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VALIDATION OF A NEWLY DEVELOPED TOOL FOR ERGONOMIC EXPOSURE ASSESSMENT IN AN UNSTRUCTURED AND UNREGULATED WORK ENVIRONMENT.

BY

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DECLARATION

I, Nana Abena Nyamedo Yeboah, hereby declare that apart from references to other people's works which have been duly acknowledged, this dissertation is as a result of my own independent work and has not been submitted for the award of any degree in any institution

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DEDICATION

I dedicate this piece of work to my parents, Mr. Franklyn Yeboah and Mrs. Mary Yeboah and to my sister, Nana Ama Yeboah.

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The input, contribution and participation of several individuals made this work a success.

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ABSTRACT

Background: Most existing ergonomic assessment tools have been designed for routine and structured work making their use in informal work setting challenging due to the high variability in work structure that exists in unstructured/informal work. A novel observation based ergonomic assessment tool which is simple to use and accounts for the high variability in tasks performed by workers was developed by Acquah and colleagues in 2020 to address the challenge of ergonomic assessment in informal work setting. The tool, however, needs detailed validation to determine its applicability and appropriateness in comparison with existing tools for the evaluation of ergonomic exposures in informal work setting.

Aim: To determine the validity and reliability of a newly developed observation-based tool for quantifying ergonomic exposures in unregulated work setting such as informal e-waste recycling.

Method: The face validity, construct validity, criterion validity, as well as the intra and inter observer reliability of the new tool were assessed. Face validity was evaluated by administering a face validity questionnaire to three experts and the results analysed using Cohen kappa statistics. Construct validity was determined by reviewing literature and documenting references of studies that influenced the theoretical concepts and inclusion of the various assessment domains presented in the newly developed ergonomic assessment tool. The new tool was then compared with existing ergonomic assessment tools such as Rapid Entire Body Assessment tool, Rapid Upper Limb Assessment tool, Ovako Working Posture Analysis System, and Quick Exposure Checklist to determine the criterion validity of the new tool. Inter and Intra observer reliability were determined using archived video data of e-waste recycling

activities. Research assistants were trained on the use of the newly developed ergonomic assessment tool after which they used the new tool to assess ergonomic exposures of e-waste workers for an entire day's shift. Inter observer agreement was determined by comparing observations of three observers who assessed ergonomic exposures of the same e-waste worker at the same time. Intra observer agreement was determined by comparing the observations of an e-waste worker conducted by the same assessor 5 days apart. Cohen Kappa's statistics was used to determine inter and intra observer agreement.

Results: The results showed that the newly developed ergonomic assessment tool had a good face validity (0.718, $p<0.035$). The development of the tool was also based on a thorough review of the existing literature and was influenced by sound theoretical concepts in literature. Inter observer agreement among users of the tool was high except assessment of upper limb posture for burners ($k=0.427$). Intra observer agreement was high for assessment of all variables. Comparison of the tool with other ergonomic assessment tools showed varied overall results mainly due to the fact that existing ergonomic assessment tools provided an assessment of a snapshot of the workers task compared to the new tool which assessed an entire day's shift. Thus, the new tool provides a more detailed and less biased estimate of the overall exposure of the worker.

Conclusion: The newly developed ergonomic assessment tool is valid and reliable for assessing ergonomic exposures in unregulated work setting and tends to provide a more detailed assessment of ergonomic exposures while accounting for the variability that exists in tasks assessed.

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LIST OF ABBREVIATIONS

E-waste-	Electronic waste
ILO-	International Labour Organisation
PATH-	Posture Activity Tools Handling
QEC-	Quick Exposure Checklist
REBA-	Rapid Entire Body Assessment
RULA-	Rapid Upper Limb Assessment
OCRA-	Occupational Repetitive Action
OWAS -	Ovako Working Posture Analysis System
WHO-	World Health Organisation
WRMSD –	Work-Related Musculoskeletal Disorders

DEFINITION OF TERMS

Item **Operational Definitions**

E-waste: End of life electrical and electronic equipment.

Burners: E-waste workers who manually open burn electrical and electronic waste.

Collectors: E-waste workers who collect waste electrical and electronic equipment from homes and offices.

Dismantlers: E-waste workers who manually disassemble the electrical and electronic waste.

Ergonomics: The science of creating working environments, tasks, and tools that promote worker health, safety, and productivity.

Ergonomic Risk factors: Workplace circumstances that cause body wear and strain and can result in injury.

Work- related Musculoskeletal injury: Injuries of the muscles, tendons, ligaments, joints, nerves and disc both cumulative and chronic that are caused or worsened by our behaviours in the workplace or work environment.

CHAPTER ONE

INTRODUCTION

1.1 Background

Globally, e-waste has become an emerging challenge. That notwithstanding, it has provided job opportunities for many in China, Serbia, Argentina, Bangladesh, Dhaka, India (Sergeant, 2019; Perkins et al., 2014), Ghana (Acquah, et al., 2019; Amankwaa, 2013) and Nigeria (Goel, 2019; Ohajinwa et al., 2018). About 75% of global e-waste are recycled by the informal sector (Perkins et al., 2014) and this is carried out by low-wage, low skill workers who pay little or no attention to proper health and safety procedures. (Leung et al., 2006, Acquah et al., 2019).

Agbogbloshie in Ghana is one of the biggest e-waste sites in sub-Sahara Africa (Mathias et al., 2012; Blacksmith Institute, 2013) where e-waste is recycled through informal methods such as manual collecting and dismantling of end-of-life electronics as well as burning of insulated wires and other e-waste components that cannot be disassembled in the open air (Acquah et al., 2019). It is estimated that over 14,000 to 24,000 people work directly as e-waste workers or trade in second hand goods recovered from e-waste recycling at Agbogbloshie and other smaller recycling sites in Ghana (Prakash et al., 2010). These large numbers represent a good percentage of the Ghanaian population who may be exposed directly or indirectly to the adverse health and environmental hazards associated with informal e-waste recycling (Perkins et al., 2014).

Several studies in Ghana have reported adverse health and environmental effects of e-waste recycling in Agbogbloshie due to the crude methods used to recover useful metals from the hazardous electronic waste (Acquah, et al., 2019; Akormedi et al., 2013; Adusei et al., 2020; Nti et al., 2020; Acquah et al., 2021). Of particular interest among these is the high prevalence of work-related musculoskeletal disorders (WRMSDs) reported among this population of workers (Acquah et al., 2019; Acquah et al., 2021a Acquah et al., 2021b). It is estimated that 90% of e-waste workers suffered from WRMSDs (Acquah, et al., 2019). The high prevalence of WRMSDs can be explained by the rudimentary methods used in e-waste recycling (Acquah et al., 2019; Acquah et al., 2021b) which subjects workers to high force exertion, repetitive movements, awkward postures, vibration, contact stress and various intensities of manual material handling (Acquah et al., 2020, 2021). The high prevalence of WRMSDs among e-waste workers has resulted in the need to investigate the associated risk factors for WRMSDs. However, researchers investigating ergonomic hazards in unstructured and unregulated work environment such as e-waste recycling face a great challenge using existing ergonomic assessment tools. Existing tools are developed with formal type of work in mind and does not adequately capture exposures in unstructured work environment. The challenge in assessing ergonomic exposures among e-waste workers is further compounded by the high variability that exists in tasks performed by these workers, within days and between days (Acquah et al., 2020;2021). To address this challenge, Acquah and colleagues developed an observation-based tool to investigate ergonomic exposures among e-waste workers (Acquah et al., 2020). This newly developed tool is pen and paper based, easy to use, requires less training than other existing tools and accounts for the high variability that exists in informal e-waste recycling. The tool is still in its early stage of development and its psychometric properties have not been fully explored. Investigating the psychometric properties of a tool is essential for improving any tool to ensure that it measures what it intends to measure.

1.2 Problem Statement

There is a high prevalence of WRMSDs among informal e-waste workers (Acquah, et al., 2019 ;Acquah, et al., 2021) which can be attributed to poor work practices (Acquah, et al., 2019) as well as prolonged exposure to physical occupational risk factors (Acquah, et al., 2021a) . The need for detailed investigations into the risk factors predisposing informal e-waste workers to WRMSDs has been of importance to researchers. A major setback in evaluating ergonomic exposures among informal e-waste workers is the lack of assessment tools that account for the unregulated nature of their job as well as the high variability that exists in tasks performed by these workers (Acquah, et al., 2021a) . Acquah et al (2020). As a first approach at addressing this challenge, Acquah and colleagues developed a novel ergonomic assessment tool for unstructured type of work such as exists among e-waste workers in Agbogbloshie. This tool assesses the relative duration and the intensity of important ergonomic risk factors that could predispose workers to WRMSDs. In comparison with other observation- based tools, the newly developed tool is pen and paper based, cost effective and easy to use. It also accounts for the high variability in work tasks performed by informal e-waste workers making it practical to use in unstructured working environments (Acquah et al., 2020). The tool is in the early phase of development and requires validation of its psychometric properties, that is, evaluation of the reliability and validity of the tool.

1.3 Justification

The most common work-related health issue among working populations around the world are WRMSDs (Public Health Agency of Ghana, 2014; Podniece & Taylor, 2008) and this needs keen attention by researchers to develop solutions to address WRMSDs among working populations. An important step in addressing WRMSDs is a thorough investigation of the risk factors that predisposes workers to WRMSDs. This can only be achieved by using well developed ergonomic assessment methods tailored to the local job context. Ergonomic assessment among e-waste workers faces a major challenge as existing ergonomic assessment tools are not able to adequately capture ergonomic exposures in this working population due to the high variability in tasks performed by these workers. Acquah and colleagues (2020) have developed a novel ergonomic assessment tool which seeks to address this major challenge. Validation of such a tool is essential for its acceptability and use among ergonomics researchers.

A major challenge in developing an observation tool is the validation of the assessment techniques used (Takala et al., 2010). The lack of reliability and validation of newly developed tools may result in poor performance of the tool and contribute to the skepticism regarding the work-relatedness of musculoskeletal disorders (David, 2005; Takala et al., 2010). The reliability of a tool plays an important role in ensuring consistency of the results obtained from the use of the tool and minimizes the chance that results obtained are due to randomly occurring factors and or measurement errors (Marczyk et al., 2005). Validity explains how well the obtained data covers the actual topic of inquiry (Ghauri & Gronhaug, 2005) and determines whether the tool measures what it is supposed to measure (Field, 2005; Brink, 2006).

Validation of a tool will help in further improvement of the tool such as simplification of its content as well as improving scoring components. Both validity and reliability are essential for improving the credibility of a newly developed tool. Determining the validity and reliability of this newly developed ergonomic assessment tool will ensure that the content of the tool is fully understood, produces consistent results and can be used easily by researchers. Results from this study will help in further improvement of this very important ergonomic assessment tool.

1.4 Objectives

1.4.1 General Objective

The study aims to determine the validity and reliability of a newly developed observation-based tool for quantifying ergonomic exposures in unregulated work setting such as informal e-waste recycling

1.4.2 Specific Objective

- To determine the face validity of a newly developed ergonomic assessment tool.
- To determine the construct validity of a newly developed ergonomic assessment tool
- To determine the criterion validity of a newly developed ergonomic assessment tool
- To determine inter and intra-observer reliability of a newly developed ergonomic tool.

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1.5 Research Question

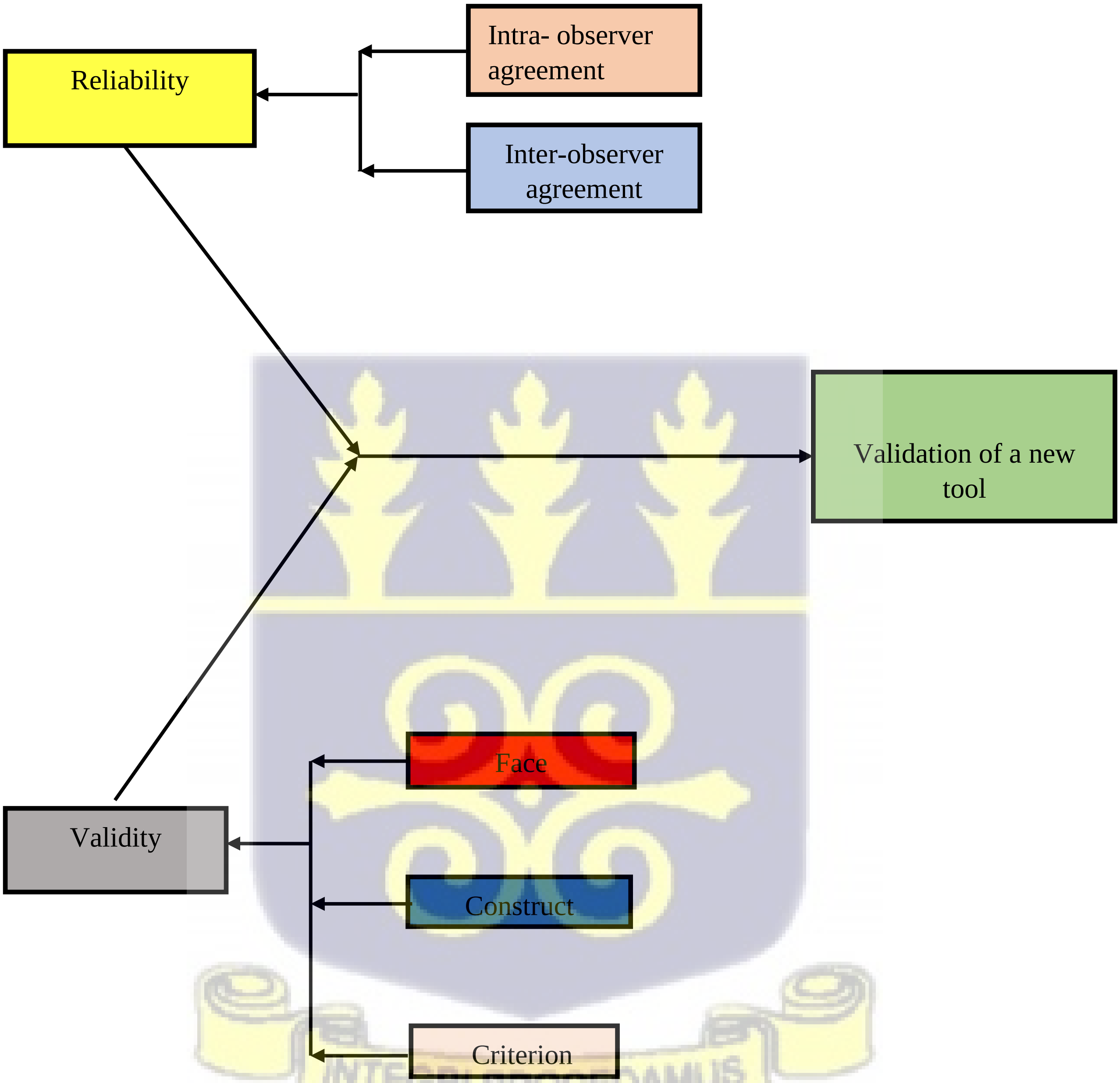
Is the content of the new ergonomic assessment tool consistent with theoretically established expectations?

