THE ERGONOMICS OF GARBAGE DISPOSAL

by

Frederick Fulton

Bachelor of Science in Kinesiology
University of New Brunswick, 2013

A thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

Masters of Science in Exercise Sport Science

in the Graduate Academic Unit of Kinesiology

Supervisor: Wayne J. Albert, PhD., Faculty of Kinesiology

Examining Board: J. Noble, PhD., Faculty of Kinesiology
J. Golding, PhD., Faculty of Forestry & Enviro. Management
T. McGarry PhD, Faculty of Kinesiology, Chair

This thesis is accepted by the

Dean of Graduate Studies

THE UNIVERSITY OF NEW BRUNSWICK

May, 2017

ABSTRACT

Introduction- Daily over 31, 000 (Stats Can, 2008) refuse workers deal with heavy and potentially hazardous waste, high cumulative loads from MMH tasks, and large amounts of energy expenditure. There is a gap in current literature in type, severity, and prevalence of musculoskeletal injuries (MSI) associated with this occupation. The specific research goals for this project were to quantify the biomechanical, neuromuscular and physical demands related to manual material handling during the typical day of a refuse worker.

Methods- Participants were fitted with a SenseWear armband to record energy expenditure over their day. Surface EMG was applied to the legs and back (see section 3.3.0-EMG) of the participant and MVC were taken pre-/post-shift. Video was taken of exterior (loading/MMH tasks) of the truck cab. Accelerometers were placed along the spine of the participant to calculate what percentage of the participant's maximum ROM was used throughout their shift.

Results- Average daily energy expenditure was 2696kCal ± 315 kCal. The bag lift had the largest percentage of awkward posture with respect to the trunk (Trunk flexion: 37.97%, Trunk Lateral Bend: 11.15%, Trunk Twist: 23.67%). The can dump had the largest percentage of awkward posture with respect to the shoulders (Right Shoulder Flexion: 44.36%, Right Shoulder Abduction: 20.45%, Left Shoulder Flexion: 40.02%). Dolly drag had the highest daily cumulative (and peak) L4/L5 compression: 0.53MN*s ± 0.01MN*s (4588.73N ± 1063.70N). Bag lift had the highest daily cumulative (and peak) L4/L5 joint anterior sheer: -0.03MN*s ± 0.02MN*s (-227.96N ± 48.96N).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Standing while driving is a task specific to refuse collectors in Fredericton, New Brunswick. Long periods of standing, repetitive strain, and other health related issues are a concern for refuse collectors (Wai, Roffey, Bishop, Kwon, & Dagenais, 2010). There is currently a gap in literature concerning the severity and prevalence of these issues. Large doses of vibration, awkward postures, heavy loads, and long shifts make refuse collection a very physically demanding occupation that places many different stresses on the worker's body (Okunribido, Magnusson, & Pope, 2006). These issues can lead to high rates of absenteeism, regular visits to health care, and claims made through workers' compensation which can be costly not only for companies, but for taxpayers as well. This research addressed the ergonomic concerns in refuse workers and quantified ergonomic concerns such as vibration dose, awkward posture, manual materials handling, and physiological factors associated with refuse collection. This is significant information as there is currently no published data quantifying the physical demands of this occupation.

1.1 Significance of the Research

There is a current gap in literature regarding the physical demands related to waste management. This research is important for the industry as many companies and their employees are unaware of the physiological and ergonomic demands associated with the occupation. This research looks to address this information gap and to encourage further research to better inform the waste management industry. This project addressed the physical demands associated with refuse collection by quantifying ergonomic concerns such as awkward posture, manual materials handling, and personal factors experienced by workers. The specific research questions for this project were:

1. Are there differences in biomechanical parameters related to the MMH of garbage bags, garbage cans, and dollies?
2. What are the physiological demands associated with this occupation?

2.0 LITERATURE REVIEW

Refuse collection is a highly repetitive manual material handling occupation. An average day requires the driver to remain standing both while driving and collecting refuse for eight hours. Through personal observation of the occupation, the repetitive work cycle entails driving between driveways, egress from the truck, handling garbage bags and cans of differing weight manually, loading garbage totes onto the mechanical arm, ingress to the truck and driving to the next driveway. This work cycle can take anywhere from 5 seconds to approximately 2 minutes depending on the amount of refuse at each stop. On average, each driver collected 10,000 lbs (4500 kg) of refuse per day. Ergonomically, the physical demands of this occupation are further challenged by various outdoor terrains affecting refuse placement and environmental conditions such as snow, ice, and extreme cold temperatures in the winter months. It is well understood that musculoskeletal injury (MSI) development has a multifaceted aetiology (reference). This study focused on three major risk factors, namely manual material handling (MMH), prolonged standing while driving, and physiological demand (energy expenditure).

2.1 MMH and Low Back Pain

Research has shown that regular MMH at work can attribute to low back pain (LBP) (Wai, Roffey, Bishop, Kwon, & Dagenais, 2010) and that there is a strong association between occupational lifting of loads greater than 10kg and 25kg and high rates of absenteeism due to LBP (Wai, Roffey, Bishop, Kwon, & Dagenais, 2010). Combined exposure of vibration and manual materials handling has shown to be the main contributor for the increased prevalence of LBP (Okunribido et al., 2006) making refuse collectors at high risk of developing LBP as both are common tasks associated with the occupation.

The National Institute of Occupational Safety and Health (NIOSH, 1992) suggests that the maximum single weight that can be lifted with two hands over the period of an 8-hour work day is 51 pounds (23 kg) during ideal lifting conditions. The ISO 11228 Standard suggests a two-handed lifting limit of 25 kg, with a cumulative load for the day not to exceed 10,000kg (Colombini, Occhipinti, Alvarez-Casado, & Waters, 2013). The maximum allowed weight of a garbage bag, imposed, but not enforced, by Fredericton City By-Law, is 40 kg. This weight is well above the recommended limit for both NIOSH and ISO standard.

High cumulative loads are also a concern in this industry. Worksafe NB suggests that any individual required to lift more than 10,000 kg in a work day is at severely high risk of MSI (WorksafeNB, 2015). A garbage truck is required to be emptied when the truck has reached its 10,000-kg capacity. Observations of the occupation and talks with company officials have shown it is not uncommon for some garbage truck drivers to empty their trucks multiple times a day – meaning the drivers have reached/exceeded the 10,000kg capacity and must unload before continuing their shift. This means that there are some individuals who are exceeding the cumulative load recommendations.

2.2 Prolonged Standing

Long periods of standing create compressive forces between the L3/L4 vertebrae. During standing the center of gravity (COG) is located ventral to the spine (figure 2.1) (Robinovitch, 2015). This creates a moment arm from the erector spinae (ES) out to the COG, meaning that the ES muscles must activate to maintain the body in an upright/standing position (Robinovitch, 2015). This creates compressive forces in vertebrae that equal about twice the weight of the body above the measured level (e.g., 700N in L3/L4 for a 70kg individual) (Robinovitch, 2015). If an individual bears a load in their hands, such as our refuse collector lifting a garbage bag, the compressive forces in the spine increase depending on weight of the load in the hands and on distance away from the body. These compressive forces can lead to severe LBP and can result in more complicated issues such as herniated discs if they are not addressed.

Figure 2.1- COG located ventral to spine when standing (recreated based on Robinovitch, 2015).

As previously mentioned, long periods of standing are common amongst refuse collectors as they are constantly egressing from the truck to dispose of the garbage. Refuse drivers in Fredericton are required to stand all day as they also stand while they drive between stops.

Dr. Callaghan and his associates from the University of Waterloo have been the most prolific regarding injury prevalence related to prolonged standing. They have shown that long periods of standing are related to both chronic LBP as well as developing LBP during the standing period. Despite relatively low magnitude of spinal loading during standing, there is still a high prevalence of LBP associated with long periods of standing (Gregory & Callaghan, 2008). In three separate studies, this research group found that a high percentage of individuals develop LBP during prolonged standing regardless of clinical status (Gallagher, Campbell, & Callaghan, 2014; Gallagher, Nelson-Wong, Callaghan, 2011; Gregory, & Callaghan, 2008). Nelson-Wong, Howarth, & Callaghan (2010) found that 40% of participants developed LBP during two hours of standing, while Gallagher et al. (2014) reported that between 40% and 70% of individuals who had no pre-existing conditions associated with LBP developed LBP after a prolonged bout of standing. Marshall, Patel, & Callaghan (2011) suggest that prolonged standing has been shown to be the most predictive factor of LBP development at work for both males and females.

