	☐	☐	☐	☐	☐

Under de senaste 7 dagarna har besvären i höft, ben och/ eller knä påverkat produktionshastigheten och/ eller kvalitén av mitt arbete (markera det svar som stämmer bäst).

Instämmer inte alls — Instämmer helt
☐1 ☐2 ☐3 ☐4 ☐5

10

HÖFT, BEN, KNÄN

Tror du besvären är relaterade till en viss arbetsuppgift eller arbetsställning?
☐ Nej ☐ Ja

Om ja, beskriv problemområde och typ av arbetsuppgift.

Område (höft, ben, knä etc) — Arbetsuppgift/ arbetsställning

__________ __________

__________ __________

__________ __________

Om du har besvär i mer än ett område markera vilket område som är det MEST utsatta (markera endast ETT svar).
- ☐ Höft
- ☐ Höger ben
- ☐ Vänster ben
- ☐ Höger knä
- ☐ Vänster knä

I följande stycke om höft,ben och knän besvara frågorna utifrån ditt tidigare svar om mest utsatt område.

Upplever du besvären:
- ☐ Endast under aktivt arbete
- ☐ Efter kort (15-30 min) vila
- ☐ Efter lång (>30 min) vila
- ☐ Kontinuerligt

Hur mycket obehag upplever du i detta område just nu? Markera på en skala från 1-10 den nivå av obehag som stämmer bäst in på dig (0 = inget obehag och 10 = värsta tänkbara obehag).

Inget obehag										Värsta tänkbara obehag
0	1	2	3	4	5	6	7	8	9	10

Har just detta besvär uppkommit pga. av en specifik händelse eller olycka? ☐ Nej ☐ Ja

Har du fått behandling för besväret antingen professionellt eller egenvård? ☐ Nej ☐ Ja

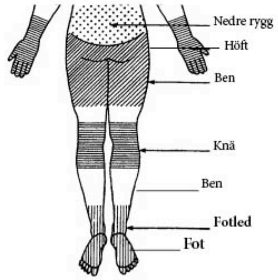
Om ja (markera de svar som stämmer bäst).
- ☐ Vila
- ☐ Kyla
- ☐ Operation
- ☐ Annat (beskriv) __________
- ☐ Antiinflammatoriska mediciner
- ☐ Sjukgymnastik

Har du varit sjukskriven från jobbet på grund av detta besvär? ☐ Nej ☐ Ja

11

FOTLED, FOT

Har du under det senaste året haft ÅTERKOMMANDE problem i FOTLED och/eller i FOT mer än 3 gånger eller längre än en vecka?
- ☐ Nej (gå till sida 14)
- ☐ Ja



Om Ja beskriv typ av besvär och område genom att göra en markering i de rutor som passar i tabellen nedan. Markera så många som behövs.

	Höger fotled	Vänster fotled	Höger fot	Vänster fot
Trötthet	☐	☐	☐	☐
Smärta	☐	☐	☐	☐
Ömhet	☐	☐	☐	☐
Värk	☐	☐	☐	☐
Pirrningar/ stickningar	☐	☐	☐	☐
Stelhet	☐	☐	☐	☐
Kramp	☐	☐	☐	☐
Domningar	☐	☐	☐	☐
Mjölksyra	☐	☐	☐	☐

Under de senaste 7 dagarna har besvären i min fotled och/ eller fot påverkat produktionshastigheten och/ eller kvalitén av mitt arbete (markera det svar som stämmer bäst).