Can ergonomic hazards assessed by the new tool be validated by comparison with other existing ergonomic assessment tools?

Are there between and within observer disagreements among expert observers using a newly developed tool in assessing ergonomic exposures among e-waste workers?

1.6 Conceptual Framework

Figure 1.1: Conceptual framework of the validation of an ergonomic assessment tool.



To ensure ongoing development and enhancement of a tool, its psychometric features must be investigated during its development (Burdorf, 2010; David, 2005; Takala et al., 2010). This can be accomplished by validating the tool, or confirming its validity and dependability. Only after these tests have been completed can an ergonomic tool be deemed valid and dependable (Buchholz et al., 1996; David et al., 2008; Hignett & McAtamney, 2000; Kemmlert, 1995). This section presents a conceptual framework that shows the processes that lead to validation of a newly developed tool.

Validation of a tool aids in determining how well the tool measures what it claims to measure (Field, 2005; Brink, 2006), which is critical for studies looking to link ergonomic risk factors to musculoskeletal health outcomes (Takala et al., 2010; David, 2005; Burdorf, 2014). Validity comprises of four different components: face validity, construct validity, and criterion validity. Face validity assesses the importance and presentation of measuring instruments by determining whether the items are practical, clear, readable, have a consistent style and format, and are acceptable (Oluwatayo, 2012). Construct validity assesses whether the tool measures what it claims to measure. It can be done in two ways: convergent construct validity and divergent construct validity (Portney & Watkins, 2009). Criterion validity involves comparing the newly developed tool to a gold standard (Taherdoost, 2018). When the new tool is compared at the same time with existing tools, it is termed concurrent validity. If the new tool produces similar results as the gold standard it is considered to be concurrently valid.

The purpose of a tool's reliability assessment is to determine the consistency and stability of the tool's output (Bellamy, 2015; Taherdoost, 2018; Streiner et al., 2015). There are two ways to do this: intra-observer and inter-observer reliability. Results between two or more observers should be consistent when carried out simultaneously and under the same conditions for a tool to have strong inter-observer agreement, whereas results taken on two or more times under comparable settings are said to have good intra-observer agreement (Bellamy, 2015; Hani et al., 2015; Streiner et al., 2015; Taherdoost, 2018; Streiner et al., 2015). A tool's inter-observer agreement may be good but its intra-observer agreement will be poor, and vice versa. As a result, a tool can be reliable but not valid, and vice versa (Bellamy et al., 2015). Both features, however, are required for further tool enhancement, such as content simplification and improved scoring components.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews literature on various assessment methods, ergonomic tools and the process of development. In addition, literature on psychometric properties and the psychometric properties of ergonomic tools were reviewed.

2.2 Ergonomic Assessment Methods

Work-related musculoskeletal diseases has been reported to be one of the top causes of worker complaints globally (Lima & Coelho, 2011; Bevan, 2015), with an estimated 2 million people succumbing to these diseases each year and over 5,840 deaths every day (Lima & Coelho, 2011; Bevan, 2015). Furthermore, since the late 1980s, it has been one of the leading causes of workplace injuries and workers' compensation claims in Western industrialized countries, as well as the second leading cause of years lost due to disability (Barbe & Barr, 2006). Tens of billions of dollars are spent on WRMSD treatment (Praemer et al., 1999). Recognizing risk variables and measuring worker exposure to these risk factors, on the other hand, can help to decrease or avoid WRMSDs (Jaffar et al., 2011), lowering worker complaints, impairments, and costs. This can be accomplished by using a variety of assessment methods, such as pen and paper observation, direct or instrumental procedures, videotaping and computer-aided observation methods, and other self-report evaluation approaches (Li & Buckle, 1999)

2.2.1 Observation based methods

2.2.1.1 Pen and Paper- based

According to a study published in 2001 by Juul- Kristensen et al., using observation methods in large field studies is more practicable than using other methods, particularly direct approaches, which have more technical requirements. Although observation approaches have been claimed to be inexpensive (Van der Beek et al., 1994; Burdorf, 1992), they are time demanding (Van der Beek et al., 1994). Furthermore, this type of assessment, which is based on pen and paper, is commonly used for posture evaluations and assessments and can be completed without disrupting work. Despite the fact that observation methods can be used in a variety of situations (Rahman et al., 2014), research reveals that they lack precision and accuracy (Burdorf, 1992; Takala et al., 2010) There is no standard criteria for low and high repetitive activities utilizing the number of observations (Genaidy et al., 1994). Furthermore, because of its subjective nature, this method is ineffective in estimating the operator's physical burden in dynamic work settings (Burdorf, 1992; Chen et al., 1989). It could reveal differences in intra- and inter-observer agreement (Burdorf, 1992). As a result, pen and paper observation has been confined to evaluating relatively static jobs, assessing protracted body postures, and observing body motions that follow a simple pattern and are repeated throughout the workday (Li & Buckle, 1999).

2.2.1.2 Video Tape and Computer Assisted

ARBAN (Holzmann, 1982), ROTA (Ridd et al., 1989), TRAC (Van Der Beek et al., 1992; De Bruijn et al., 1998), HARBO (Wiktorin et al., 1995), and PEO (Wiktorin et al., 1995) are other observation approaches (Fransson-Hall et al., 1995). These systems use a videotape to capture work actions and postures on the job, which is then analyzed directly by a computer.

Due to the lack of an observer, this method avoids observer bias; however, evaluating the recordings is tedious and time-consuming, and would necessitate the involvement of a well-trained analyst. Furthermore, in instances requiring continual movement of the operator, the camera's position will influence the operator's posture angles, resulting in disparities between the video recording and real-world posture angles (Li & Buckle, 1999). According to studies, using monitor screens to analyze upper extremity postures, particularly wrist posture is difficult (Keyserling, 1986; Baluyut et al., 1995). However, there are systems that record body movement and posture through a video-recording system, such as the observer system, in a two or three-dimensional plane (Noldus, 1991; Rolfe, 1992). With the use of advanced software, this strategy simplifies data analysis and makes it simpler to link recorded data to specific activities. It is, however, expensive (Li & Buckle, 1999).

2.2.2 Self -Report Assessment Methods

Self-report methods include the 'body map' (Corlett & Bishop, 1976), rating scales (Shackel et al., 1969; Borg, 1985), questionnaires, interviews (Kuorinka et al., 1987; Bigos et al., 1991; Dickinson et al., 1992; Wiktorin et al., 1993), and checklists (Shackel et al., 1969; Drury & (Li & Buckle, 1999). It is the most extensively utilized method of evaluation of bodily discomfort and tension due to its cost effectiveness, feasibility, and ease of implementation in applied settings (Burdorf, 1992; Takala et al., 2010). According to a 1992 paper by Burdorf, the questionnaire approach is the most prevalent method for assessing back postural load (Burdorf, 1992). Because of its subjective nature, data obtained using this method is more likely to be impacted by factors or tasks other than the one under investigation (Rantanen, 1981), as well as, have a low accuracy and precision score (Takala et al., 2010). This technique has also been found to have low validity (Burdorf & Laan, 1991) and reliability (Burdorf & Laan, 1991; Wiktorin et al., 1993). Furthermore, the self-reported approach does not account for the length of time that a worker is in a poor working position (Van der Beek & Frings-Dresen, 1998). When compared to the observation approach, the self-reported approach is prone to overestimation of risk prevalence due to individuals having a longer exposure integration period (Neitzel et al., 2013).

2.2.3 Direct Measurement

Direct measurements are a group of procedures that have been developed to measure variables of interest directly on the subjects at work (David, 2005). They can be done manually or with electric equipment using devices such as an inclinometer and goniometer (Loebl, 1967; Li & Buckle, 1999). This method produces more detailed and precise findings, making it better suited to work involving a variety of activities (Juul-Kristensena et al., 2001), but not to circumstances requiring continuous motion tracking. Direct measurements, while providing more accurate data, have the potential to disrupt work flow (Neitzel et al., 2013). Furthermore, the cost of purchasing, maintaining, and employing or training people to use these machines can be high. It may take some time to interpret and analyse data (Li & Buckle, 1999).

On the other hand, a combination of observations, direct measurements, and worker self-report methods can provide a more comprehensive picture of occupational exposures (Neitzel et al., 2013).

2. 3 Advantages and disadvantages of selected ergonomic assessment tools for formal and informal work environment.

Observational approaches are still utilized in contemporary procedures to evaluate exposure to risk factors related with WRMSDs, primarily because they are cheap and easy to implement in a variety of workplaces, whereas other methods would be difficult to implement due to the potential for disruption (Beek & Dressen, 1998; Li & Buckle, 1999a; David, 2005; Brodie, 2008; Takala et al., 2010). Because of their cost effectiveness, feasibility, and ease of implementation, self-reported techniques of assessment such as questionnaires are also used. (Takala et al., 2010; Burdorf, 1992).

Researchers or users should however thoroughly characterize their needs (Takala et al., 2010) and consider the structure and regularity of the task when choosing the most appropriate way of assessing physical exposure in a specific situation. Due to limited exposure data, structured work settings are easier to classify than unstructured and irregular contexts, where job intensity, repetitions, and duration fluctuate over time and among workers. It can be difficult to acquire a meaningful representation of the exposure profile because it necessitates extensive periods of assessment and should be done across numerous workers to capture variability.

There is currently few research on ergonomic exposure evaluation in non-structured and sporadic informal jobs (Emmatty & Panicker, 2019; Todd, 2009). The majority of research focuses on formal work environments, such as manufacturing (Lavender et al., 1999; Mossa et al., 2016), construction (Parida & Ray, 2012), agriculture (Kong et al., 2018), and healthcare (Kong et al., 2018; Czuba et al., 2012; Janowitz et al., 2006; Stucke & Menzel, 2007). The assessment's purpose is to determine the quantity of exposure (such as difficult postures and force exertion), movement repetitions, and exposure time (Andreas & Grooten, 2018; Chiasson et al., 2012; Li & Buckle, 1999; Takala et al., 2010).

To minimize inaccuracies in the assessment of physical exposure in occupations such as e-waste recycling and other scrap metal recovery jobs, the frequent quick shift in occupational tasks must be considered when selecting an ergonomic tool for assessing exposure (Neitzel et al., 2013). Existing techniques designed for structured work may be inadequate and difficult to use for assessing physical exposure in unregulated and unstructured activity such as e- waste recycling.

2.3.1 Ovako Working Posture Analysis System (OWAS)

Some approaches, such as the Ovako Working Posture Analysis System created by the Ovako Oy Steel Co. in Finland, were primarily designed for identifying and assessing working postures of body segments (low back, shoulder, and lower limbs) (Karhu et al., 1977; Li & Buckle, 1999), see Table 2.1. The tool was created in two stages. The available literature on the topic of interest was first reviewed. Photographs of workers in various positions were taken in various areas of the steel mill. Postures were sorted and categorised based on a subjective assessment of discomfort, the negative impacts of each pose, and the feasibility of the observational analysis. A pilot study was carried out to determine the feasibility of the procedure. Classification was retained based on the results and the tool's reliability was examined (Karhu et al., 1977).

However, the amount of body segments it examines is limited, with neck, elbow, and wrist postures being excluded. It also disregards the frequency and duration of body posture assumption (Takala et al., 2010)

2.3.2 Rapid Upper Limb Assessment (RULA) & Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment, developed by Highett and Mcmurray in 2000, is an observational-based sensitivity tool for assessing working postures among health care professionals and other service industry employees (Hignett & McAtamney, 2000). The first body segments were selected by analyzing movement, load, distance, and height fluctuations in simple tasks done. The body part ranges were determined using data from NIOSH (Waters et al., 1993), RPE (Borg, 1985), OWAS (Karhu et al., 1977), Body Part Discomfort Survey

(Corlett & Bishop, 1976), and Rapid Upper Limb Assessment (Corlett & Bishop, 1976). Three experts in the field (physiotherapists/ergonomists) categorized 144 posture combinations and proposed that load, coupling, and activity scores, as well as danger and action levels, be included. Finally, over 600 postures from the manufacturing, health, and electrical industries were assessed by 14 experts. The findings were used to create final tool changes, and the tool's inter-observer reliability was assessed (Hignett & McAtamney, 2000)

A tool that is similar, Rapid Upper Limb Assessment (RULA) (McAtamney & Nigel Corlett, 1993) assesses upper extremity and trunk postures during work. It varies from Rapid Entire Body Assessment (REBA) solely in that it does not include lower limb postures (Hignett & McAtamney, 2000) However, both are restricted by the quantity and complexity of body segments and details. Because the right and left sides are assessed individually, a lengthy application period is necessary, and it is not appropriate for employment with frequent task modification. Its capacity to consider the duration and frequency of things is similarly limited (Takala et al., 2010), see Table 2.1.