These studies all used a prolonged continuous standing period of two hours. Refuse collectors are often required to stand for up to eight hours, therefore it is assumed that the previous findings of LBP development and musculoskeletal disorders would be magnified in the refuse collectors as time spent standing is increased by such a large margin.

A decrease in balance reactions during narrow base conditions and a reduced capacity to resist side-loads are both results of prolonged standing (Nelson-Wong et al., 2010). These are important for refuse collectors as they must be able to work on uneven and unpredictable work surfaces in the winter or when weather conditions are not ideal for working. Refuse collectors also primarily work on one side (the right) as it is quicker and easier for them to throw bags to the right after exiting the garbage truck.

A study by Gregory & Callaghan (2008) showed that 13 of 16 participants who had no previous symptoms of LBP developed low back discomfort after the two-hour standing task. Furthermore, hard surfaces (like the floor of a garbage truck) have been shown to elicit more movement due to discomfort when compared to a soft surface (Gregory & Callaghan, 2008). They also demonstrated that standing on a bare floor has been associated with higher perceived whole body and lower limb fatigue, as well as increased back extensor muscular fatigue when compared to standing on various types of mats or insoles (Gregory & Callaghan, 2008).

Gallagher, Nelson-Wong, & Callaghan (2011) reported that during an extended period of standing, participants increased their BW shift frequency and decreased average shift duration. LPB was also associated with the inability of individuals to control their balance during dynamic tasks, such as shifting into a single-leg stance (Gallagher, Nelson-Wong, & Callaghan, 2011).

In exploring whether sitting breaks between periods of standing would be a method for prevention/recovery of LBP, Gallagher et al. (2014) found that a 3:1 stand to sit ratio was not adequate in reducing LBP related issues.

2.3 Vibration and standing

Refuse collectors must stand for the duration of their shift with intermittent bouts of whole body vibrations as they drive the truck from stop to stop. Previous research has shown that in-vehicle vibrations can be harmful to the driver and can be linked to LBP (Hoy et al., 2005). Drivers who experience cases of whole body vibration are more than twice as likely to experience LBP when compared to controls who experience no vibration (Hoy et al., 2005). Back pain is also shown to be more severe for the drivers who experience vibration with 44% reporting severe back pain, compared to only 22% of controls reporting their pain as severe (Hoy et al., 2005). Research has shown that 45% of bus drivers had experienced LBP in the past 12 months due to vibrations occurring while driving (Alperovitch-Najenson et al., 2010). Research that looked at back pain in many different drivers who experience vibration found that 56% reported having previous LBP with 30% reporting having back pain occurring at the time of the study (Olanrewaju, Okunribido, Shimbles, Magnusson, & Pope, 2007). Regular and prolonged doses of vibration cause stress on the body and can often lead to low back pain, especially in conjunction with MMH tasks.

2.4 Previous Research on Refuse Collection

Although there has been little research done around refuse collection in North America, there has been previous research done on the refuse collection industry around the World. One of the main findings that many studies agree upon is that this is a physically demanding occupation (Presser et al., 2016; Frings-Dresen et al., 2007). Studies have found that refuse collectors average VO_2 Max is above 30% which is classified as upper range and defined as Hard Work (Presser et al., 2016; Frings-Dresen et al., 2007).

Due to the physically demanding nature of the occupation, it is not surprising to see that there is a high risk of musculoskeletal injuries (MSI) associated with refuse collection (Reddy & Yasobant, 2015; Kuijer et al. 2010). However, MSI are not the only concerns for refuse collectors. Refuse collectors are often exposed to different chemicals (Poulsen et al. 1995) which can attribute refuse collectors with a high risk of varying gastrointestinal diseases (Kuijer et al., 2010).

Previous studies have looked at the risk associated with different lifts (bags, cans, dollies) and have all agreed that the bag lift is the most detrimental of all the lifts (Cakit, 2015; Frings-Dresen et al., 2007; De Looze et al., 2007; Kuijer et al., 2004; Kuijer & Frings-Dresen, 2004; Kuijer et al., 2003; Kuijer et al., 1998). Cakit, 2005 measured lifting and dumping postures (weight of 9.5 kg) and found that lifting (bags) were more harmful to trunk than dumping (cans) but dumping (cans) more harmful for wrist/shoulders.

Frings-Dresen et al. 2007 looked at bags, mini-containers (dollies) and large containers (four wheeled crates) and found that bags resulted in the most awkward trunk posture and highest back loads. The mini-containers (dollies) pulling/pushing forces did not exceed NIOSH limits and were found to be the best solo option (Frings-Dresen et al., 2007). The large containers were found to be best used by pairs (Frings-Dresen et al., 2007). This agrees with previous research that also found the bag to be the most detrimental due to its high peak/cumulative forces, with the mini-container (dolly) being the most favourable lift (de Looze et al., 2007; Kuijer & Frings-Dresen, 2004).

Because of the bags being so harmful for refuse collectors, the Netherlands have completely removed plastic bags as a pick-up option (Kuijer et al., 2003). Furthermore, redesigned with the handle deeper and higher up and bigger wheels resultd in a reduced moment in the lower back (Kuijer et al., 2003).

2.5 Pilot Work

Pilot work was conducted to inform the field research outlined in this thesis by determining the postural and neuromuscular demands required of typical MMH tasks associated with refuse collection, namely dumping a garbage can into the truck, throwing garbage bags into the truck, and dragging the garbage tote (or dolly, as they are referred to in Fredericton) from the forward and rearward facing position and loading it on to the mechanical arm for emptying. Electromagnetic motion tracking and muscle monitoring using surface electromyography (EMG) were used to track muscle activity and body movements.

Methods

Five male participants (age 26.6 ± 5.68) were recruited from the Ergonomics class at UNB and performed three trials of each of the MMH tasks. Prior to lifting, each participant was instructed on technique and “normal” lifting patterns seen by refuse collectors. Prior to testing, electromagnetic motion tracking sensors (Liberty Latus, Polhemus, Vermont, USA) were attached to the center of mass of the participant’s hands, upper arm and back with double-sided tape and Velcro straps to measure the lifting kinematics. Surface electromyography (EMG) electrodes were placed on the skin (see section *3.3.0-EMG* and *3.3.1.EMG - Skin Preparation procedures* for electrode type, placement, and skin preparation procedures) over the muscles on the lower leg (tibialis anterior, gastrocnemius), lower back (erector spinae longissimus; electrodes placed at 2 finger width (3cm) lateral from the spinous process of the L1), shoulder/neck (trapezius descendens), and the upper arm (biceps brachii). A simulated standing driving/stopping task was performed at a mock steering wheel and accelerator pedal assembly before each lift to simulate driving a garbage truck and so that lower body movements could be assessed. Body motions and muscular activity were collected for the duration of the lifting task. Prior to starting the lift, a static calibration was used to establish relationships between each electromagnetic sensor and corresponding anatomical landmarks. These landmarks were then reconstructed based on the measured lifting kinematics, and used to determine the anatomical joint angles. Data was collected for the duration of the lift (approximately 10 seconds).

Results

Postural assessments were done using 3DMatch, a posture matching computer program that transposes the participant's body segments to a 3D model and determines the amount of time spent in neutral or awkward postures for the duration of the task. It was found that participants spent a significant amount of time (up to 50%) in non-neutral postures. This is known to increase MSI risk, especially when the loads required to be lifted exceed NIOSH or ISO safety limits (WorkSafe, 2015).

It was found that garbage disposal using a can requires severe postures for the highest percent of the work cycle and places unsafe loads on the spine for compression (above the NOISH recommended load). Neither the bag nor the dolly handling exceeded

NIOSH limits. This is likely due to the relatively low weight used in this study (5.4 kg for bags, 21.6 for dollies).

3.0 METHODS

3.1 Research Methods

3.1.1 Participants

Nine participants (age: 44 ± 12.3 years, height: 1.79m ± 0.05m, mass: 95.7 ± 17.9kg, BMI: 29.9 ± 5.5 kg/m^2, waist circumference (WC): 102cm ± 16 cm) participated in this study. All participants were recruited from a local refuse collection company. The study was approved by the University's research ethics board. Information about the study, ethics approval, and experimental protocol was shared with the participants before the study began. All participants signed an informed consent in advance of their participation.

3.1.2 Procedures

Participants arrived at the Trius facility one hour prior to the beginning of their scheduled shift. At this time, participants signed a form of informed consent approved by the University Ethics Review Board (Appendix A) and were given the opportunity to ask questions and familiarize themselves with the equipment and procedures.