Instämmer inte alls				Instämmer helt
1	2	3	4	5

12

Appendix G: List of materials, Posture and Time study

Tool	Weight (kg)	Triaxial vibration value	Time to EAV	Time to ELV	Work material	Feed force
SID/SIW 14-A Impact drivers/wrenches 	1.3	$7.5 m/s^2$	53min	212 min	Concrete, M12 metal screw	Feed force high enough to ensure a safe and stable operation
WSR 22-A Saws 	3.8	$16 m/s^2$ $18 m/s^2$	12min 9min	48 min 36 min	Cutting off 38 mm chipboard Cutting off (100 x 100) mm wooden beam	Horizontal feed force 50N - 100N
TE 6-A36 Cordless rotary hammers **TE DSR-6-A Vaccum cleaner** 	4	$9 m/s^2$	37min	148 min	Concrete $40 N/mm^2$	About 60N Vaccum cleaner: Additional required contact force: 55N

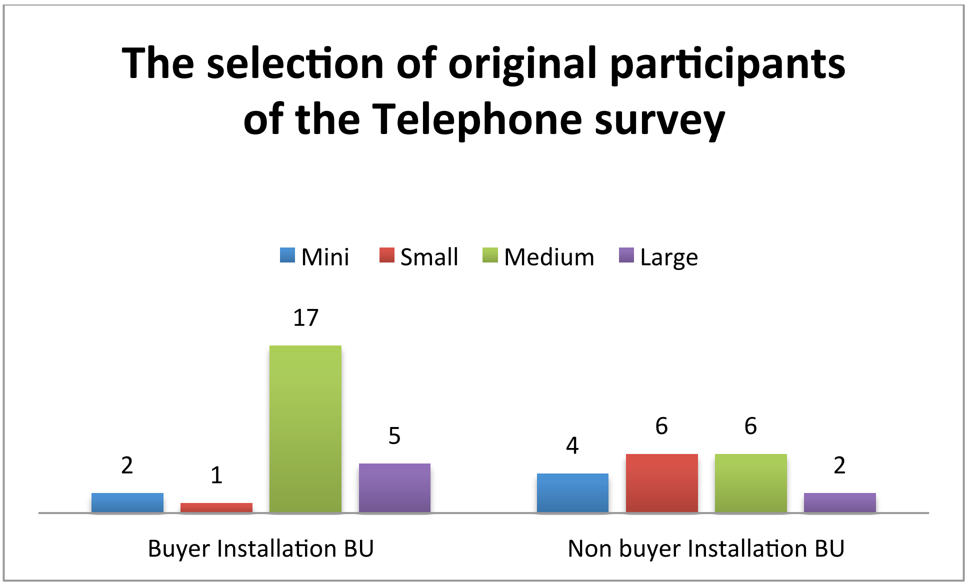
Pipes	Article number	Amount	Length (meter)
Steel pipe Ø 100	1341312	2	6
Steel pipe Ø 50	1341239	2	6
Steel pipe Ø 25	1341163	2	6

System 1	Article number	Amount
Install. channel MF-U2 2M, Sormat M8x52, 72 and 92	426183	20
Connector M8 x 80	3818838	100
Hex nut with flange M8	271508	250
Pipe ring Ø 100	3804747	10
Pipe ring Ø 50	3804139	15
Pipe ring Ø 25	3804133	20
Pipe ring Ø 100 (insulated pipes)	43710162	12
Pipe ring Ø 50 (insulated pipes)	3808620	12
Pipe ring Ø 25 (insulated pipes)	3808616	12
Bolt M6x20		
Screw M6x16	216443	100
Screw M6x25	216444	100
Bolt M8x25	216448	100
Bolt M6	216464	100
Bolt M8	216465	100