2.3.3 Occupational Repetitive Action (OCRA)

The occupational repetitive action (OCRA) methods were developed by Occhipinti and Colombini in 1996 to assess workers' exposure to risk factors such as repetitiveness, force, awkward postures and movements, and a lack of recovery periods, all of which are linked to the occurrence of WRMSDs in the upper limbs (Columbini & Occhipinti, 1996), see Table 2.1. The tool was created using a consensus statement from the International Ergonomics Association (IEA) technical committee on musculoskeletal disorders (Columbini et al., 2001), and it generates genuine indications that take worker rotation into account. The tool's validity has been determined; however there have been no rigorous tests on its reliability. It's usually used to (re)design or analyze workstations and tasks in depth (Columbini et al., 1998, 2002). The tool is difficult to use and takes a long time to complete. The OCRA checklist, based on the OCRA index, was created as a simplified tool for initial screening of workstations with repeated duties (Occhipinti et al., 2000; Colombini et al., 2002). This application makes it easy to map out high-exposure workplaces in a corporation, although it can only be used for preliminary study. Both tools, however, have a huge number of details, making them difficult to use. They focus more on repetition, assessing the worker's risk level by taking into account all of the repetitive actions in a complex job, and are unsuited for unstructured work due to their rigidity. The use of these instruments necessitates the presence of appropriately trained observers (Takala et al., 2010). When the OCRA index and the checklist scores were applied to the identical work situations by two separate experts, Occhipinti and colleagues showed a very high agreement between the two approaches in a study published in 2000. (Occhipinti et al., 2000).

2.3.4 Quick Exposure Assessment (QEC)

Quick Exposure Assessment (QEC), created by Li and Buckle in 1998, is an observational method designed to assess WRMSD risk exposure and serve as a foundation for ergonomic intervention. It was created for those who work in the field of occupational health and safety. There were two stages to the development. A review of the literature on the relationship between physical and psychological factors and the development of WRMSDs was conducted in order to identify and prioritize the most essential risk factors that might be included in the questionnaire. To aid in the creation of the tool, other tools and methodologies were examined. Following that, ninety-three practitioners were given a questionnaire to express their thoughts on current exposure assessment methods, challenges connected with them in terms of workplace assessment and needs, and provide recommendations and requirements for a new tool. The answers of the questionnaire were examined by 40 occupational health and safety practitioners divided into five focus groups. 8 practitioners evaluated exposure by seeing video footage of three simulated tasks and making verbal assessments. The information was analyzed and used to determine the preferred nomenclature and the order in which the various bodily parts were evaluated. The reliability and concurrent validity of the tool were then assessed (David et al., 2005). The tool then moved to the second phase.

In the second step, a telephone interview was conducted with seven existing users to collect data on their opinions after using the tool. A review of the tool's issues was conducted. After utilizing the tool to analyse five manual tasks, eight experts (ergonomists) provided feedback on the tool's usefulness and suggestions for improvement. Following that, the literature was reviewed to acquire information on recently published information that could be useful in the tool's development. This data was utilized to detect problems, and the necessary revisions were made. Using a manual assembly task and a questionnaire, ten practitioners evaluated the prototype and assessed the tool's usability. To explore how to improve the evaluation and scoring forms, a group discussion was convened. Finally, the enhanced versions were assessed by 12 practitioners and 7 ergonomists, resulting in the tool's final modification or enhancement. The legitimacy and dependability of the data were checked once more (David et al., 2005).

The tool is simple to use, quick, and can be used to examine a variety of body segments, including the back, shoulder/upper arm, wrist/hand, and neck, as well as assess various working postures. It also assesses repeated movement and offers information regarding hand force exertion, maximum weight handled, vibration, task visual demand, and task time gathered from the worker. See Table 2.1 Although observers may not require extensive training, they may experience difficulties if they are used to perform a wide range of duties (Li & Buckle, 1999a).

2.3.4 Posture, Activity, Tools and Handling (PATH)

Buchholz developed PATH (Posture, Activity, Tools, and Handling) in 1996 to describe the ergonomic exposure of construction workers and other non-repetitive job tasks (Buchholz et al., 1996). It was created in response to reports of high prevalence and incidence of WRMSDs in the construction industry. Construction work is non-repetitive and involves irregular or long hours, ergonomic hazards were identified using a working sample approach and posture codes, as well as other codes to describe the worker's actions, tools utilized, and weights handled. (Buchholz et al., 1996).

It contains a systematic and well-designed sampling strategy, as well as a procedure for creating job-specific templates, however this method solely addresses exposure levels and relative durations. The observers must undergo extensive training (Takala et al., 2010). There is scarcity of literature on the tool's development, validity, and reliability.

2.3.5 Plibel Checklist

PLIBEL is a screening tool that uses a checklist (Kemmlert & Kilbom, 1987) to identify 'ergonomic hazards' in the workplace. It includes questions about work posture, workplace or tool design, or movements associated with specific body regions such as the neck/shoulders and upper back, elbows/forearms and hands, feet/knees and hips, and low back. See Table 2.1 The literature on WRMSD risk factors was reviewed in the development of this questionnaire, and relevant items needed for a workplace evaluation were listed and organized into a checklist. The validity and interobserver reliability of the data were also evaluated (Kemmlert, 1995).

Although it is a useful tool for detecting occupational risk factors linked to musculoskeletal injuries in certain body regions (Li & Buckle, 1999), it is subjective, hence the risk cannot be quantified (Takala et al., 2010)

Table 2. 1: Commonly used ergonomic assessment tools and the risk factors they assess.

METHODS	RISK FACTORS					
	POSTURE	FORCE EXERTION	REPETITION	VIBRATION	CONTACT STRESS	DURATION
RULA	*	*				
REBA	*	*			*	
PATH	*	*				
QEC	*	*	*	*		*
OWAS	*	*				
PLIBEL	*	*				
OCRA	*	*	*	*	*	*

2.4 The need for assessment methods tailored to informal work environment

Except for OCRA, no other tool addresses the whole range of workplace physical risk variables (see Table 2.1), which include posture, repetition, force exertion, vibration, contact stress, and task duration (David, 2005; Takala et al., 2010). There is a need to expand the current set of physical risk factors and consider how they interact (David, 2005). The bulk of existing observational tools only examine posture of specific body parts, rather than addressing critical workplace physical exposure aspects (David, 2005; Burdorf, 2010; Takala et al., 2010). Furthermore, despite the claim of "rapidity," of these methodologies, while good and relevant in many work situations, cannot be used for real-time evaluation of unstructured and unregulated work or tasks that vary greatly such as e-waste recycling centers. The rudimentary methods used in recycling puts e-waste workers at risk of work-related musculoskeletal disorders (Akormedi et al., 2013). This has been reported in several studies; Nigeria (Ohajinwa et al., 2018), Brazil (Binion & Gutberlet, 2012), India (Chikarmane et al., 2009 as cited by Akormedi et al., 2013), and Ghana (Adusei et al., 2020; Amankwaa, 2013). Acquah and colleagues reported 90% prevalence of WRMSDs among e-waste workers at Agbogbloshie which can be ascribed to poor work practices (Acquah et al., 2019) as well as prolonged exposure to physical occupational risk factors (Acquah et al., 2021). The majority of e-waste employees in Accra work 10 to 12 hours per day, or 300 to 360 hours per month, which is 108 to 168 hours higher than workers in the official sector, who work 8 to 10 hours per day, or 210 to 260 hours per month (Prackash et al., 2010). Researchers have emphasized the importance of conducting detailed investigations into the risk factors that predispose informal e-waste workers to WRMSDs. As a result, it was prudent to develop a dedicated assessment strategy for assessing physical/ergonomic exposures among e-waste workers that addresses the challenge while being simple and requiring minimal training.

To address this issue, Acquah et al (2020) created a novel ergonomic evaluation technique for unstructured work environments, such as those found among Agbogbloshie e-waste workers. This tool determines the duration and severity of significant occupational risk factors that may predispose workers to WRMSDs.

2.5 The need for assessment methods tailored to informal work environment

Acquah and colleagues developed the tool in 2020 to quantify ergonomic risk factors in jobs that are unstructured and uncontrolled, such as informal e-waste recycling. Initially, the researcher obtained data from the literature on e-waste, work-related musculoskeletal disorders, and ergonomic risk assessment methods such as RULA, REBA, OWAS, PATH, OCRA, and QEU. To comprehend and document the work processes involved in e-waste, multiple visits to the field, walkthrough observations, and interviews with e-waste employees were conducted. Work procedures were split down into task components and tools needed for each job. The data coding criteria were constructed based on information acquired from field trips, walkthrough observations, worker interviews, and other observational approaches. The development of the tool was informed by in-depth conversations with specialists, information acquired from the pilot study, and input from experts in the subject of interest. The tool evaluates posture (neck, trunk, upper and lower limbs, as well as waking and sitting postures), force, repetition, contact stress, and vibration, as well as manual material handling activities including carrying, lifting, and pushing/pulling a cart. At least two or three levels of an ordinal scale are employed to define postures. The neck is classified as neutral (flexion or lateral bending of less than 30^0) or non-neutral (flexion or lateral bending of more than 30^0). The neck classification was based on Buchholz et al. findings, according to Acquah et al. in 2020. Neck pain was one of the top six MSDs reported by e-waste workers in 2019, according to Acquah et al., in 2020 making neck posture an important risk factor to consider. Neutral, (45^0) forward flexion, and/or lateral bending were the three stages of trunk classification. These criteria were developed from Buchholz et al (1996), PATH approach and NIOSH standards in 2020, according to Acquah et al (2014). Flexion postures are frequently associated with lateral bending or twisting; hence, they were grouped together (Acquah et al., 2020). Punnett et al. reported a link between back diseases and severe vs. mild trunk flexion, twisting, and lateral bending in 1991, which accounted for its inclusion in the instrument, according to Acquah et al. in 2020. (Acquah et al., 2020). Hands/arms below waist height, below shoulder height but above waist height, and above shoulder height were grouped into three categories, comparable to PATH (Buchholz et al., 1996) Walking, sitting, and standing are the three basic categories for lower limbs, equivalent to PATH and OWAS (Acquah et al., 2020). Walking can be classified as either walking without pulling or pushing a cart or walking while pushing or pulling a cart, which is frequent among e-waste collectors (Acquah et al., 2020). Standing was either neutral or with knees bent more than 45^0 degrees (Acquah et al., 2020). There are three types of sitting: sitting with hips and knees around 90^0, hips and knees greater than 90^0, and hips and knees less than 90^0(Acquah et al., 2020) and OWAS (Karhu et al., 1977).

Acquah et al., in 2020, used ordinal categories to assess force effort and repetition, which is similar to QEC. The force is classified as low (1kg), moderate (1kg to 4kg), or high (4kg). Low (10x per minute), medium (11-20x per minute), and high (20x per minute) repetition rates were assigned. Subjectively, force and repetition are rated (Acquah et al., 2020). Contact stress and vibration are classified on a binary scale, meaning that they are either present or absent (Acquah et al., 2020). Based on comprehensive conversations with experts in the field and tool piloting, the tool also measures manual material handling such as carrying, lifting, pushing/pulling a cart. Lifting and carrying activities were classified as Light (under 5kg), Moderate (6–10kg), Heavy (11–20kg), and Very Heavy (above 20kg), comparable to the QEC (Acquah et al., 2020). Prior to the start of the evaluation, the weight of the most commonly used objects is weighed to provide the researcher with an estimate of the tool's weight. Whether the wheelbarrow or cart was empty or loaded is more important when coding the pushing/pulling (Acquah et al., 2020).

Other factors such as kicking and stamping are also assessed by the instrument.

However, the tool is still in its early phases of development and needs to be evaluated for modification based on the findings of the study.

2.6 Validation of ergonomic assessment tools

The evaluation of psychometric qualities is required for the creation of ergonomic exposure assessment tools, especially for research seeking to demonstrate a causal relationship between ergonomic risk factors and musculoskeletal health outcomes (Burdorf, 2010; David, 2005; Takala et al., 2010). According to Takala et al. (2010), it is a major step in establishing an observational instrument. Poor performance of exposure assessment methods contributes to skepticism about the relation of work to musculoskeletal diseases and this is attributed to lack of assessment of the psychometric properties of these tools (Takala et al., 2010; David, 2005). Psychometric properties of ergonomic assessment tools are evaluated by conducting validity and reliability tests.

2.6.1 Validity

Validity refers to how effectively the data collected is relevant to the research (Ghauri & Gronhaug, 2005). "Measure what is designed to be measured," as the phrase goes (Field, 2005; Brink, 2006). Face validity, construct validity and criterion validity are some of the types of validity that will be explored (Taherdoost, 2018).

2.6.1.1 Face Validity

The extent to which a measuring instrument is related to a certain model based on the judgment of non-experts such as test takers is known as face validity. The content of the instrument must appear relevant to the test taker in order for it to get a high face validity score (Taherdoost, 2018). Face validity assesses the significance and presentation of measuring instruments in terms of whether the items are clear, readable and have a consistent style and format (Oluwatayo, 2012) in terms of the researcher's or test taker's subjective opinion. A dichotomous scale with a categorical choice of yes or no can be used to test face validity, where yes signifies approval of the item in terms of its objective structure and no means rejection (Taherdoost, 2018). Cohen's kappa statistics is used to analyse the results. A score of more than 0.60 implies that the measuring instrument has strong face validity (Gelfand, Donna, Hartmann, Donald, Cromer et al., 1975). However, because it is the least reliable kind of validity, it is not regarded a valid validity test (Taherdoost, 2018).