The participant was then fitted with accelerometers (Analog Devices ADXL377Z) and the SenseWear arm band on their left arm (as per SenseWear instruction) to monitor energy expenditure during work hours as well as during leisure hours (pre/post work) for two complete days. GoPro cameras (HD Hero2) were mounted onto the exterior and interior of the truck to look at time spent driving/standing (interior) as well as the lifting techniques used when loading refuse into the truck (exterior).

After the participant and their truck were fitted with all the necessary instrumentation, the participant performed two pre-work standing grip strength measurements with a hand dynamometer (following CSEP assessment guidelines). They then performed 3 range of motion (ROM) movements (Spine Flexion ROM, Trunk Flexion ROM, Trunk Full ROM) to determine max range of motion.

Spine Flexion ROM is when the participant flexes their spine to its max ROM. This was accomplished by the participant flexing forward as far as they could without hinging from the hips. Trunk Flexion ROM was performed by the participant flexing as far forward as they could while hinging from the hips (e.g., to touch one's toes). Trunk Full ROM involved four movements one after the other. The four movements were: Trunk Flexion (bend forward as far as they could), Trunk Extension (bend backwards as far as they could), left trunk lateral bend (bend to the left as far as they could), right trunk lateral bend (bend to the right as far as they could). ROM was measured using accelerometers that were placed along the spine of the participant.

A rate of perceived discomfort (ROPD) questionnaire was administered through the EVAS application on an iPad. Data was collected for one hour (the beginning of their shift). The ROPD questionnaire was administered again and the participant continued daily duties. The researcher administered the ROPD questionnaire again at 1:00pm. Data was collected for one hour (at the end of their shift) to examine any changes that occurred. The participant and researcher returned to the facility where the ROPD questionnaire was administered a last time. Two post-work grip strength measurements were taken. The participant was given a healthy lifestyle questionnaire and the Par-Q to be completed on their own time (see appendices D & E) at which point the data collection period was concluded.

All collections were conducted in the same side-loading disposal truck equipped with a mechanical arm to lift garbage dollies.

Figure 3.1 Side loading refuse truck

Figure 3.2 Close up of Loading area

Figure 3.3 Close up of standing area

Ground to Hopper Opening (A) 122cm
Ground to Dump Lever (B) - 76cm
Ground to Step (C) – 32cm
Step to Truck Floor (D) – 7cm

3.2 Experimental Protocol

3.2.1 Instrumentation

3.2.1.1 Video

Videotaping occurred within the cab of the disposal truck as well as outside the truck in order to capture the changes in standing posture and manual material handling postures, respectively.

Figure 3.4. GoPro mounting position for windshield (standing/driving)

Figure 3.5. Go pro mounting position for outside (MMH tasks)

All recording using the GoPro (HD Hero2) were recorded at 720p (30fps). Video was collected to capture body posture that was used to determine average and cumulative time spent driving the truck, average and cumulative time outside of the truck (throwing bags/dragging dollies), average number of loads per stop, average number of stops per day, and technique of drivers dragging dollies and throwing bags.

3. 2.1.2 Force Transducers

Garbage bags and cans were weighed and the required force to move the dollies was recorded using a NK series Analog Force Gauge. This was completed by the researcher post participant data collection (researcher went around neighbourhoods collecting weights of bags, cans, and dollies after all participant data collection had been completed). This provided average, cumulative, and peak loads to be used in the biomechanical modeling. A spring-loaded hand dynamometer (Baseline Digital Smedley Spring Hand Dynamometer) was used to measure grip strength before and after the shift.

3. 2.1.3 Accelerometers

Three tri-axial accelerometers (Analog Devices ADXL377Z) were placed along the participant's spine (C7, T8, and S1) using hypoallergenic Hypafix© tape. These accelerometers were used to calculate what percentage of the participant's maximum range of motion they used over the course of the day and have a sampling rate of 2048Hz.

Figure 3.6. Tri-axial accelerometer (Analog Devices ADXL377Z)

3.2.1.4 SenseWear Armbands

SenseWear armbands (Body Media, Pro2) were worn on the left upper arm to assess physiological changes that occur throughout the duration of the tasks. These armbands have a three-axis accelerometer that can detect motion and number of steps taken throughout the day, and sensors that measure Galvanic skin response, skin temperature, and heat flux. Drivers wore these armbands throughout the day and energy expenditure was recorded for each driver. High energy expenditure rates were expected due to the physical demands of this occupation. Participants continue to wear the armbands for two days after the data collection so that at home values are represented as well.

3.3 Data Processing

3.3.1 Posture Assessment

Exterior video was collected in 15-minute segments for one hour total both before and after lunch. Exterior video was cut and organized using Pinnacle Studios 18. It was cut to remove times when the refuse collector was not present (driving, getting refuse located away from/on other side of the truck). Each 15-minute video clip was then broken down into the three lifts (bag toss, can dump, and dolly drag). This means that for each 15-minute collection there were 3 separate files to analyze: 0-15min bag toss, 0-15min can dump, 0-15min dolly drag; 15-30min bag toss, 15-30min can dump, 15-30 min dolly drag; etc. The video was then processed using Virtual Dub (v1.10.4) to remove audio and reduce the framerate to 3fps. This allowed for easier analyzing within the posture match program (3D Match, Callaghan, 2008). Previous research has found that the posture matching program used in this study is a valid tool and accurately represents actual body angles (Sutherland et al., 2007; Sutherland et al., 2008).

3.3.2 Force Transducers

The researcher went from house to house along a pick-up route and weighed 15 bags, 15 cans, and measured 30 dolly drag forces (15 with wheels engaged and 15 without). This data was inputted into excel and an average bag weight, can weight, and dolly drag force was computed. These averages were used in the posture matching program.

3.3.3 SenseWear

SenseWear armband data was inputted into the SenseWear software. SenseWear armbands have three sensors to monitor physical activity: accelerometer (measures movement), heat flux (measures the amount of heat being produced and the rate at which it is being produced), galvanic skin response (measures the conductivity of the skin and the dilation of sweat glands). This device, along with the software provided by SenseWear, takes all of this information and runs it through proprietary equations (unable to obtain) and cross-references those equations to return values such as average total energy expenditure (TEE), average active energy expenditure (AEE), average number of steps taken daily, and METs. Johannsen et al. (2010) showed that the SenseWear armband is a valid tool for measuring activity.

3.3.4 Accelerometers

Code was created using MatLab (McKinnon & Rae, 2015) to process the accelerometer data. This code takes the participants' max ROM (calculated from the movements collected at the beginning of the day by researcher) and calculates what percentage of the subject's max ROM was used throughout the day (during daily work tasks).

3.3.5 ROPD/eVas

An iPad app for visual analog scale (eVas) was used to collect participants' perceived pain or discomfort experienced throughout the course of the day. Time points 1, 2, 3, and 4 correspond to before the shift began, one hour after they began their shift, one hour prior to the end of their shift, and after they had completed their shift, respectively. Data from the application was put into excel to see if there were any changes in discomfort for different body parts throughout the day.

3.3.6 Grip Strength

Pre/Post-work grip strength measurements were taken using a hand-grip dynamometer. From a standing position, participants were asked to take the hand grip dynamotor in their hand and put their arm in a comfortable position at their side. They were then told to squeeze as hard as they could for approximately two seconds. The measurement was taken and the procedure was repeated. The two measurements for pre/post respectively were put into excel and averaged. Pre/post differences were then calculated for each subject.

3.4 Data Analysis

3.4.1 Posture Assessment

3.4.1.1 Posture

Processed videos were transferred into 3D Match. This allowed the researcher to analyze body segment angles frame-by-frame throughout the duration of the lifts. From this, the percentage of time spent in neutral and non-neutral postures was computed.

Video clips of each task (bag toss, can dump, dolly drag) were analyzed frame-by-frame and then the postures from the video were matched to a set of pre-determined posture categories (see Appendix E), viewed in 3DMatch on the computer screen. Posture categories include: trunk flexion, trunk lateral deviation, trunk rotation, neck flexion, neck lateral deviation, shoulder flexion, shoulder abduction, and elbow flexion. Trunk flexion was represented by six posture categories from −30 to 130 degrees. The frontal and transverse planes of the trunk motion were each represented by six categories. Similar bin selections are conducted for the neck flexion (four categories), neck lateral bend (four categories), flexion/extension of the right and left elbow (three categories), and flexion/extension (six categories) and abduction of the right and left shoulder (four categories). Each category was developed from previous posture-based tools and by considering the range of motion for each joint. 3DMatch also generates information regarding time and percent of work cycle spent in principal joint posture. The height and body mass of each participant were put into 3DMatch in order to develop customized models for each driver.