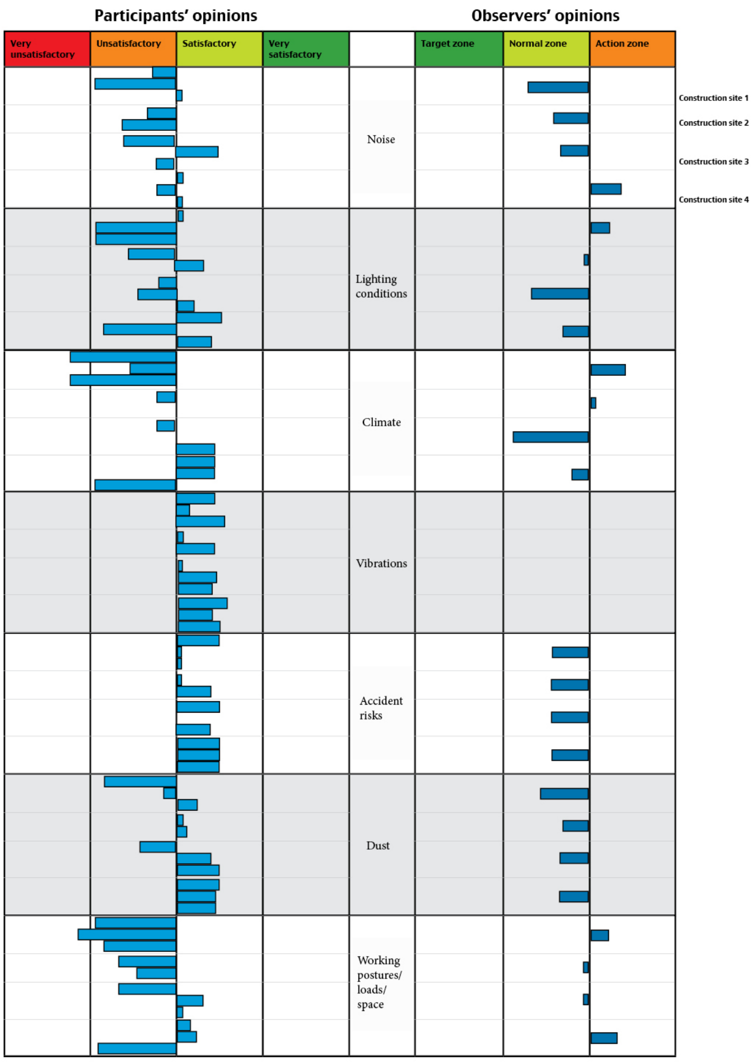
System 2	Article number	Amount
Install. channel MF-U2 2M Sormat M8	426183	
Threaded stud AM8x80 4.6 zinced	216384	100
Hex nut with flange M8	*271508*	
Pipe ring with insulation Ø 100	3808023	10
Pipe ring with insulation Ø 50	3808020	20
Pipe ring with insulation Ø 25	3808016	20
Pipe ring with insulation Ø 100 (insulated pipes)	43724140	10
Pipe ring with insulation Ø 50 (insulated pipes)	43724076	10
Pipe ring with insulation Ø 25 (insulated pipes)	43724048	10

	Article number	Amount
Install. channel MM-C-30 2m	418749	12
Screw anchor HUS-P 6x40/5	416745	100
Screw anchor HUS-H 6x40/5	416735	100
Pipe ring saddle MM-S M8	418760	75
Hex nut with flange M8	*271508*	
Threaded stud AM8x80 4.6 zinced	*216384*	
Comfort pipe ring MPN-RC 4" B	335698	20
Comfort pipe ring MPN-RC 2" A	335683	20
Comfort pipe ring MPN-RC 1" A	335678	25
Comfort pipe ring MPN-QRC 2" M8	340124	50
Comfort pipe ring MPN-QRC 1" M8	340119	50
Refrig. pipe ring MIP-M/114	314157	6
Refrig. pipe ring MIP-M/60-64	314152	12
Refrig. pipe ring MIP-M/34-38	314148	12

Appendix H: Telephone survey, original participants



Appendix I: Individual scores, Work Environment study



Appendix J: Individual HARM scores

System 1	HARM Score	Estimated time of workday (h)	Total task time (min)
Cutting takjärn	14.50	0.38	4.58
Cutting takjärn	13.50	0.32	3.82
Preassembly	9.50	2.48	30.03
Preassembly	8.00	1.75	21.17
Drilling holes	12.00	0.54	6.49
Drilling holes	13.00	0.75	9.03
Mounting takjärn	9.00	1.10	13.36
Mounting takjärn	14.00[2]	0.82	9.95
Installing pipes	11.00	2.36	28.59
Installing pipes	10.70[3]	2.94	35.77
Adjusting pipes	13.00	1.06	12.88
Adjusting pipes	11.00	1.42	17.23