2.6.1.2 Construct Validity

The construct validity of a concept, idea, or behavior refers to how well it can be turned or adjusted into a workable and measurable reality (Taherdoost, 2018). In general, construct validity necessitates the ability of an instrument to measure an abstract concept that cannot be directly observed but was developed to reflect an abstract feature (Portney & Watkins, 2009). Construct validity, which is made up of two parts: convergent and discriminant validity, determines whether the instrument measures what it sets out to measure.

A. Discriminant Validity

Discriminant validity also known as divergent validity is the extent to which a measuring instrument differentiates between persons or populations which were anticipated to differ (Bannigan & Watson, 2009). It is the extent to which variables differ. In summary, this validity test, the concept that items which are not expected to be related actually do not have a relationship. Therefore, two measures which are believed to have different concepts or ideas will have a poor correlation (Bannigan & Watson, 2009). The newly created ergonomic tool (ErgoEnf) to assess WRMSDs among nurses was validated using construct validity in a study by Coluci and Alexandre in 2014. The survey was provided to two categories of people: office employees and nurses. Nurses' work involves diverse and dynamic movements and postures, whereas office workers' activities primarily include sitting and using a computer. This experiment was carried out to see if the outcomes of the two groups differed. Due to the contrasting work activities, the questionnaire recorded higher values in nurses as compared to office workers because it was designed specifically for nurses also verified with the known-groups technique, thus the construct validity of the tool was good (Coluci & Alexandre, 2014).

Convergent Validity

It is the notion that two measures with comparable theories will have similar results in practice, hence, measures that are connected in theory will have a high correlation in practice (Portney & Watkins, 2009). In a 2014 study, Coluci and Alexandre evaluated ErgoEnf's Convergent validity by comparing the findings of EngoEnf's pain-measurement items to the results of the Numerical Pain Scale after it was delivered to individuals who complained of pain (Coluci & Alexandre, 2014). PLIBEL was validated by citing all of the checklist items' references. Authentic scientific articles were used as references, and topics that could not be discovered in original scientific journals were validated using textbooks (Kemmlert, 1995).

2.6.1.3 Criterion Validity

The degree to which a measure or tool complies with a gold standard or the external criterion of the thing being measured (Bellamy, 2015). Criterion-related validity, also known as criterion or concrete validity, refers to a test's capacity to anticipate or agree with the results of an external criterion that is thought to be valid, and is hence referred to as the gold or reference standard. Both tests are conducted on the same people, and the test results are compared to the results of the reference standard (Taherdoost, 2018; Bellamy, 2015). It refers to the degree to which one measure is linked to an outcome and predicts the scores or outcomes of another. It's a useful strategy for forecasting performance or conduct in comparable situations. This test can be used to forecast future outcomes or to separate people into groups (Taherdoost, 2018). The absence or lack of gold standards is a major constraint in the use of criteria as a technique of verifying a tool. Some ostensibly gold standards may not accurately reflect the phenomenon being studied. Bellamy et al., 2015). Concurrent, predictive, and postdictive validity are the three types of criterion validity.

A. Predictive Validity: The measuring instrument is predictively valid if the test accurately predicts what it is supposed to predict based on theory using the same construct. To determine the predictive validity, the instrument is used to collect data first and the criterion is used to collect data last, the scores from the instrument should be similar to the scores from the criterion when the data is collected with the criterion later (Taherdoost, 2018). The scores from the test instrument should predict the criterion scores, that is the performance of the criterion can be predicted by simply using the results of the test instrument (Taherdoost, 2018). Predictive validity requires long term study and large sample sizes. In summary, predictive validity is tested when the measuring instrument is used to collect data and measured prospectively to determine the relationship between the measuring instrument and the criterion scores to determine whether the instrument is a reliable predictor of the outcome (Portney & Watkins, 2009). Jones et al. (2015) in a study to determine the ergonomic risk of workers in four sawmill jobs reported that REBA, RULA and OCRA had a 64%, 99% and 28% predictive validity respectively (Jones et al., 2015). QEC assessment was also assessed by comparing results of QEC scores for tasks in a workplace carried out by 6 practitioners with expert assessments made from a video recording (David et al., 2005). Occhipinti and Colombini (2004) also reported a high ability of OCRA index to predict the prevalence of Upper limb WRMSDs in the exposed populations.

B. Concurrent validity can be used to determine the ability of a test or instrument to predict other outcomes. It is the degree to which the results or scores of a measuring instrument is similar to those of a previously established measuring instrument for the same concept (Taherdoost, 2018). In determining the concurrent validity, the test is carried out with the measuring instrument and the criterion measure at the same time so it reflects the same results (Taherdoost, 2018). Concisely, the concurrent validity is the instrument's ability to differentiate between groups that literature says are different. A study by Kee and Kawowksi in 2007 compared RULA, REBA and OWAS in assessing postural load in different industries reported 48% consistency between OWAS, and REBA, thus, OWAS and REBA generally underestimated postural loads for the 301 postures that were analyzed as compared to RULA , regardless of the work type, industry and the presence and absence of body postures in a balanced state (Kee & Karwowski, 2007), however, Jones and Kumar in 2015 reported that comparisons should be done using small sample size in the same industry (Jones et al., 2015). Chiasson et al. (2012) reported a 73.7% consistency between OWAS and REBA. For all risk categories combined, OCRA and QEC were in agreement 57% of the time (Chiasson et al., 2012). Also, the concurrent validity of QEC was determined by assessing 4 task using simulations using QEC and SIMI*3D computerised motion analysis and comparing results. This was done by 18 practitioners (David et al., 2005). Validity for PLIBEL was assessed through some workplace assessments performed simultaneously using PLIBEL and Arbeitswissenschaftliche Erhebungsverfahren zur Tatigkeitsanalyse (AET), a German ergonomics job analysis procedure (Kemmlert, 1995).

C. Postdictive Validity, data collected using the standard measuring instrument was taken in the past, that is, the criterion was administered in the past. The degree to which the scores on the measuring instrument of interest are related to the scores on another, already established instrument or criterion administered at an earlier point in time determines the postdictive validity (Taherdoost, 2018).

2.6.2 Reliability

Reliability is the extent to which a measurement of an event produces stable and consistent results (Carmines & Zeller, 1979). The reproducibility of the results obtained with the measuring device is the basis for reliability. If a measuring device is reliable, it means that if the measurement is repeated under the same conditions, the same results will be obtained (Moser & Kalton, 1989). According to Straub et al. in 2004, a test should have a score of 0.60 or above to be considered reliable (Straub et al., 2004). Excellent reliability (0.90 and above), high reliability (0.70-0.90), moderate reliability (0.50-0.70), and low reliability (0.50 and below) are the four cut-off values proposed by Hinton et al. (2004). (Hinton et al., 2004). Inter-observer agreement and intra-observer agreement are the two categories of reliability.

2.6.2.1 Inter- observer agreement

The degree to which two or more observers acquire identical scores when the test is administered simultaneously using the same variables under the same settings is known as inter-rater reliability (Karanicolas et al., 2009; Portney & Watkins, 2009). Without the upper arm category, inter-observer reliability of REBA was found to be between 62 and 85 percent (Hignett & McAtamney, 2000). The inter-observer agreement for QEC was determined in two stages. Using video recordings, eighteen practitioners assessed 18 industrial static and dynamic activities in phase one. Inter-observer reliability was moderate, as established by the level of agreement between the practitioners' scores for each task using Cohen's k-coefficient, percentage agreement (David et al., 2005). In the second phase, the tool was improved, and the inter-observer reliability was examined using six practitioners, the study indicated a higher inter-observer agreement than phase one (David et al., 2005). Karhu stated in 1977 that the OWAS reliability test was fairly excellent after two work engineers used the instrument to analyze work activities (Karhu et al., 1977). After being analyzed by numerous observers, the inter-observer reliability test for PLIBEL was rated as fair to moderate (Kemmlert, 1995).

2.6.2.2 Intra- Observer agreement

Intra-observer reliability refers to the consistency or resemblance of the results obtained when the same measuring instrument is used by the same observer on two or more times to measure the same variables under the same conditions. When the same or similar results are produced using a measuring device, it is considered to have a high reliability score (Karanicolas et al., 2009; Portney & Watkins, 2009). In a study that examined the three observational methodologies in assessing postural loads in an industry, the intra-observer agreement for OWAS, RULA, and REBA was 95.0, 91.7, and 97.3 percent, respectively (Kee & Karwowski, 2007). After analyzing 18 recorded tasks on two consecutive occasions over three weeks, the intra-observer agreement of QEC was evaluated by comparing the scores of each of the 8 test-takers. There was moderate intra-observer agreement, according to the report (David et al., 2005).

CHAPTER THREE

METHODOLOGY

3.1 Study Design

This study was a cross-sectional study using secondary video data collected as part of the West Africa-Michigan CHARTER II for GEOHealth. This design was used because a snapshot of the work processes of e-waste recyclers was required to conduct the study and not a long term follow up. However, this study used secondary data due to the government's relocation of e-waste workers from the Agbogbloshie scrap yard at the time of this study, hence the researcher had no control over how the data was collected.

3.2 Study Site

The study was conducted at Agbogbloshie, a 6.2-hectare site in the western section of Ghana's capital city, Accra. It is located between the banks of the Korle lagoon and a large food market (Davis et al., 2019; Laskaris et al., 2019; Oteng-Ababio, 2012). It is one of the world's largest e-waste recycling and disposal facilities (Bridgen et al., 2008). The area is heavily industrialized and urbanized, with recyclers working in open areas and small structures. The work environment is informal, unstructured and unregulated. Agbogbloshie is divided into two sections. The first area focuses on offloading electronic waste items from cargo trucks, collecting carts, bicycles, tricycles, or motorcycles for sorting them out into various piles based on their metallic constituents. The sorted items are subsequently dismantled to recover valuable items. The second region, near the banks of the Odaw river is the designated site for burning of e-waste items that cannot be dismantled (e.g., copper wires) in order to recover valuable metal constituent.

3.3 Study Population

The study involved collectors, dismantlers, and burners at Agbogbloshie's e-waste recycling site. Collectors are e-waste workers that collect end-of-life devices in the city's surrounding towns and neighborhoods. Dismantlers break down these obsolete devices into individual components in order to extract valuable metals. Copper cables, which cannot be removed, are burned in the open to separate the insulating layer from the copper (Acquah et al., 2019). Metals are retrieved, weighed, and priced according to their weight before being sold to middlemen who then sell them to industrial enterprises at a higher price, for processing into iron rods and cooking utensils. A total of three male e-waste workers between the ages of 18 and 30 years. were involved in this study (a collector, a dismantler and a burner).

3.4 Sampling

Convenience sampling was used due to the unstructured nature of the Agbogbloshie e-waste site and the lack of a well-organized workstation setup. Participants were approached while they were resting in their work sheds, and informed about the study's aim. After they agreed to participate in the West Africa-Michigan CHARTER II for Global Environmental and Occupational Health Project, a GoPro camera was utilized to record them working for a whole day's shift. The videos used were conveniently sampled. It was based on the clarity of the video.

3.5 Inclusion and Exclusion criteria

Inclusion criteria:

Electronic waste workers involved in collection, dismantling and burning of e-waste at Agbogbloshie.

Exclusion criteria:

E-waste workers who participate in physically demanding non-e-waste activities (for example construction workers).

3.6 Data collection Approach

3.6.1 Data collection tools

This section elaborates on the various questionnaires and assessment tools used for collection of data for this study.

3.6.1.2 Face Validity Questionnaire

The face validity questionnaire, a subjective questionnaire for quantitatively measuring the tool's face validity was adapted from a study by Olutawayo (2012). The questionnaire evaluates the tool in terms of whether the items are clear, legible and have a consistent style and structure using a dichotomous scale (Oluwatayo, 2012; Taherdoost, 2018).

3.6.1.3 Criterion validity assessment tools

Criterion validity was determined by comparing the newly developed ergonomic assessment tool with existing tools such as the Ovako Working Posture Analysis System (OWAS), Rapid

Upper Limb Assessment tool (RULA), Rapid Entire Body Assessment tool (REBA) and Quick Exposure Checklist (QEC).

Ovako Working Posture Analysis System evaluates static working postures of body segments (trunk, shoulder, lower extremity) and force/ load (Karhu et al., 1977; Li & Buckle, 1999). It provides a unified score of all the assessed components.

Rapid Entire Body Assessment assesses static working postures of the neck, trunk, upper limb (shoulder, forearm, wrist) and lower extremity. It also assesses force exertion and provides an overall score for all components assessed.

Rapid Upper Limb Assessment similar to Rapid Entire Body Assessment evaluates static working postures of the neck, trunk, upper limb (shoulder, forearm, wrist) and lower limb. With regards to this tool, lower limb is scored based only on whether lower limbs are supported or not, where as in Rapid Entire Body Assessment, lower limb is scored based on the degree of flexion of the knee. In addition, the tool analyses force exertion and makes provision for a unified score of all the items.

Quick Exposure Checklist examines a variety of body segments, including the back, shoulder/upper arm, wrist/hand, and neck. It also assesses repeated movement and offers information regarding force exertion, maximum weight handled, vibration, task visual demand, and an estimate of time spent sustaining the posture or exerting force.

3.6.1.4 Newly Developed Ergonomic Assessment Tool

Acquah and colleagues developed a pen-and-paper observation-based tool for assessing ergonomic risk factors in unregulated and unstructured work (Acquah et al., 2020). This tool assesses the duration spent in awkward postures (neck, trunk, upper and lower limbs), forceful exertion, repetitive movement, contact stress, and vibration, as well as manual material handling activities like carrying, lifting, pushing/pulling a cart (Acquah et al., 2020). The tool comprises of a coding template/sheet and a coding guide. The coding template is made up of rows which correspond to the ergonomic risk factors being assessed and columns which correspond to the observation time. Each cell corresponds to a 60-second observation period (Acquah et al., 2020). The tool will be used to assess ergonomic exposures using video data.