A paired t-test was done between pre- and post-shift to see if any posture changes occurred throughout the day. A single factor ANOVA was also completed to assess any differences between lifts (Bag, Can, Dolly) for each body segment (Trunk Flexion, Trunk Lateral Bend, Trunk Twist, Right Shoulder Flexion, Right Shoulder Abduction, Left Shoulder Flexion, Left Shoulder Abduction, Neck Axial Twist). A Bonferroni adjustment was made to correct for multiple comparisons and to avoid type-1 errors.

3.4.1.2 Peak and Cumulative loads

3DMatch uses the postures from the posture matching process to estimate the location of the segments based on their angular orientation. The program uses the weight of each segment multiplied by its distance from the axis of rotation (shoulder or lower back) to provide a simple $r \times F$ to calculate joint (moments). Throughout the posture matching process the average weight for each of the lifts was inputted into the corresponding hand whenever the refuse collector was seen to bear a load. From this, shoulder, low back peak, and cumulative loads were computed by task (bag lift, can dump, dolly drag). The cumulative load for each activity was determined providing daily and weekly cumulative loading exposures.

A single factor ANOVA was completed for lumbar loading to asses any differences in L4/L5 daily cumulative compression, L4/L5 peak compression, L4/L5 daily cumulative joint anterior sheer, and L4/L5 peak joint anterior sheer between the three lifts (Bag, Can, Dolly).

3.4.2 Force Transducers

Weights of 15 bags, 15 cans, and 30 dolly drag forces (15 with wheels engaged, 15 without wheels engaged) was entered into excel. These weights were then averaged and used in the posture matching program.

3.4.3 SenseWear

Daily average total energy expenditure (TEE), average active energy expenditure (AEE), and average number of steps taken daily were calculated and averaged between all subjects using the SenseWear software. To get a better sense of how strenuous the occupation was, the researcher calculated the Physical Activity Level (PAL) for each subject (Shetty, 2005). The basal metabolic rate (BMR) for each participant was calculated using the equation: $[BMR = (10 \times weight) + (6.25 \times height) - (5 \times age) + 5]$ (Mifflin & St. Joer, 1990). The calculated BMR was added with the AEE from the SenseWear data to get and overall energy expenditure (EE): $[EE = BMR + AEE]$. From this, PAL was calculated by dividing EE and BMR: $[PAL = EE \div BMR]$ (Shetty, 2005). This calculated PAL would give a good representation of how strenuous the occupation would be (Shetty, 2005).

3.4.4 Accelerometers

The percent range of trunk motion that each participant used while completing their daily work routines was determined by comparing the daily recordings to the pre-work measurements of maximum trunk motions in all three primary axes.

3.4.5 eVas

The majority of participants showed no signs of pain throughout the day. For those that had pain occur, a paired t-test was completed to see if there was any significant difference as the day went on (Appendix-H).

3.4.6 Grip Strength

A paired t-test was run to determine differences in pre/post grip strength recordings.

4.0 Results

4.1 Subject Information

The average age of the participants in this study was 43.9 ± 12.3 years old. The average BMI was 30.0 ± 5.5 kg/m^2 which is considered on the lower end of obesity. Lastly, the average truck weight (the weight of refuse collected at the end of the day) was 8862Kg ± 1414Kg which was lower than expected after talking to different drivers and management.

The physical activity level and number of steps taken daily for each participant are represented in Table 4.2. The average PAL was 1.91 ± 0.20 which is considered moderate to strenuous activity (Shetty, 2005). The average number of steps taken was 12856 ± 1846 which is considered "highly active" (Tudor-Locke & Bassett Jr, 2004).

Table 4.1 Subject anthropometric measures and truck weight at end of day (TW)

	Avg	SD
Age (yrs)	43.9	12.3
Height (m)	1.79	0.05
Weight (kg)	95.7	17.9
BMI (kg/m^2)	30.0	5.5
WC (cm)	102	16
TW (KG)	8862	1414

Table 4.2 Pal and # of Steps for each participant (SenseWear)

Subject	PAL	# of Steps (Daily)
01	1.90	11845
02	1.83	12025
03	1.52	12963
04	2.00	10091
05	2.20	12292
06	1.92	14786
07	2.19	16911
08	1.80	12834
09	1.88	11958
Avg	1.91	12856
SD	0.20	1846

4.2 Grip Strength

The average grip strength recorded before the participant's shift was 49.3Kg ± 3.0Kg. The average grip strength recorded after the participant's shift was 48.7Kg ± 4.5Kg. This gives an average difference (pre-post) of -0.6Kg ± 2.1Kg and a p-value of 0.53 after running a paired t-test.

Table 4.3 Pre/Post grip strength and change in grip strength

Sub	01	02	03	04	05	06	07	08	09	AVG	SD
Pre (Kg)	48	51	50.5	42	50	55	45	47.5	55	49.3	3.0
Post (Kg)	46	50	48	45	48	56.5	41	49	55	48.7	4.5
Diff. (Kg)	-2	-1	-2.5	3	-2	1.5	-4	1.5	0	-0.6	2.1
	p-value: 0.53			t-Stat: 0.81				DoF:8			

4.3 Force Transducers

Force transducers were used to measure the average weight of the bags and cans (table 4.3), as well as the average dragging force required to move the dolly (with/without wheels engaged) (Table 4.3). These measurements were used in the posture assessment program to compute cumulative and peak loads for each of the lifts.

Table 4.4. bag weights, can weights, and dolly drag forces

	Bag	Can	Dolly Drag (No wheels)	Dolly Drag (Wheels)
	6.67	9.7	21.5	8.46
	7.64	13.99	23.34	9.5
	5.06	12.28	33.21	8.56
	5.2	9.64	17.64	8.42
	7.21	15.18	13.56	8.65
	7.16	12.16	20.24	8.31
	8.42	13.29	20.52	9.24
	8.49	12.95	16.42	7.92
	4.96	9.5	12.34	7.98
	8.5	12.2	17.34	9.86
	7.42	14.14	19.52	7.86
	7.51	13.41	16.66	7.54
	4.76	15.75	21.2	6.97
	8.47	13.46	13.2	8.15
	7.13	12.91	16.85	9.51
Avg	6.97	12.70	18.90	8.46
SD	1.31	1.83	4.93	0.77

4.4 Posture Assessment

The average time spent in neutral, mild and severe non-neutral postures were determined for each lifting task and are presented in figures 4.1 - 4.9, respectively. The posture categories are based on the work of Punnett et al. (2003) and are as follows: 1) trunk flexion: mild (20°-45°), severe (>45°); 2) trunk lateral bend: mild (15°-30°,), severe (>30º); 3) trunk twist: mild (15°-30°), severe (>30°); 4) shoulder flexion: mild (20°-90°), severe (>90°); 5) shoulder abduction: mild (45°-90°), severe (>90°); 6) shoulder adduction: (>10°); 7) neck axial twist: mild (15°-30°), severe (>30°). The percent of time spent in the bag lift, can dump, and dolly drag for the participants were 16%, 19%, and 66% respectively. Meaning that they spent more time completing the dolly drag task.

4.4.1 Pre-lunch Condition

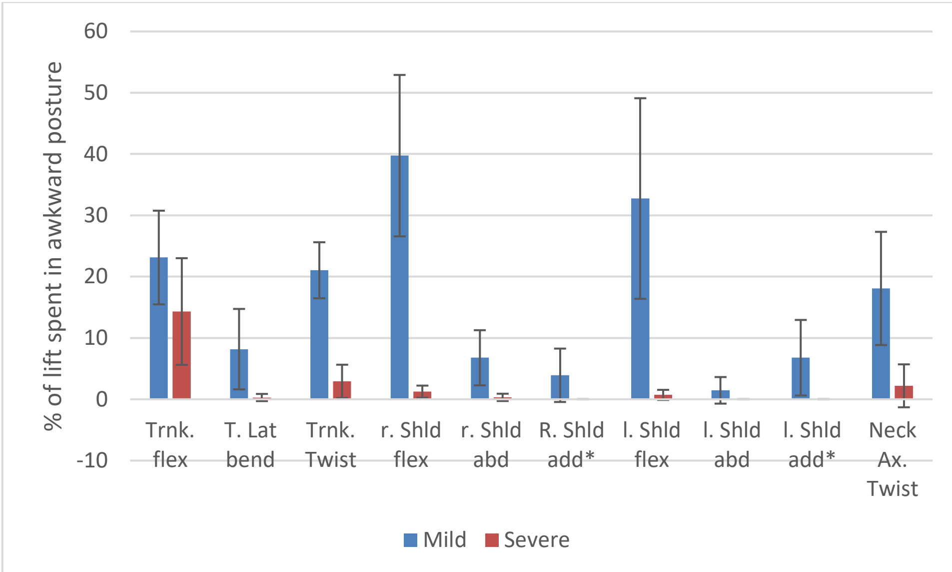


Figure 4.1 Average % of time spent in awkward posture and standard deviation- Bag