System 2	HARM Score	Estimated time of workday (h)	Total task time (min)
Cutting takjärn	14.50	0.39	3.31
Cutting takjärn	14.00	0.35	2.97
Preassembly	8.00	2.17	18.3
Preassembly	10.95[4]	2.97	25.03

[2] High score due to hammer frequency

[3] Time score 1.07

[4] Time score 1.46

Drilling holes	12.50	0.69	5.83
Drilling holes	12.00	1.23	10.43
Mounting takjärn	9.50	1.27	10.67
Mounting takjärn	14.00[5]	0.97	8.12
Installing pipes	11.00	2.06	17.38
Installing pipes	10.50	1.48	12.49
Adjusting pipes	11.50	1.42	11.97
Adjusting pipes	11.50	1.00	8.38

System 3	**HARM Score**	**Estimated time of workday (h)**	**Total task time (min)**
Cutting channels	14.00	0.47	4.12
Cutting channels	14.00	0.34	2.80
Preassembly	8.50	1.99	16.88
Preassembly	7.49[6]	2.57	21.12
Drilling holes	11.50	0.70	5.92
Drilling holes	12.00	1.23	10.17
Mounting channels	9.50	1.03	8.70
Mounting channels	11.50	0.60	4.97
Installing pipes	10.50	1.52	12.80
Installing pipes	10.50	1.42	11.62
Adjusting pipes	11.50	2.27	19.22
Adjusting pipes	11.50	1.84	15.05

[5] High score due to hammer frequency
[6] Time score 1.07

Appendix K: Goal achievement

This master thesis project have provided valuable insights into a possible work description of an engineer. Knowledge has been gained on how to plan and execute a project of this size. It has been educational to define important questions at issue and strive to find suitable methods to answer them.

This thesis project has concerned issues such as working environment and ergonomic aspects within the construction and P&H industry. While prior knowledge in the ergonomic field has been provided in the course *Cognitive and Physical Ergonomics* many of the other areas were new to the authors. However other courses of the program *Master of science in Mechanical Engineering and Industrial Design* has provided a solid foundation of technical knowledge that has simplified the work of understanding these new areas.

During the project several methods for collecting data such as interviews, observations and questionnaires have been investigated providing a practical experience from different ways to gather information. It has been interesting to explore all these methods and much knowledge on the importance of being particulate and foreseeing when performing scientific investigations have been gained. Valuable skills on how to document completed work and present it in a scientific and correct way have also been accomplished.

In retrospect, better results would perhaps have been reached if the efforts were concentrated to fewer methods with larger groups of participants. The use of different methods for the ergonomic evaluation of the Posture and Time study would perhaps also provide more concise results, but for reasons described in the report no better choices of methods were found.

All in all, this thesis project has been very educational, both in terms of academic merits as well as practical abilities such as project planning and interpersonal skills.

Appendix L: Division of work

This thesis projects was done in collaboration between two persons. The project has been performed in a joint manner with both parties taking equally responsibility when carrying out task and moving the project forward. At several points the work has been divided although both authors have been involved in all parts. For example one author performed the HARM analysis for participant A while the other was responsible for the analysis of participant B. Whenever work was divided the authors made sure to discuss critical points and aid one another in order for the project to be coherent. The workload of the project has been divided equally between both thesis workers.

Aid with finding suitable construction sites to visit and participants for the numerous studies has been provided from sales-staff at Hilti. Furthermore valuable help was provided from employees at Hilti during the planning and performance of the Posture and Time study.