3.6.2 Procedure for data collection for validity test

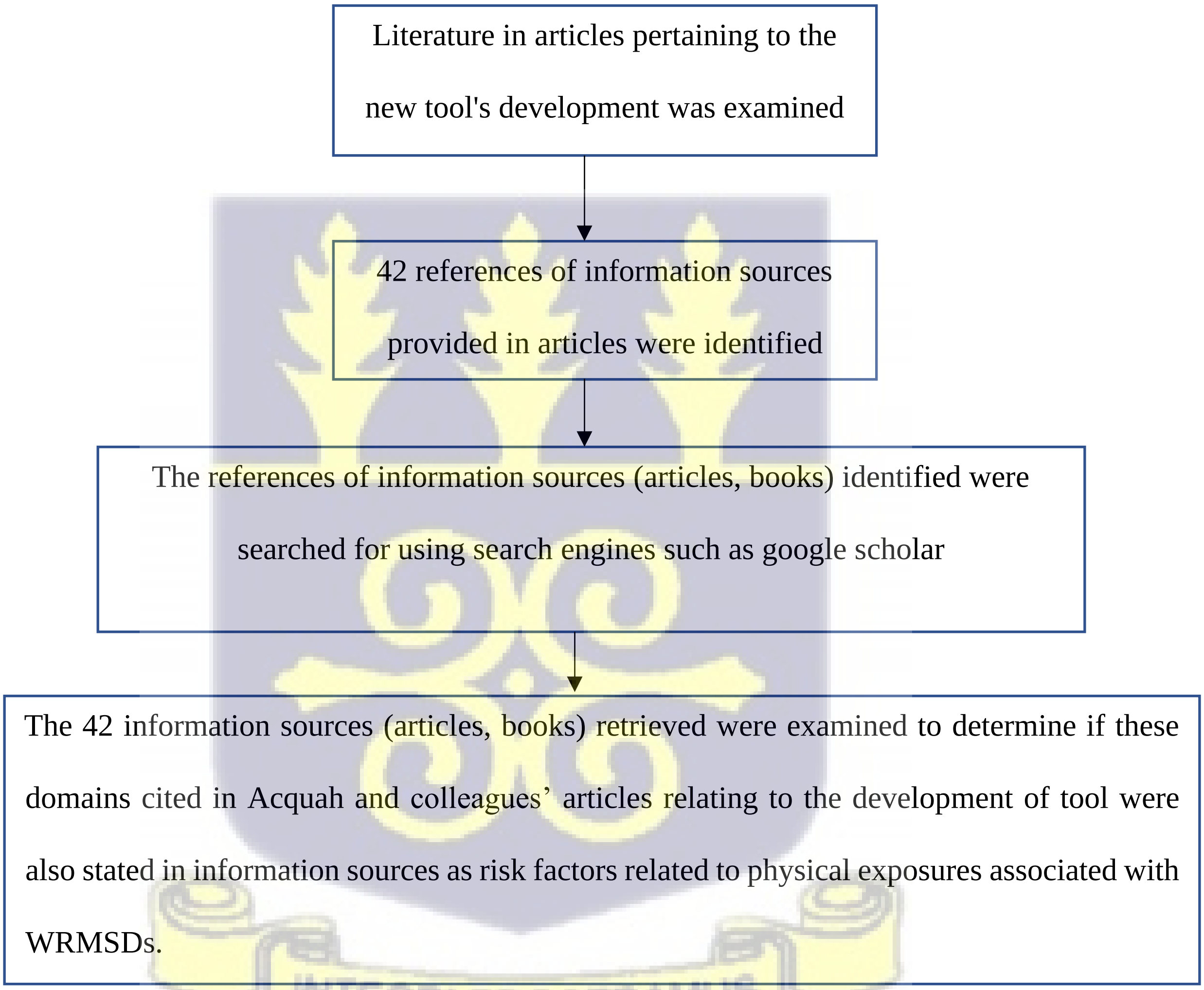
3.6.2.1 Face Validity

The face validity questionnaire was administered to three researchers. These researchers were familiar with the newly developed ergonomic assessment tool and had used it to quantify ergonomic risk factors e-waste workers at Agbogbloshie were exposed to, in previous studies carried out by Acquah and colleagues. The researchers had to review the overall design and individual items included in the tool and indicate whether they approved or disapproved inclusion of these items in the design of the tool. As part of the review, the researchers were required to indicate their approval or disapproval of indicated items by ticking yes or no to respective questions on the face validity questionnaire (Oluwatayo, 2012; Taherdoost, 2018). The researchers also provided comments and suggestions to help improve the tool. The responses obtained from the face validity questionnaire were analyzed using the Cohen kappa statistics to determine the level of agreement between researchers' responses. A score above 0.60 indicates good face validity (Taherdoost, 2018)

3.6.2.2 Construct validity

A literature review was carried out by the researcher. The researcher was involved in the collection of data in previous studies by Acquah and colleagues in relation to the development of the tool. The literature pertaining to the tool's development was examined by the researcher in order to determine the information sources used in the tool's development. The sources were then checked to confirm that the tool and the items assessed conformed with current ergonomic assessment domains and the items assessed related to physical exposures associated with WRMSDs (Coluci & Alexandre, 2014; Hignett & McAtamney, 2000; Kemmlert, 1995; Li & Buckle, 1999).

Figure 3.1: A flowchart of the process of determining construct validity



3.6.2.3 Criterion validity

Criterion validity was assessed by assessing selected e-waste recycling activities with the newly developed tool and comparing the results with assessments of the same tasks using existing tools such as REBA, RULA, QEC, OWAS. The e-waste recycling activities assessed were collecting, dismantling and burning of e-waste. Each existing tool (REBA, RULA, QEC, OWAS) was used to assess and score the selected e-waste recycling activities based on its scoring system. Since the new ergonomic assessment tool being validated does not have a dedicated scoring system yet, scoring was done by computing the percentage of time spent by workers in the various domains of ergonomic exposures being assessed. To enable comparison of the scoring systems from each of the tools used in the criterion validity a colour coding scheme which corresponded to the severity of the ergonomic exposure assessed was generated for each tool and the colour codings compared. The colour codes were red, yellow and green and corresponded to severe, moderate and low risks for WRMSDs respectively. Red represented all high to very high scores for the existing tools and scores above 60% for the new tool. Yellow represented moderate scores for the existing tools and a score between 30% to 60% for the new tool. Green represented low scores for existing tools and a score of lower than 30% for the new tool.

3.6.3 Procedure for data collection for Reliability test

3.6.3.1 Training of Research Assistants

Two (2) research assistants, were recruited and trained for two weeks (David et al., 2008; Hallgren, 2012; Acquah et al., 2020). The Research Assistants were shown videos that highlighted the processes and work methods involved in e-waste recycling during the first week of training. A coding guide developed as part of the new tool was used to explain the various items assessed by the tool and the respective codes that represent their level of intensity. Research assistants were then taught how to code ergonomic risk factors with the new tool using archival video data of e-waste recycling activities. The research assistants were allowed to pause the video when needed to enable effective identification of exposures.

Where the research assistants were unclear about a particular item or activity, they discussed with the principal investigator and the uncertainties were resolved. Following successful training of the research assistants within the two weeks training period, they were allowed to code video data independently throughout the rest of the study period.

3.6.3.2 Intra- observer Agreement

Two observers analyzed video data from an entire work day to assess ergonomic exposures among e-waste employees using the new ergonomic assessment tool. The assessment was repeated after 5 days by the same observers on the same subjects using the same video footage (Hani et al., 2015).

The observations for exposures recorded before and after the 5-day interval were compared using Cohen Kappa's statistics and the level of agreement between observations for each observer (intra observer agreement) computed. A score of 0.90 and above represents excellent reliability, 0.70- 0.89 represents high reliability, 0.50-0.69 shows moderate reliability and below 0.50 for low reliability (Hinton et al., 2004).

3.6.3.3 Inter- Observer Agreement

To assess inter-observer agreement, three research assistants used the new ergonomic assessment tool simultaneously to evaluate physical exposures among e-waste workers. The three research assistants used the same video which was an entire day's shift of e-waste recycling activities and assessed the ergonomic exposures associated with the recycling activities using the new ergonomic tool. The observations of both research assistants were compared using Cohen Kappa statistics to establish the level of agreement between the observations. A score of 0.90 and above represents excellent reliability, 0.70- 0.89 represents high reliability, 0.50-0.69 shows moderate reliability and below 0.50 for low reliability (Hinton et al., 2004).

3.7.1 Data Analysis

All data obtained from the data were entered into Microsoft Excel 2019 and cleaned for analysis. The data was then exported to Statistical Package for The Social Sciences (SPSS) version 23 for statistical analysis.

Data from the face validity questionnaire were reported descriptively by indicating the yes or no responses of the assessors for each item on the questionnaire. For inter- and intra-observer agreement, Cohen Kappa statistics were computed in SPSS. For construct validity, references reviewed were reported in tables under their respective domains. In order to compare ergonomic risk scores among the tools used to assess criterion validity, the respective scores from each tool were recoded to conform with a three-colour coding system: red, yellow and green. This was necessitated by the variations in the scoring systems and interpretations used by each of these tools. The colour coding allowed easy comparison of ergonomic risks by converting scores to represent one of the three colours used.

Red represented high to very high scores for REBA, RULA, QEC and OWAS while scores above 60% represented red (high risk) for the new tool. Yellow represented moderate scores for the existing tools and 30% to 60% score for the new tool. Green represented low scores for existing tools and less than 30% score for the new tool. Scoring for the existing tools used were based on the recommended scoring system used by the developers of the tool. The new tool was scored as a proportion of the total working time the worker was exposed to the various risk factors under consideration. Red codes indicated high risk for WRMSDs, Yellow indicated moderate risk for WRMSDs and Green, low risk for WRMSDs.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents results on the validity and reliability of a new ergonomic assessment tool developed for unregulated and unstructured work environment such as e-waste recycling in Agbogbloshie, Accra Ghana.

4.2 Face Validity

The new tool had a face validity of 0.718, $p<0.035$ as shown in Table 4.1

Other aspects of face validity assessed indicated the items on the tool were appropriately formatted and the instrument's structure in terms of construction, and the format was well thought out. All three reviewers also agreed that the items assessed were all relevant to the purpose of the tool. In the initial stage of the review, reviewer one and two stated that the printout was not legible but this was later resolved in subsequent printouts. Reviewer one voted no for the attractiveness of the paper in contrast to reviewers two and three. All three participants agreed that the tool was difficult to use in the absence of training.

Table 4. 1: Face validity of the newly developed ergonomic assessment tool

Domain	**Reviewer 1**	**Reviewer 2**	**Reviewer 3**
Are the items in the tool clear and unambiguous?	0	0	0
Is the tool difficult to use	0	0	0
Are the words in the tool spelt correctly	0	0	0
Are items spaced well?	0	0	0
Are instructions adequate?	0	0	0
Are items related to the purpose of the instrument?	0	0	0
Is the printout legible	1	1	0
Is the paper attractive	1	0	0
Is the structure of the tool in a well-thought out format?	0	0	0

Interpretation of codes

0= Yes (agreement of item)

1= No (disagreement of item)

4.3 Construct Validity

Table 4.2 below shows the ergonomic risk factors assessed during construct validation of the new tool and the corresponding literature that supported inclusion of these risk factors.

A total of 42 articles were reviewed, 4 publications were cited for the inclusion of posture, 7 for sitting, 13 for standing, 8 for force exertion and 5 for manual material handling.

Table 4. 2: Ergonomic risk factors assessed during construct validation of the new tool and the corresponding literature that supported inclusion of these risk factors.

Posture	Sitting	Standing	Walking	Repetition	Force Exertion	Duration	Manual Material Handling
Buchholz et al., 1996	Hoogendorn et al., 1999	Chaffin et al., 2006	Morrison et al., 2016	Andreas & Grooten, 2018	Andreas & Grooten, 2018	Andreas & Grooten, 2018	Hoogendorn et al., 1999
Punnett et al., 1991	Roffey et al., 2010	Halim & Omar, 2011	Roffey et al., 2010	Roffey et al., 2010	Roffey et al., 2010	Roffey et al., 2010	Merhdad et al., 2008
Karhu et al., 1977	Chaffin et al., 2006	Garcia et al., 2015,2016, 2018	Chaffin et al., 2006	Chaisson et al., 2012	Chaisson et al., 2012	Chaisson et al., 2012	Kuijer et al., 2010
Li & Buckle, 2000	Beach et al., 2005	Lafond et al., 2009	Pereira & Goncalves, 2011	Li & Buckle, 1999	Li & Buckle, 1999	Li & Buckle, 1999	Roffey et al., 2010
	Challaghan & McGill, 2001	Madeleine et al., 2007	Walsh et al., 2008	Marras, 2008	Marras, 2008	Marras, 2008	Abou- Elwafa et al., 2012
	Emmatty & Panicker, 2019	Marras, 2008	Yoshina et al., 2004	Takala, 2010	Takala, 2010	Takala, 2010	
	Ohanjiwa, 2018	Marras et al., 1998	Akormedi et al., 2013	Eatough et al., 2012	Eatough et al., 2012	Eatough et al., 2012	
		Chandrasakar et al., 2003	Yu et al., 2017	Kuorinka et al., 1995	Kuorinka et al., 1995	Kuorinka et al., 1995	
		Musa et al., 2000					
		Wai et al., 2010a					
		Tomei et al., 1999					
		Adanu et al., 2020					
		Little, 2016					

4.4 Criterion Validity

Table 4.3 shows a comparison of ergonomic risk scores among collectors, dismantlers and burners of e-waste using REBA, RULA, OWAS, QEC and the newly developed ergonomic assessment tool.