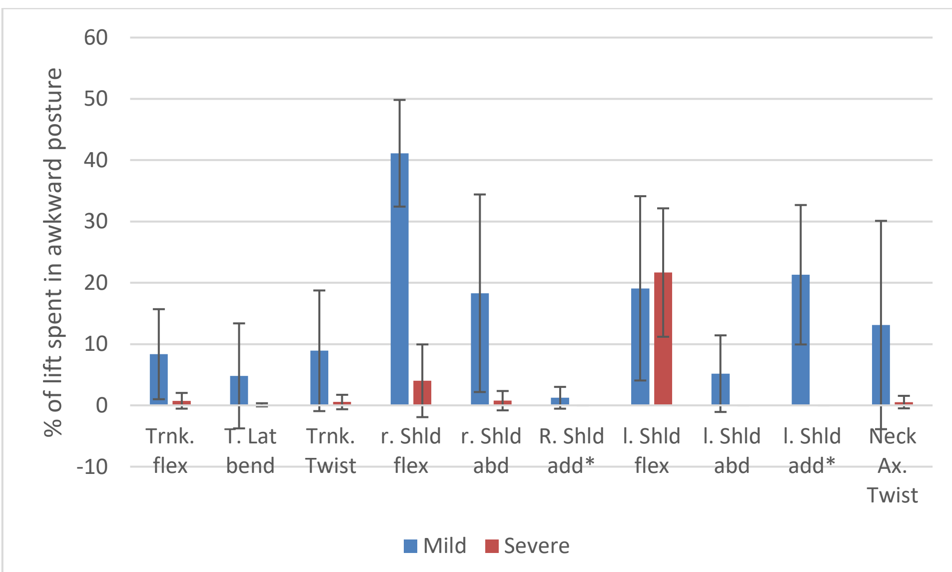


Figure 4.2 Average % of time spent in awkward posture and standard deviation- Can

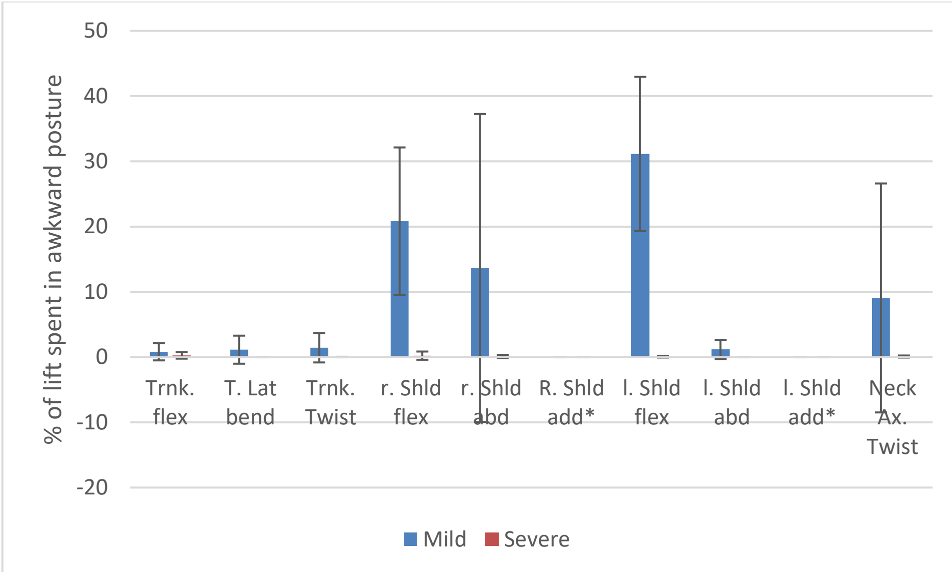


Figure 4.3 Average % of time spent in awkward posture and standard deviation- Dolly

4.4.2 Post-lunch Condition

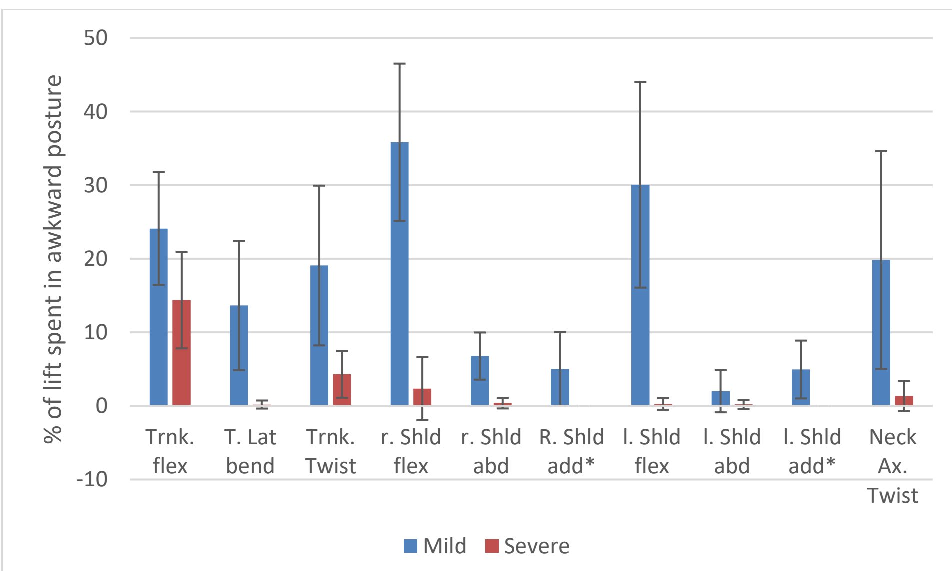


Figure 4.4 Average % of time spent in awkward posture and standard deviation- Bag

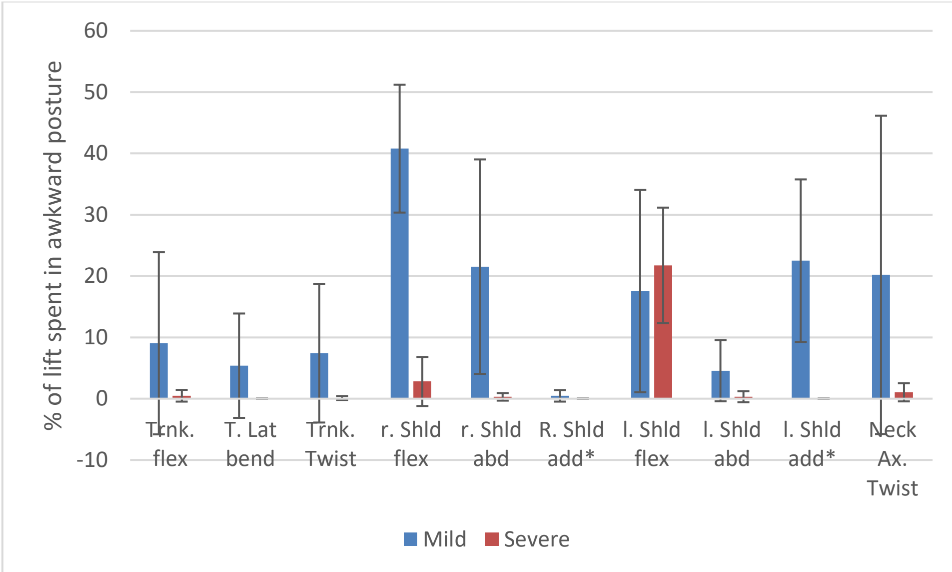


Figure 4.5 Average % of time spent in awkward posture and standard deviation- Can