Appendix M: Time frame

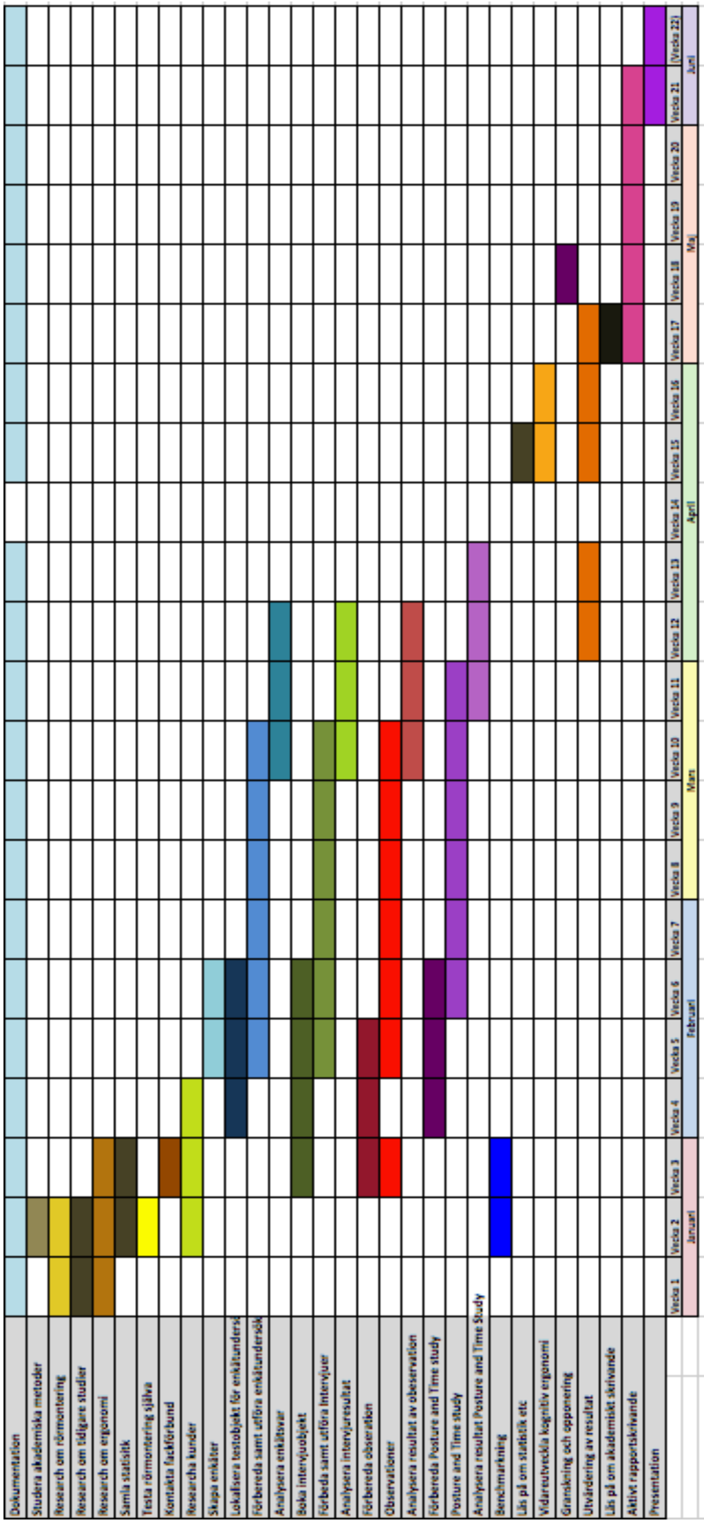
Some differences between the planned time schedule and the actual time schedule occurred during the project. The research on ergonomics was conducted in two segments since additional information was needed. After completing the questionnaire study there was not much time, to analyse the answers since the Posture and Time study needed to be planned. The analysis was therefore performed after the analysis of the results from the Posture and Time study.

The execution of the Posture and Time study was delayed compared to the planned time schedule due to difficulties of finding dates that would suit everyone involved. In order not to loose too much time the phase of active writing of the report was started earlier while waiting for the chosen test days to arrive. Furthermore the analysis with HARM and REBA took one week longer than anticipated.

In order to be finished in time, the segment of further developing cognitive ergonomics was disregarded. Even so an extra week was added to the time frame of the project in order to have enough time to present a satisfactory result.

The planned time schedule and the actual time schedule are presented below.

Planned time schedule



Actual time schedule