Blank spaces indicate that the ergonomic assessment tool under consideration does not assess the related risk factor.

The new tool showed that more than half (69.4%) of the day's activity of a collector was spent exerting moderate force (NT= 1). REBA, RULA and OWAS also reported high force exertion for collectors (REBA=3, RULA=3, OWAS=3). REBA, RULA and QEC reported high scores for shoulder posture for dismantlers (REBA=4, RULA=4, QEC=44). Vibration was moderate as reported by QEC (QEC=4) and the new tool (NT= 1) and was present 4.1% of the total duration spent burning in a day.

Table 4. 3: Comparison of ergonomic risk scores among collectors, dismantlers and burners of e-waste using REBA, RULA, OWAS, QEC and the newly developed ergonomic assessment tool.

Risk Factor	Collector					Dismantler					Burner				
	REBA	RULA	OWAS	QEC	N.T (%)	REBA	RULA	OWAS	QEC	N.T (%)	REBA	RULA	OWAS	QEC	N.T (%)
Neck	2	2		18	1(69)	2	2		18	1(60)	3	3		18	1(19)
Trunk	3	3	3	44	1(69)	3	3	4	30	0(60)	3	3	3	32	1(19)
Upper limb	2	2	1	40	0(69)	4	4	2	44	2(26)	2	2	2	36	0(19)
Lower limb	2	2	7		0(69)	4	1	1		2(60)	2	2	5		0(19)
Force	2	2	3		1(69)	2	2	2		1(26)	1	1	1		1(19)
Repetition										1(60)					1(19)
Contact stress					1(69)					1(60)					1(19)
Vibration				9	1(69)				9	1(60)				4	1(4)
Overall	8	7	1			10	7	3			9	7	2		

Red- High risk for WRMSDs

Yellow- Moderate risk for WRMSDs

Green- Low risk for WRMSDs

N.T- New Tool

4.5 Reliability

4.5.1 Inter-observer reliability

There was high level of agreement (k>0.90) between observers for the assessment of neck postures. There was also higher level of agreement in coding trunk postures among dismantlers (0.957) compared to burners (0.855) and collectors (0.766). Lower level of agreement was observed in repetition and contact stress for dismantlers and burners as shown in Table 4.4.

Table 4. 4: Inter-observer agreement of three observers using the new tool to assess ergonomic exposures among collectors, dismantlers and burners.

		Collector	Dismantler	Burner
Domain	**Variable**	**Cohen Kappa (k)**	**Cohen Kappa (k)**	**Cohen Kappa (k)**
Posture	**Walking**	0.960	-	*
	Standing	*	*	1.000
	Sitting	*	1.000	*
	Neck	0.943	0.978	0.964
	Trunk	0.766	0.957	0.855
	Upper limbs	0.536	0.952	0.427
Risk factor	**Force exertion**	0.686	0.945	0.920
	Repetitive movement	0.930	0.549	0.632
	Contact stress	0.918	0.801	0.603
	Vibration	0.982	0.984	0.830

*Perfect agreement

-were not assessed because they were seldomly done by e-waste workers

4.5.2 Intra-observer reliability

There was high level of agreement (k>0.90) within each observer for the assessment of neck and trunk postures in all 3 job categories. Lower level of agreement was observed within observer 2 (0.942) as compared to observer 1 (0.766) for force exertion in collectors as shown in Table 4.5.

Table 4. 5: Intra-observer agreement of two observers using the new tool to assess ergonomic exposures among collectors, dismantlers and burners

		Collector		Dismantler		Burner	
		Cohen Kappa (k)		Cohen Kappa (k)		Cohen Kappa (k)	
Domain	**Variable**	**Observer 1**	**Observer 2**	**Observer 1**	**Observer 2**	**Observer 1**	**Observer 2**
Posture	**Walking**	1.000	0.991	-	-	*	*
	Standing	0.698	1.000	*	*	1.000	1.000
	Sitting	*	*	1.000	1.000	*	*
	Neck	1.000	0.992	1.000	1.000	1.000	1.000
	Trunk	0.978	0.985	1.000	0.906	1.000	0.994
	Upper limbs	0.794	0.887	1.000	0.986	1.000	1.000
Risk factor	**Force exertion**	0.942	0.766	1.000	0.985	*	*
	Repetitive movement	1.000	0.641	0.985	1.000	0.892	0.873
	Contact stress	1.000	0.901	1.000	1.000	1.000	0.967
	Vibration	0.989	0.865	1.000	1.000	0.887	1.000

*Perfect agreement.

-were not assessed because they were seldomly done by e-waste workers

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This study determined the validity and reliability of a newly developed observation-based tool for quantifying ergonomic exposures in unregulated work setting such as informal e-waste recycling. The findings of the study are discussed in this section. In addition, the findings are also compared and contrasted with similar studies in literature.

5.2 Face Validity

Face validity of the new tool developed by Acquah and colleagues 2020 was tested to determine if the items in the tool were relevant, clear and concise to users of the tool. Results from the study indicated a strong face validity of the new tool. The items on the tool were clear, concise and appropriately formatted. Comments from all three reviewers for face validity of the tool indicated that the structure of the tool in terms of construction, and the format was well thought out. The items were also related to the instrument's objective. The tool assesses the duration spent in awkward posture, force exertion, repetitive movement, contact stress, vibration, and manual material handling tasks. This is in contrast to other assessment tools like REBA, RULA, and OWAS that evaluates the magnitude of awkward postures or other ergonomic risk factors and rarely consider the duration. For these tools, more than one tool may be necessary to assess the risk of WRMSDs because none captures all the work-related characteristics of interest (Hignett & McAtamney, 2000; Karhu et al., 1977; McAtamney & Nigel Corlett, 1993;

Rahman, 2014). Existing tools also do not account for the variability in tasks which on the other hand is one of the main strengths of the newly developed ergonomic assessment tool by Acquah et al., 2020.

The printout was legible, and the instructions on the use of the tool were adequate. That notwithstanding, the interpretation of the codes was on a separate sheet and that could be problematic for users since they need to constantly refer to the coding sheets to ensure the right values have been captured on the observation sheet. Reviewers one and two suggested that the interpretation of codes should be on the coding sheet to make coding easier. In addition, images could be used to give users a better understanding of the postures being assessed. According to all the reviewers, the newly developed ergonomic assessment tool despite its appearance, was sophisticated and required extensive training for effective use of the tool. The use of the tool also necessitated the users undivided attention. The tool presents a challenge in categorizing force exertion, as has been the case with other observation tools in literature (Hignett & McAtamney, 2000; Karhu et al., 1977; McAtamney & Nigel Corlett, 1993) due to observation-based tools being inadequate in measuring the operator's physical strain in dynamic work contexts (Burdorf, 1992; Chen et al., 1989). In order to accurately assess force exertion as well as weights handled during manual material handling during the use of the new tool, reviewers suggested the weights of items being handled should be measured prior to observation and assessment of those tasks. Face validity is regarded the poorest kind of validity because it is informal and subjective, hence the need to validate the newly developed ergonomic assessment tool using other validity tests such as the construct and criterion validity.

5.3 Construct Validity

The existing literature was reviewed to ensure that items included in the design of the new ergonomic assessment tool were in line with known risk factors attributed to the development of WRMSDs. The developers of the new tool (Acquah et al., 2020) ensured that references of scientific literature from original papers, review papers and textbooks on occupational risk factors for musculoskeletal disorders were reviewed prior to development of the tool (Acquah et al., 2020; Acquah, et al., 2021). A review of existing literature during construct validation of the tool revealed that manual material handling risk factors had been assessed by #5 other authors whiles standing risk factor had been assessed by #13 other studies. In addition, walking, repetition, force exertion and duration had also been assessed by #8 other studies hence its inclusion as a domain in the new tool. This study corroborated with Plibel and Quick exposure checklist construct validity which reported that the inclusion of risk factors as domains in PLIBEL and QEC was based on a review of original and review articles as well as textbooks (David et al., 2008; Kemmlert, 1995).

5.4 Criterion Validity

The three categories of jobs at the e-waste site, namely: burning, collecting, and dismantling of e-waste were assessed using different ergonomic tools: rapid entire body assessment tool, rapid upper body assessment tool, quick exposure checklist and ovako working posture assessment system. Posture (neck, trunk, upper limbs, lower limbs), as well as risk variables (force exertion, repeated movement, contact stress, and vibration), were evaluated.

Blank spaces indicate that the related posture or risk factor was not assessed by the instrument used. Red highlight indicates high risk, yellow- moderate risk and green low risk. REBA evaluates posture (neck, trunk, shoulder, forearm, wrist, lower limbs) and other risk factors (force and contact stress). RULA assesses posture (neck, trunk, shoulder, forearm, and wrist; lower limbs are solely classified as supported or unsupported) as well as force. The OWAS system also evaluates posture (trunk, forearm, and lower limbs), as well as risk factor (force). QEC examines risk factor (vibration) and posture (neck, trunk, shoulder, and wrist). The new tool, on the other hand, evaluates posture (neck, trunk, upper and lower limbs) force exertion, repetitive movement, contact stress and vibration. It also takes into account the amount of time spent maintaining each posture and other ergonomic risk factors assessed as well as time spent in manual material handling tasks. Unlike QEC and the new tool, REBA, RULA, and OWAS provide a unified scoring system which is indicative of ergonomic risk. The newly developed ergonomic assessment tool however is still in the early stages of development and as such lacks a unified scoring system but rather estimates the proportion of time workers are exposed to various ergonomic risk factors during their work shift. In addition, REBA, RULA, OWAS and QEC estimates ergonomic risks using a subset of tasks performed by the worker. The new tool on the other hand provides a more detailed assessment of the workers tasks for an entire work shift. As such, the new tool is advantaged in its ability to account for the level of variability that exists in tasks performed during the entire work shift.

5.4.1 Criterion validation of collecting task

E- waste worker walks through the city, pulling a cart collecting e-waste from households or the streets. Ergonomic assessment of collecting task revealed high score for the neck, trunk, and upper limbs in all the ergonomic assessment tools used. This could be as a result of these domains being in non-neutral positions for long durations. The collector's neck was flexed majority of the time and trunk was mostly in about 20^{o}-45^{o} flexion whereas the upper limb was mostly in about 20^{o} extension accounting for the high scores in the new tool. QEC also reported a high score, which may be linked to maintaining these awkward postures for prolonged periods. QEC in scoring each risk factor takes into consideration an estimation of the duration in which the posture or risk factor was held and the number of times it was repeated accounting for its high scores for neck, trunk and upper limbs posture. The new tool indicated that walking and hauling carts account for majority of a worker's activities. The results were however contrasting in REBA, RULA and OWAS and could be attributed to REBA assessing static posture based on the degree of knee flexion without taking into account walking. RULA assesses only whether or not the worker's lower limbs were supported and OWAS although it assesses walking does not consider duration or repetitive movement. The new tool reported high ratings for lower limbs due to the duration spent walking in a working day. The weight of the cart and the objects on it contributed to the high force exertion reported by REBA, RULA, and OWAS. This was also evident in the new tool and present throughout collectors pulling their loaded collecting cart. According to results from the new tool, contact stress was present throughout the work duration from the pressure of the truck's handle applied to the hand during grasping. QEC assessment indicated that there was high vibration during the task of hauling the cart which was similar to findings from the new tool. REBA, RULA, and OWAS total scores indicated high risk and a need for reforms in the assessed task.

5.4.2 Criterion validation of dismantling task

Dismantlers are typically seated on a low stool, whiles dismantling end-of-life electronics with basic manual tools such as a hammer and chisel. Ergonomic assessment of dismantling task revealed high neck and trunk posture scores for all assessment tools used. QEC assessment for dismantling indicated very high scores, which could be linked to maintaining non-neutral neck and trunk postures for an extended period of time or repeatedly. Throughout the dismantling period, the neck and trunk of the workers were mostly sustained in nonneutral positions, but the upper limbs changed frequently. Upper limbs may be below the waist, between the shoulder and the waist, or above the waist. For this study, the most awkward upper limb posture was determined to be above the shoulder, which is associated with significant force exertion and accounts for a quarter of a dismantler's daily operations.

The low lower limb scores in RULA and OWAS were due to workers being seated most of the time during the dismantling process, however, REBA reported a high score because it does not consider sitting in the category of lower limb posture, thus, the high score was attributed to a high degree of knee flexion. Sitting to dismantle though considered as low risk accounts for more than half of a dismantler's daily activity, hence the high percentage in the new tool. REBA, RULA and OWAS recorded high force exertion but the new tool reported low scores because high force was exerted only one fourth of the time spent dismantling. This finding highlights the limitation of existing tools such as REBA, RULA, OWAS which may tend to overestimate exposures because these tools capture only a section of the work tasks.

For these tools, often the “worst case scenario” of the task under consideration is considered for assessment which may introduce some bias in the estimation of ergonomic risk. As has been shown with the use of the new tool, in highly variable tasks such as e-waste recycling, the “worst case scenarios” are often sustained for shorter durations relative to the entire work shift and this should be considered as such in the overall estimation of ergonomic risks. The new ergonomic assessment tool also captured the presence of contact stress from the use of hand-held tools such as the hammer in dismantling. The rapid and repetitive movement of the hand whiles dismantling resulted in high vibration scores in QEC as well as the new tool. With regards to the new tool, the vibratory was carried out for more than half of the entire work period. The overall scores for REBA, RULA, and OWAS were high indicating a high risk of WRMSDs.