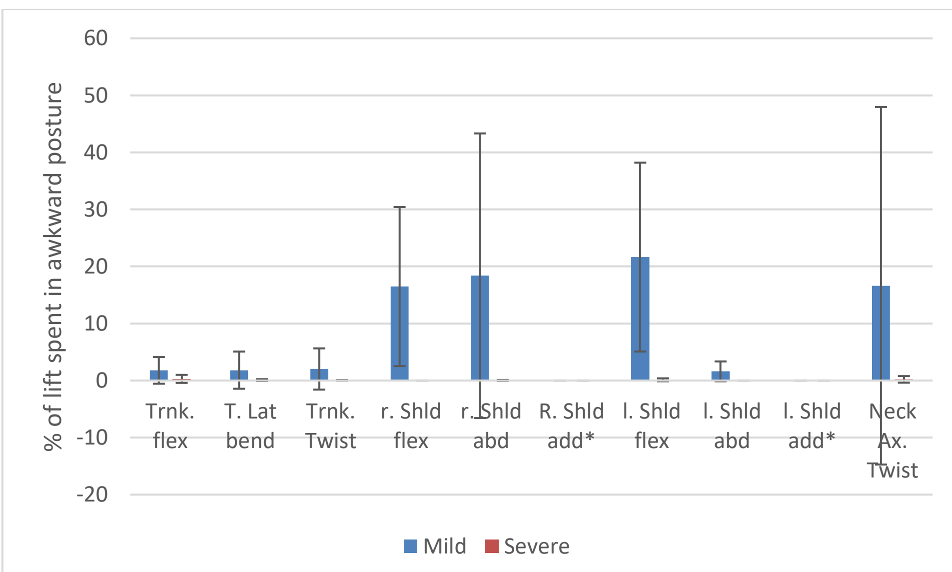


Figure 4.6 Average % of time spent in awkward posture and standard deviation- Dolly

4.4.3 Combined (Pre & Post)

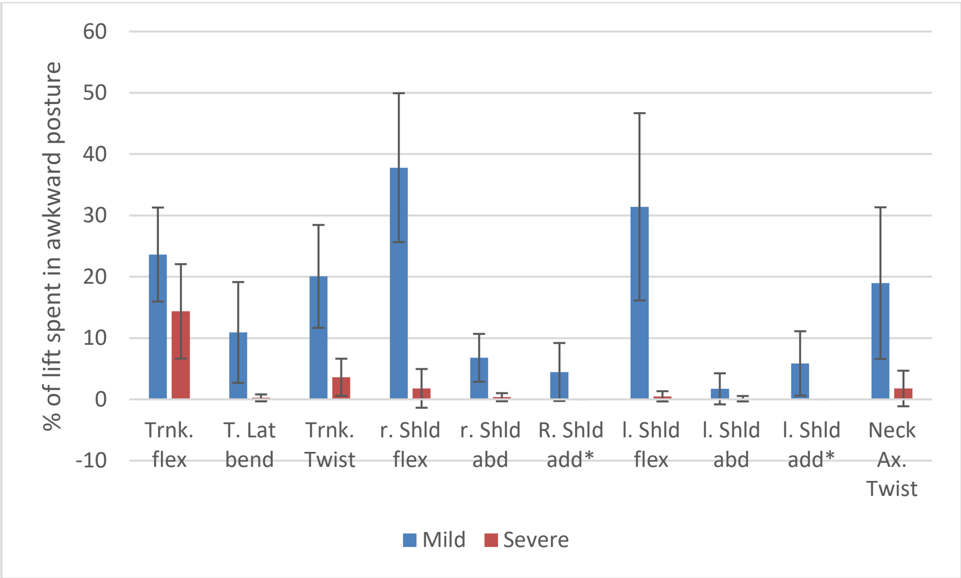


Figure 4.7 Average % of time spent in awkward posture and standard deviation- Bag

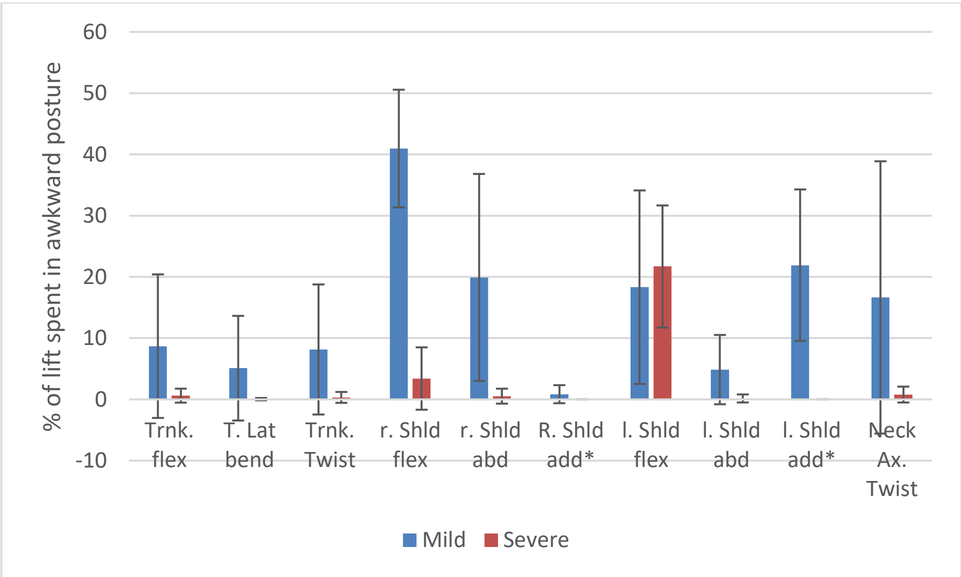


Figure 4.8 Average % of time spent in awkward posture and standard deviation- Can

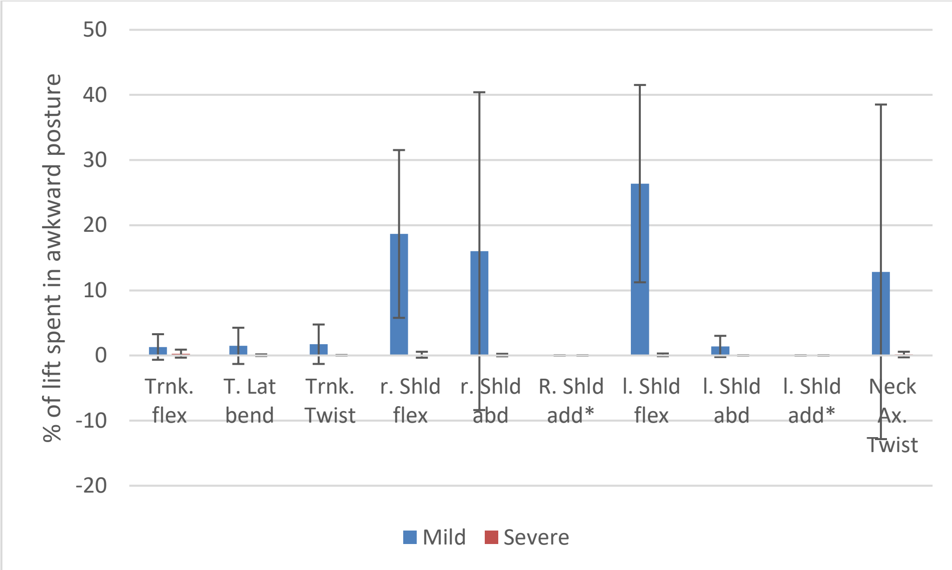


Figure 4.9 Average % of time spent in awkward posture and standard deviation- Dolly

4.4.4 Post-Pre difference in % awkward posture

Post-pre differences were calculated for each lift and a paired t-test was run to see if there were any significant differences in lifting patterns between the pre-lunch condition and the post lift condition. Table 4.5 - Table 4.10 show that there were no significant differences observed in lifting between the two conditions.