5.4.3 Criterion validation of burning task

REBA and RULA both reported a high total score for burning task, indicating a high risk of musculoskeletal problems among workers, necessitating more inquiry and change implementation in burning task. OWAS score indicates that postures assumed during burning are damaging to the individual and that corrective action is required. REBA and RULA demonstrated moderate force exertion contrasting OWAS and the new tool's low scores. Burners exerted force when lifting items as well as turning and hitting them with a burning rod although this constituted a small fraction of their overall work shift. The new tool revealed that contact stress was present throughout the period of burning. QEC indicated moderate vibration, which is in contrast to the new tool's low score. This risk factor was present when burners hit the burning items with the long rod in order to extinguish the fire, however, this was seldom done which may be a reason for the low vibration scores in the new tool. The high lower limb scores in RULA can be attributed to the lower limb being unsupported. In burning, the burner used the long rod to flip the burning items whiles one lower limb was in neutral position and the other slightly flexed at the hip and knee joint accounting for the high scores in OWAS. REBA reported a moderate score attributed to the slight degree of knee flexion whiles turning the burning items. Burners had their trunk slightly flexed and twisted whiles burning items accounting for the high scores in REBA, RULA, OWAS and QEC, where as in the new tool this posture was held for a short period accounting for the low scores.

5.5.4 Advantages and disadvantages of ergonomic tools

Comparing all variables in the new tool to items in other ergonomic observation-based tools proved difficult. Some approaches, such as the OWAS (Ovako Working Posture Analysis System) created by the Ovako Oy Steel Co. in Finland, were primarily designed for the identification and assessment of unsuitable working postures (trunk, shoulder and lower extremity) and force (Karhu et al., 1977; Li & Buckle, 1999). Neck, elbow, and wrist postures, on the other hand, were not included. It also disregards repetition, contact stress, vibration, and the duration of body posture assumption or time activity for each risk factor (Takala et al., 2010).

Highett and Mcmurray created the Rapid Entire Body Assessment in 2000 to identify unexpected working postures among health care workers and other service industry employees (Hignett & McAtamney, 2000). Rapid Upper Limb Assessment (RULA) is a comparable instrument that examines upper extremity and trunk postures during work (McAtamney & Corlett, 1993). It differs from Rapid Entire Body Assessment (REBA) only in that it excludes lower limb postures (Hignett & McAtamney, 2000). Both are popular ergonomic aids, although they are constrained by the amount and complexity of body segments and details. Because the right and left sides are assessed individually, a lengthy application period is necessary, and it is not appropriate for jobs that demand frequent task modification. Its capacity to consider the duration, vibration, and frequency of things is likewise limited (Takala et al., 2010).

Li and Buckle created the Quick Exposure Assessment (QEC) in 1998 to assess risk of WRMSDs and to act as a foundation for ergonomic management. It was created for those who work in the field of occupational health and safety. The tool is simple to use, quick, and versatile, allowing it to examine more working postures of body segments such as the back, shoulder/upper arm, wrist/hand, and neck. Furthermore, it assesses repeated movement, force exertion, maximum weight handled, vibration, task visual demand, and task duration. Observers do not require extensive training, although they may experience difficulties if it is applied to highly varied work task (Li & Buckle, 1999a).

The new ergonomic assessment tool however assesses posture (neck, trunk, upper and lower limbs), force, repetition, contact stress, and vibration, as well as manual material handling activities like carrying, lifting, pushing/pulling a cart, and the proportion of time spent on each risk factor. The tool was scored based on the percentage of the time spent performing each risk factor in a day. This made comparison with other ergonomic assessment tools a challenge however, it makes it more suitable for quantifying risk in work environments both formal and informal.

5.5 Inter-observer agreement

5.5.1 Collectors

There was excellent agreement for walking, neck posture, contact stress, and vibration. It was simple to code because the neck posture was either neural or unneutral. Vibration and contact stress were either present or absent/negligible. The observers had a high level of agreement on trunk posture. The disparity in trunk posture ratings could be attributed to the challenge in distinguishing between neutral (<20º flexion) and slight trunk flexion (between 20º and 45º). Upper limbs and force exertion had moderate agreement among observers. Force exertion could also be the result of each observer assessing the amount of force a worker is exerting based on their own judgement. Distinguishing between moderate and severe force is challenging, particularly for observational coding of hand forces into multiple nominal categories (Latko et al., 1997). Poor upper limb scores are ascribed to the classification of posture into three groups, which can be difficult to recall.

5.5.2 Dismantlers

Sitting or lower limb posture is categorized into three groups, but each group has distinct characteristics that makes it easy to recognize and code, thus, the excellent level of agreement. Furthermore, the posture is maintained for long periods of time, so observers did not have to change codes frequently, which can be difficult. The neck, trunk, upper limb, force exertion, and vibration all had excellent agreement between the observers. Contact stress had a high level of agreement. Vibration and contact stress were easy to identify and code since dismantling tasks were performed with high force intensity using hammers and chisels. Repetition had a moderate level of agreement, which could be due to the difficulty of observers needing to count while analyzing other items in the new tool in a minute.

5.5.3 Burners

Standing or lower limb posture and neck posture demonstrated an excellent inter observer agreement, this may be due to them having only two categories, neutral and non-neutral which makes it easy to identify the posture and code. Trunk posture, vibration, repetitive movement, and contact stress all had a high level of agreement among observers. It is possible that trunk posture scores are due to less variable trunk posture. Vibration is also divided into two categories: present and absent, making it simple to code. Furthermore, it was not common; it was only present while the burners were attempting to extinguish the fire, allowing observers to easily determine if it was present or not. Repetitive movement can be difficult to code because observers had to count the repetitions while trying to focus on other risk factors and posture in under a minute. The frequent movement of upper limbs, particularly from a score of 0 (hands below waist) to a score of 1 (hands between waist and shoulder), may have made it difficult for observers to code, contributing to the low inter-observer reliability.

Overall, the Interobserver agreement of the new tool ranged from moderate to outstanding, which is similar to other ergonomic tools. The inter-observer reliability of REBA was found to be moderate without the upper arm category (Hignett & McAtamney, 2000). A study by David et al in 2005 also revealed that the inter-observer reliability for QEC was moderate (David et al., 2005). Karhu concluded in 1977 that the OWAS reliability test was fairly good (Karhu et al., 1977). The inter-observer reliability test for PLIBEL was assessed as fair to moderate (Kemmlert, 1995). Inter-observer reliability for dismantlers and burners is similar to Acquah and colleagues' earlier work where the inter- observer reliability test was carried out for 30minutes (Acquah et al., 2020).

5.6 Intra observer agreement

The new instrument, like other existing ergonomic tools such as OWAS, RULA and REBA, demonstrated excellent intra-observer agreement for both observers (Kee & Karwowski, 2007) but contrasts the intra- observer reliability of QEC which reported moderate agreement (David et al., 2005). The level of agreement within the two observers varied. Observer one reported excellent level of agreement in more variables than observer two. The few discrepancies in findings between observer one and two may be due to occupation. Unlike observer two who has a background in earth science and had no prior awareness of WRMSDs, risk factors, or ergonomic assessment tools when the study began, observer one is a physiotherapist with prior knowledge of WRMSDs, risk factors, and ergonomic assessment methods.

In addition, intra-observer agreement for the new ergonomic assessment tool was higher than inter-observer agreement, which corroborates with a study by Takala et al. in 2010 that reported that level of agreement is greater among observers than within them.

6.3 Limitations

1. Due to government's relocation of e-waste workers from the Agbogbloshie scrap yard at the time of the study, the reliability test was carried out using only video data. Comparison with direct field observations were not possible at the time of the study.

2. The newly developed ergonomic assessment tool estimates the proportion of a workers entire working time spent in awkward postures, repetitive movements, forceful exertion, contact stress and vibration exposures. The other ergonomic assessment tools used for comparison with the new tool often assesses ergonomic exposures via a combination of multiple risk factors for a snapshot of the workers shift thus, making comparison with the new tool challenging.

Finally, judging moderate vs. severe force, as well as, weight of items lifted or carried was also a challenge for observers.

CHAPTER SIX

CONCLUSION

6.1 Introduction

This study determined the validity and reliability of the newly developed ergonomic assessment tool developed by Acquah and colleagues (2020). This chapter presents a summary of the study, recommendations and limitations.

6.2 Summary of the study

Assessing the validity and reliability of an assessment tool is essential for modifications during the development of the tool. The aim of this study was to determine the validity and reliability of the newly developed ergonomic assessment tool. The study findings revealed that the tool has a good face validity, it is clear, concise and has a well laid out format according to users of the tool. The tool was also developed based on theoretical concepts from original and review articles and referenced accordingly. Comparison of the new tool with other ergonomic assessment tools showed varied overall results mainly due to the fact that existing ergonomic assessment tools provided an assessment of a snapshot of the workers task compared to the new tool which provides a more comprehensive assessment covering an entire day's shift. The new tool thus, provides a more detailed and less biased estimate of the overall exposure of the worker. The study also reported a moderate to high agreement between and within assessors who used the new tool.

6.3 Recommendations

The following recommendations are proposed based on the findings of this study.

6.3.1 Public Health

The new ergonomic assessment tool provides a reliable and detailed approach to investigate ergonomic exposures in unregulated and informal work environment. This assessment method can be extended to other unregulated work setting in Ghana where the physical demands of work predispose workers to physical risk factors which may be predictive of WRMSDs.

6.3.2 Future Research

1. Future Research should focus on the development of a scoring sheet for the new tool to provide a unified score.

2. Future research should determine the reliability of the tool using real- time field observations and compare findings with data presented in this study.

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https://doi.org/10.5271/sjweh.2876

APPENDIX I

FACE VALIDITY QUESTIONNAIRE

Name of User: …………………………………

	yes	No
Are the items in the tool clear and unambiguous?		
Is the tool difficult to use		
Are the words in the tool spelt correctly		
Are items spaced well?		
Are instructions adequate?		
Are items related to the purpose of the instrument?		
Is the printout legible		
Is the paper attractive		
Is the structure of the tool in a well-thought out format?		

APPENDIX II

ERGONOMIC EXPOSURE ASSESSMENT TOOL FOR UNREGULATED AND UNSTRUTURED E- WASTE RECYCLING

Worker ID: ……………………………………………………………………………

Day and date of observation: ………………………………………………………….

Job Category/Name: ……………………………………………………

Name of Worker / Telephone number: ……………………………………………….

Age: ……………………………………………….

Educational Status: …………………………………………………………….

Worker Anthropometry: Height (cms):……………………… Weight (kgs):………………

Hand Dominance: Right / Left/ Both (ambidextrous)

Years of work / Experience: …………………………………………………….

Work Schedule (start and end time): ………………………………………………….

Tools used: ………………………………………………………………………………….

Most difficult task performed: …………………………………………………….

Personal protective equipment used: ……………………………………………….

Work methods: …………………………………………………………………………….

Irregular activities: ………..

Coding Guide

POSTURE		OTHER RISK FACTORS		MANUAL MATERIAL HANDLING	
NECK	0 = Neutral	FORCE EXERTION	0 = Hand activity with low force exertion	LIFTING/ LOWERING	0 = Light weight 5kg or less
			1 = Hand activity with medium force exertion		1 = Moderate weight (6 to 10kg)
	1 = Non-neutral		2 = Hand activity with high force exertion		2 = Heavy weight (11-20kg)
					3= Very heavy weight (>20kg)
TRUNK	0 = Neutral	REPETITIVE MOVEMENT	0 = Low (<10x per min)	CARRYING	0 = Light weight 5kg or less
	1 = Moderate forward flexion and or lateral bending		1 = Medium (11-20X per min)		1 = Moderate weight (6 to 10kg)
	2 = Severe forward flexion and or lateral bending		2 = High (20>x per min)		2 = Heavy weight (11-20kg)
					3= Very heavy weight (>20kg)

UPPER LIMBS	0 = Hands below waist height		CONTACT STRESS	0 = very minimal or absent		
	1 = Hands/arms below shoulder height but above waist height			1 = contact stress present		
	2 = Hands/arms above shoulder height					
LOWER LIMBS	Walking	0=Normal/ordinary walking	VIBRATION	0 = very minimal or absent	PUSHING WHEEL BARROW	0 = empty
		1 = Walking and pulling a cart (or wheel barrow)		1 = vibration present		1 = loaded
	Standing	0 = Neutral				
		1 = Non-neutral (knees bent > 45^0)			PUSHING CART	0 = empty
	Sitting	0 = Hips and knees at about 90^0				1 = loaded
		1 = Hips and knees greater than 90^0			OTHER	0 = Absent
		2 = Hips and knees less than 90^0				1 = Present