Table 4.5 Difference in % awkward posture between pre/post conditions (post-pre) for the bag lift

Posture	Trnk. flex	T.Lat bend	Trnk. Twist	r.Shld flex	r.Shld abd	R.Shld add*	l.Shld flex	l.Shld abd	l.Shld add*	Neck Ax.TW
Mild	1	5.47	-1.95	-3.89	0.01	1.11	-2.68	0.54	-1.83	1.76
Severe	0.07	-0.1	1.37	1.1	0.08	0	-0.44	0.21	0	-0.85

Table 4.6 p-value for difference in % awkward posture between pre/post conditions (post-pre) for the bag lift

Posture	Trnk. flex	T.Lat bend	Trnk. Twist	r.Shld flex	r.Shld abd	R.Shld add*	l.Shld flex	l.Shld abd	l.Shld add*	Neck Ax.TW
Mild	0.795	0.194	0.682	0.525	0.997	0.442	0.745	0.796	0.289	0.8
Severe	0.979	0.705	0.189	0.481	0.844	1	0.373	0.347	1	0.32

Table 4.7 Difference in % awkward posture between pre/post conditions (post-pre) for the Can Dump

Posture	Trnk. flex	T.Lat bend	Trnk. Twist	r.Shld flex	r.Shld abd	R.Shld add*	l.Shld flex	l.Shld abd	l.Shld add*	Neck Ax.TW
Mild	0.69	0.57	-1.51	-0.34	3.25	-0.77	-1.54	-0.61	1.2	7.09
Severe	-0.27	-0.09	-0.44	-1.2	-0.47	0	0.08	0.32	0	0.5

Table 4.8 p-value for difference in % awkward posture between pre/post conditions (post-pre) for the can dump

Posture	Trnk. flex	T.Lat bend	Trnk. Twist	r.Shld flex	r.Shld abd	R.Shld add*	l.Shld flex	l.Shld abd	l.Shld add*	Neck Ax.TW
Mild	0.905	0.881	0.159	0.934	0.526	0.095	0.533	0.72	0.743	0.244
Severe	0.337	0.347	0.321	0.396	0.425	1	0.977	0.347	1	0.238

Table 4.9 Difference in % awkward posture between pre/post conditions (post-pre) for the Dolly Drag

Posture	Trnk. flex	T.Lat bend	Trnk. Twist	r.Shld flex	r.Shld abd	R.Shld add*	l.Shld flex	l.Shld abd	l.Shld add*	Neck Ax.TW
Mild	0.96	0.69	0.6	-4.35	4.72	0	-9.48	0.44	0	7.55
Severe	0.02	0.09	0.02	-0.22	-0.07	0	0.07	0	0	0.13

Table 4.10 p-value for difference in % awkward posture between pre/post conditions (post-pre) for the dolly drag

Posture	Trnk. flex	T.Lat bend	Trnk. Twist	r.Shld flex	r.Shld abd	R.Shld add*	l.Shld flex	l.Shld abd	l.Shld add*	Neck Ax.TW
Mild	0.13	0.139	0.345	0.298	0.39	1	0.094	0.417	1	0.173
Severe	0.935	0.169	0.309	0.347	0.256	1	0.177	1	1	0.446

4.4.5 Between-lift (bag, can, dolly) Statistical Analysis

A single-factor ANOVA was run to check for significant differences in % awkward posture between each lift (bag, can, dolly) for each body segment (Trunk Flexion, Trunk Lateral Bend, Trunk Twist, Right Shoulder Flexion, Right Shoulder Abduction, Left Shoulder Flexion, Left Shoulder Abduction, Neck Axial Twist).

Table 4.6 shows that there was a significant difference between the bag lift and the other two lifts for the trunk body segment. The bag lift put the trunk in more mild t flexion, lateral bend, and twist when compared to the other two lifts. The bag lift also put the trunk into more severe trunk flexion and twist when compared to the other two lifts.

Tables 4.5-4.10 also shows that the dolly lift put the right shoulder into more mild flexion when compared to the other two lifts. This happens when the driver uses the lever to engage the mechanical arm of the truck.

Lastly, Tables 4.5-4.10 shows that the can lift puts the left shoulder into more severe flexion when compared to the other two lifts. This happens when the can is dumped out into the truck and the left arm is position high on the can for balance while dumping. A Bonferroni adjustment was made to correct for multiple comparisons and to avoid type-1 errors.

Table 4.11 p-value for % awkward posture between lifts (bag, can, dolly)

	Mild				Severe			
	ANOVA	T-Test			ANOVA	T-Test		
		Bag-Can	Bag-Dolly	Can-Dolly		Bag-Can	Bag-Dolly	Can-Dolly
Trnk. flex	>0.001	0.021	>0.001	0.191	>0.001	>0.001	>0.001	0.663
T. Lat bend	0.011	0.074	0.003	0.286	0.511	0.332	0.606	0.150
Trnk. Twist	0.004	0.051	0.001	0.218	>0.001	0.002	0.002	0.475
r. Shld flex	0.001	0.363	0.007	0.001	0.227	0.826	0.142	0.065
r. Shld abd	0.234	0.032	0.211	0.773	0.416	0.790	0.184	0.242
l. Shld flex	0.286	0.121	0.288	0.627	>0.001	0.000	0.621	>0.001
l. Shld abd	0.212	0.249	0.751	0.134	0.591	0.790	0.332	0.332
Neck Ax. Twist	0.952	0.973	0.796	0.807	0.305	0.730	0.149	0.158

4.4.6 Cumulative and Peak loads

3D Match also considers the loads that the participants carry throughout the lift and calculates the peak and cumulative load experienced by the participant. Figures 4.10 and 4.11 show the cumulative and peak compressions respectively for each lift. Figures 4.12 and 4.13 show the cumulative and peak joint anterior shear respectively for each lift. Statistical analysis was run for each condition to see if any significant differences were present (Appendix G).

The dolly showed a significantly lower cumulative compression (Figure 4.10), however also showed a significantly higher peak compression (Figure 4.11). The lower cumulative compression is due to the dollies mainly being drug throughout the shift whereas the high peak compression comes from the one or two times a day where the dolly had to be lifted briefly to maneuver around an obstacle. This leads to a high peak compression (with low reoccurrence) and a low cumulative compression due to the dollies mainly being drug instead of lifted. The bag lift showed a significantly higher cumulative joint anterior shear (Figure 4.12) and peak joint anterior shear (Figure 4.13).