Data Coding Sheet

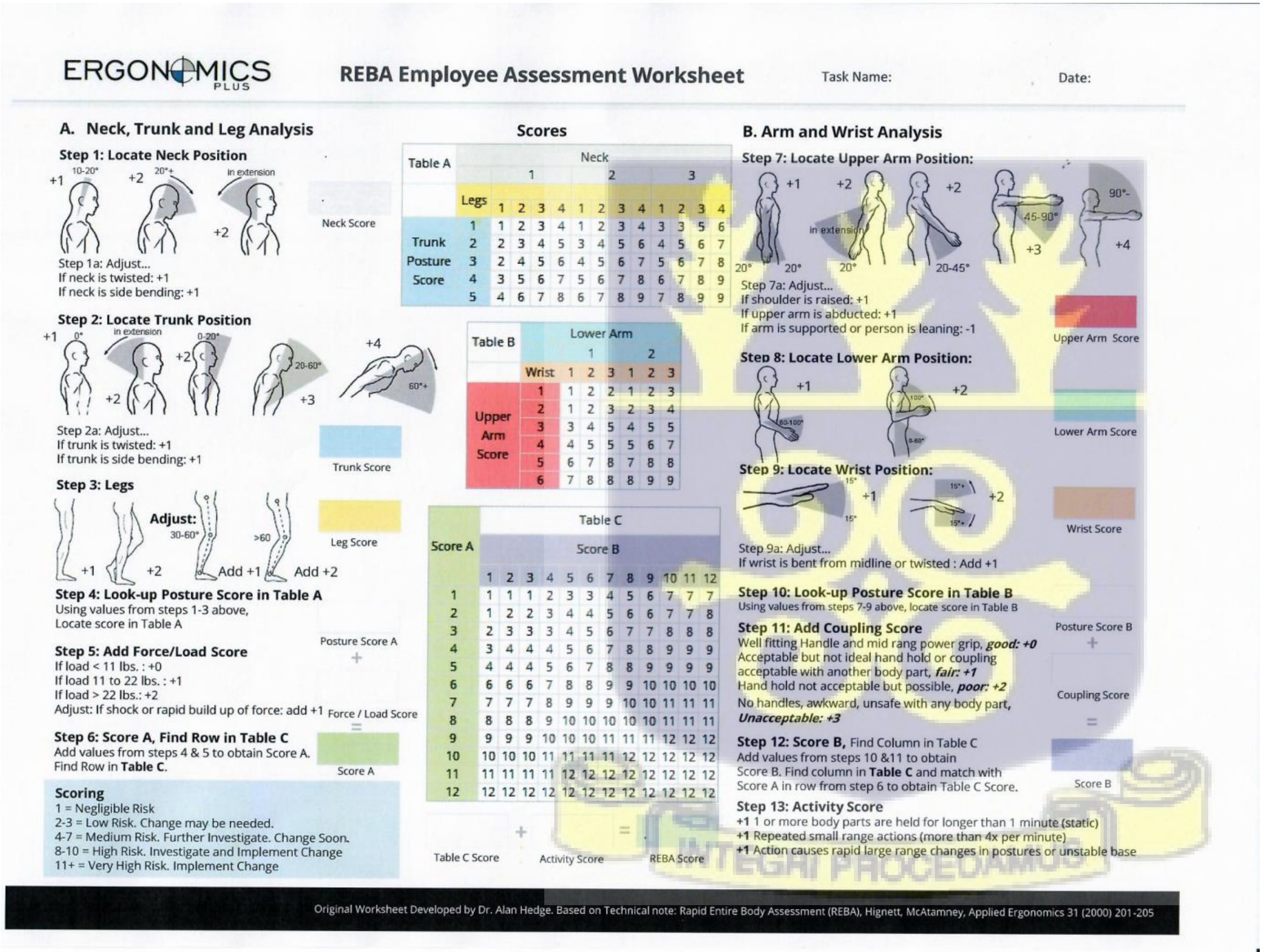
Worker ID:………….. Day no.:……………… Sheet no.:………………. Date:…………………………. Temp.:………………… ºC

		Observed video frame number (60 seconds interval)																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	13	19	20	21	22	23	24	25	26	27	28	29	30
POSTURE	**Walking**																														
	Standing																														
	Sitting																														
	Neck																														
	Trunk																														
	Upper limbs																														
RISK FACTORS	***Force exertion**																														
	***Repetitive movement**																														
	***Contact stress**																														

	***Vibration**																														
M M H	**Lifting/ lowering**																														
	Carrying																														
	Pushing wheelbarrow																														
	Pulling cart																														
OTHER	***other -** **(Kicking, stamping with feet, rattling of cart handle)**																														

APPENDIX III

RAPID ENTIRE BODY ASSESSMENT



ERGONOMICS PLUS

REBA Employee Assessment Worksheet

Task Name:

Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

+1 10-20°

+2 20°+

in extension +2

Neck Score

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position

+1 0°

in extension +2

+2 0-20°

+3 20-60°

+4 60°+

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs

+1

+2

Adjust: 30-60° Add +1

>60 Add +2

Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above,
Locate score in Table A

Posture Score A

\+

Step 5: Add Force/Load Score
If load < 11 lbs. : +0
If load 11 to 22 lbs. : +1
If load > 22 lbs.: +2
Adjust: If shock or rapid build up of force: add +1

Force / Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find Row in **Table C.**

Score A

Scoring
1 = Negligible Risk
2-3 = Low Risk. Change may be needed.
4-7 = Medium Risk. Further Investigate. Change Soon.
8-10 = High Risk. Investigate and Implement Change
11+ = Very High Risk. Implement Change

Scores

Table A		Neck 1				Neck 2				Neck 3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B		Lower Arm 1			Lower Arm 2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C

Score A	Score B 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score = REBA Score

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

+1 20° 20°

+2 in extension 20°

+2 20-45°

+3 45-90°

+4 90°+

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:

+1 60-100°

+2 100°+ 0-60°

Lower Arm Score

Step 9: Locate Wrist Position:

+1 15° 15°

+2 15°+ 15°+

Wrist Score

Step 9a: Adjust...
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B

\+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body part, ***Unacceptable: +3***

Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain Score B. Find column in **Table C** and match with Score A in row from step 6 to obtain Table C Score.

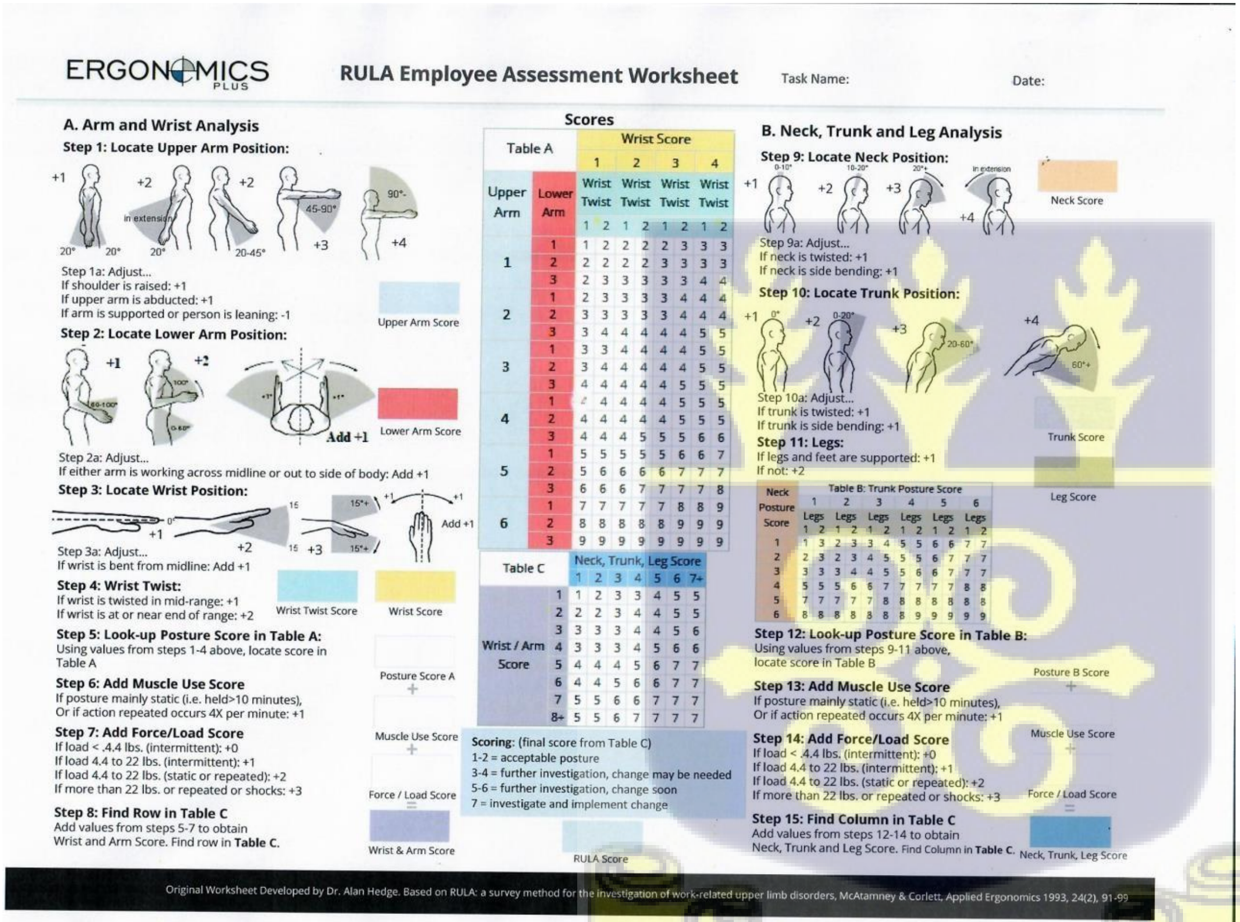
Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

APPENDIX IV

RAPID UPPER LIMB ASSESSMENT TOOL


ERGONOMICS PLUS

RULA Employee Assessment Worksheet

Task Name:

Date:

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:

Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Wrist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 7: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

Scores

Table A		Wrist Score 1		Wrist Score 2		Wrist Score 3		Wrist Score 4	
Upper Arm	Lower Arm	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C		Neck, Trunk, Leg Score 1	2	3	4	5	6	7+
Wrist / Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:

Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Neck Posture Score	Table B: Trunk Posture Score 1		2		3		4		5		6	
	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture B Score

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

Step 14: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

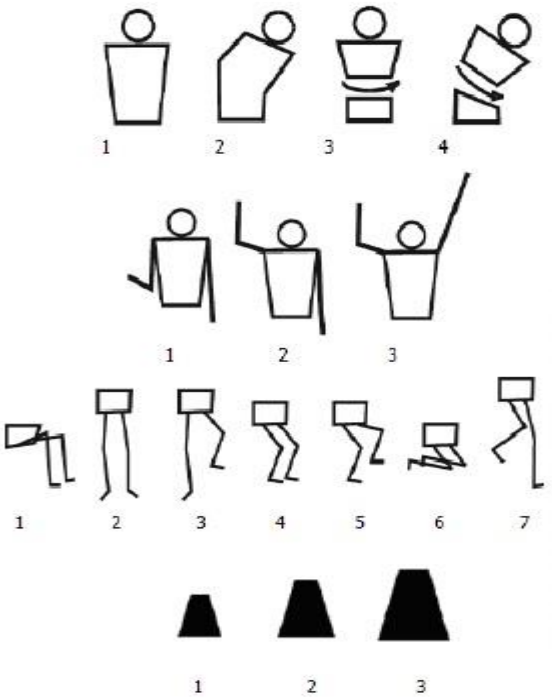
Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk, Leg Score

Original Worksheet Developed by Dr. Alan Hedge. Based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

APPENDIX V

OVAKO WORKING POSTURE ANALYSIS SYSTEM



back posture
1 – upright
2 – leaning forward
3 – flexuous
4 – leaning forward and flexuous

forearms posture
1 – both below elbow joint
2 – one above elbow joint
3 – both above elbow joint

legs work
1 – sitting position
2 – standing with legs upright
3 – standing with one leg upright
4 – standing with legs bent
5 – standing with one leg bent
6 – kneeling on one or both knees
7 – walking

external load volume for men [kg]
1 – below 10
2 – within the range 10-20
3 – above 20

back posture code	forearms position code	legs work code	external load volume code

APPENDIX VI

QUICK EXPOSURE CHECKLIST

Worker's name ____________________ Date ____________

Observer's Assessment

Back

A When performing the task, is the back
(select worse case situation)
- A1 Almost neutral?
- A2 Moderately flexed or twisted or side bent?
- A3 Excessively flexed or twisted or side bent?

B Select ONLY ONE of the two following task options:

EITHER

For seated or standing stationary tasks. Does the back remain in a static position most of the time?
- B1 No
- B2 Yes

OR

For lifting, pushing/pulling and carrying tasks (i.e. moving a load). Is the movement of the back
- B3 Infrequent (around 3 times per minute or less)?
- B4 Frequent (around 8 times per minute)?
- B5 Very frequent (around 12 times per minute or more)?

Shoulder/Arm

C When the task is performed, are the hands
(select worse case situation)
- C1 At or below waist height?
- C2 At about chest height?
- C3 At or above shoulder height?

D Is the shoulder/arm movement
- D1 Infrequent (some intermittent movement)?
- D2 Frequent (regular movement with some pauses)?
- D3 Very frequent (almost continuous movement)?

Wrist/Hand

E Is the task performed with
(select worse case situation)
- E1 An almost straight wrist?
- E2 A deviated or bent wrist?

F Are similar motion patterns repeated
- F1 10 times per minute or less?
- F2 11 to 20 times per minute?
- F3 More than 20 times per minute?

Neck

G When performing the task, is the head/neck bent or twisted?
- G1 No
- G2 Yes, occasionally
- G3 Yes, continuously

Worker's Assessment

Workers

H Is the maximum weight handled MANUALLY BY YOU in this task?
- H1 Light (5 kg or less)
- H2 Moderate (6 to 10 kg)
- H3 Heavy (11 to 20kg)
- H4 Very heavy (more than 20 kg)

J On average, how much time do you spend per day on this task?
- J1 Less than 2 hours
- J2 2 to 4 hours
- J3 More than 4 hours

K When performing this task, is the maximum force level exerted by one hand?
- K1 Low (e.g. less than 1 kg)
- K2 Medium (e.g. 1 to 4 kg)
- K3 High (e.g. more than 4 kg)

L Is the visual demand of this task
- L1 Low (almost no need to view fine details)?
- *L2 High (need to view some fine details)?

* *If High, please give details in the box below*

M At work do you drive a vehicle for
- M1 Less than one hour per day or Never?
- M2 Between 1 and 4 hours per day?
- M3 More than 4 hours per day?

N At work do you use vibrating tools for
- N1 Less than one hour per day or Never?
- N2 Between 1 and 4 hours per day?
- N3 More than 4 hours per day?

P Do you have difficulty keeping up with this work?
- P1 Never
- P2 Sometimes
- *P3 Often

* *If Often, please give details in the box below*

Q In general, how do you find this job
- Q1 Not at all stressful?
- Q2 Mildly stressful?
- *Q3 Moderately stressful?
- *Q4 Very stressful?

* *If Moderately or Very, please give details in the box below*

* *Additional details for L, P and Q if appropriate*

* L

* P