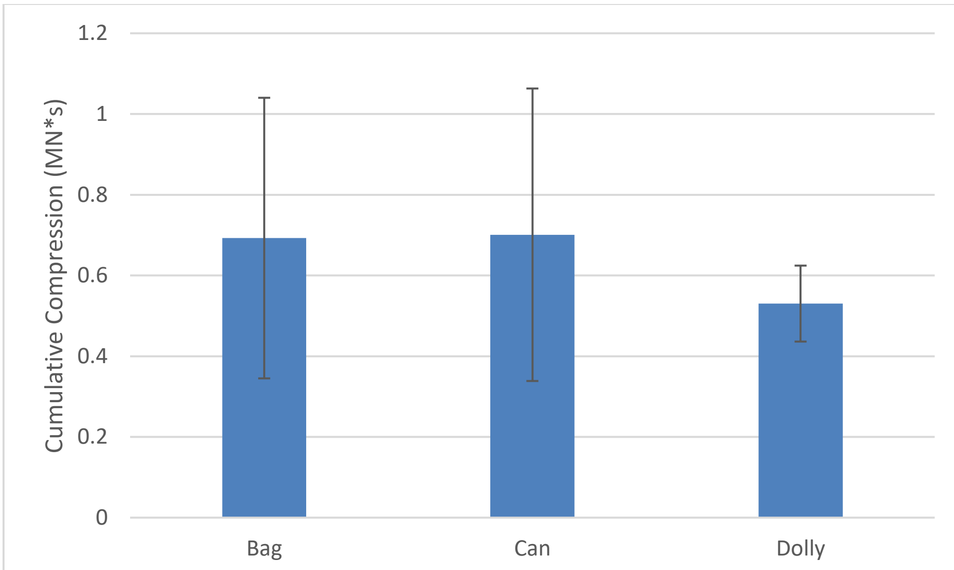


Figure 4.10 Average L4/L5 Daily Cumulative Compression

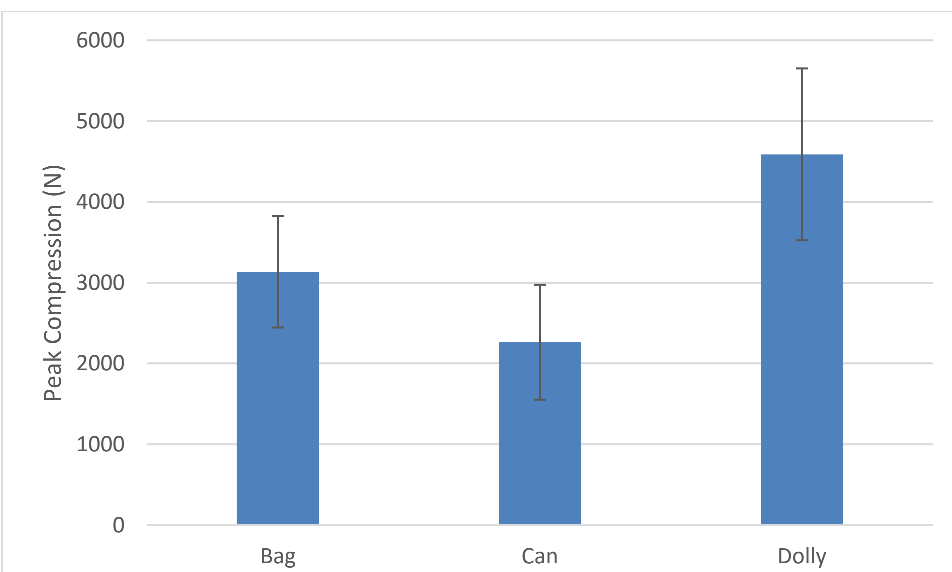


Figure 4.11 Average L4/L5 Peak Compression

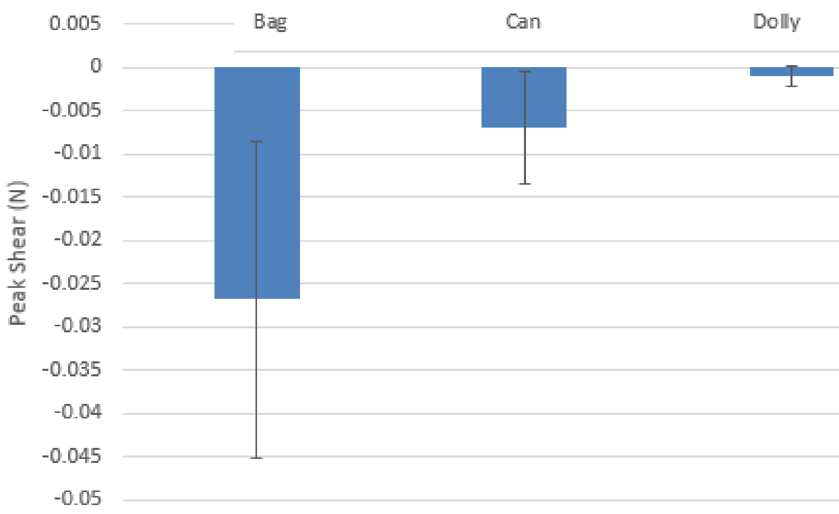


Figure 4.12 Average L4/L5 Cumulative Joint Anterior Shear

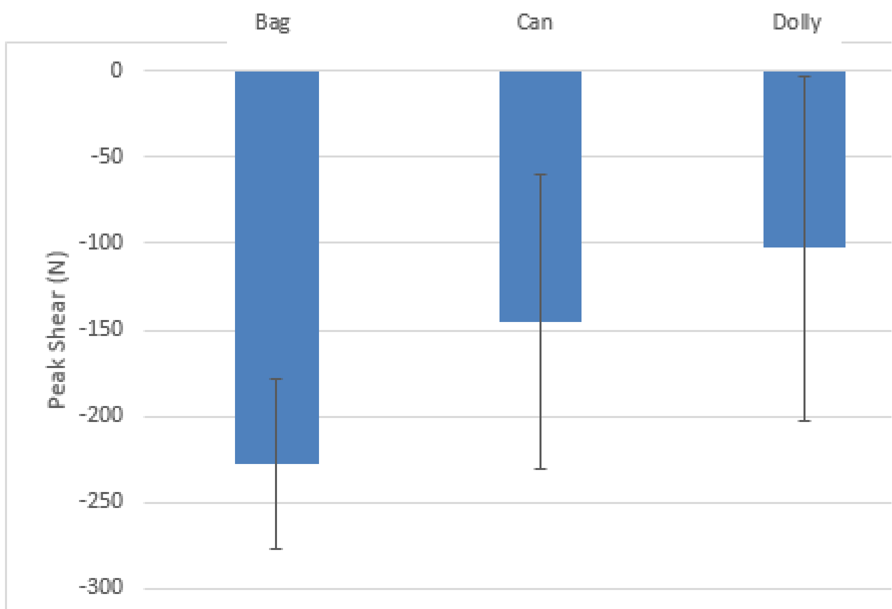


Figure 4.13 Average L4/L5 Peak Joint Anterior Shear

4.4 Accelerometers

Participants' max range of motion (ROM) were collected at the beginning of the shift. Table 4.7 shows what maximum percentage of the participant's maximum range of motion was used throughout the day. This shows what percentage of the participants' maximum ROM was used while performing their daily work tasks. (100 = went to max ROM, 50 = went half way to their max ROM).

Table 4.12 Percent range of motion for the Lumbar/Thorax (LUM/THX)

Subject	LUM_FE	LUM_LA	THX_FE	THX_LA
01	100.0	36.9	15.8	56.1
02	0.0	100.0	51.5	28.8
03	74.3	60.9	67.0	41.3
04	100.0	36.9	15.8	56.1
05	94.6	71.2	37.5	28.5
06	100.0	36.9	15.8	56.1
07	37.9	53.2	30.7	58.3
Average	72.4	56.6	33.4	46.5
SD	36.3	21.7	18.6	12.4

**Unable to obtain data for Sub008 & Sub009 due to broken equipment*
**FE= Flexion extension, LA=lateral*

5.0 Discussion

The study's main objective was to fill a gap in the literature for this occupation. One of the first objectives of this research was to determine whether it was a strenuous occupation or not. To determine this, we examined the physical activity level of each subject as well as the daily steps taken by each subject.

For men, a PAL of 1.55 is considered light activity, 1.78 is considered moderate activity, and 2.10 is considered strenuous activity (anything >2.0 can be *considered* strenuous) (Shetty, 2005). The average PAL of our participants was 1.91 ± 0.20. This falls in-between the moderate and strenuous PAL and is near that "strenuous" cut-off.

Furthermore, per Tudor-Locke (2004), <5000 steps/day may be used as a 'sedentary lifestyle index'; (ii) 5000–7499 steps/day is typical of daily activity excluding sports/exercise and might be considered 'low active'; (iii) 7500–9999 likely includes some volitional activities (and/or elevated occupational activity demands) and might be considered 'somewhat active'; and (iv) ≥10 000 steps/day indicates the point that should be used to classify individuals as 'active'. Individuals who take >12 500 steps/day are likely to be classified as 'highly active'. The average number of daily steps in this study was 12856 ± 1846. This would categorize these individuals as 'highly active'. This categorization as well as the PAL would allow us to safely classify this occupation as a strenuous one. Furthermore, previous research has found that refuse collection is a physically demanding occupation (Presser et al., 2016; Frings-Dresen et al., 2007). Studies have found that refuse collectors average Vo^2 Max is above 30% which is classified as upper range and defined as Hard Work (Presser et al., 2016; Frings-Dresen et al., 2007).

Another objective of this study was to look at the biomechanical demands of this occupation and determine if there were any differences that occurred throughout the day. To do this any changes that occurred between early in the shift vs later in the shift (one hour at the beginning of the shift/one hour towards the end of the shift) were examined. To examine any changes, posture (3DMatch), lumbar loading (3DMatch) and muscle fatigue (Grip Strength) were examined.

A change in posture was expected after an extended period of cyclic lifting (Bonato, Ebenbichler, Roy, Lehr, Posch, Kollmitzer, & Della Croce, 2003). However, there was no significant difference seen in our participants' percentage of time spent in awkward posture between the pre- and post-conditions. One reason for this could be that the participants often had a lunch break shortly before the post condition began (around 1:00pm). They were also given another break (5-10min) as the researcher set up the equipment before starting the post-condition data collection. These breaks could have been enough time to allow for the participant to recuperate from the lifting that occurred in the morning. Another possible reason as to why no postural differences were seen was that the participant knew they were being recorded. This could have led to them trying not to do anything wrong or perform any awkward lifting techniques that may normally occur due to fatigue towards the end of the shift when they are not being recorded.

Muscle fatigue often occurs after periods of lifting (Potvin, & Norman, 1993) and standing (Gallagher, Campbell, & Callaghan, 2014; Gallagher, Nelson-Wong, Callaghan, 2011; Gregory, & Callaghan, 2008). This occupation requires refuse collectors to stand throughout the majority of their day and spend most of their time lifting bags or cans into the garbage truck. Therefore, fatigue was expected to be seen in our participants. There was no significant difference in grip strength for the pre- and post-conditions. A change in grip strength could have also indicated muscular fatigue (Potvin, & Norman, 1993). This could mean that there was no muscular fatigue that occurred throughout the day. However, some extraneous variables could have played a part in this finding. One possible extraneous variable was that participants had more small breaks that occurred throughout the day because of the data collection preparation. Furthermore, subjects were much more comfortable with the researcher and the study at the end of the day. Consequently, they may not have tried to perform as well during the pre-grip strength and pushed harder during the post-grip strength due to increased levels of comfort and understanding of the study. These factors could have led to the similarities seen between the pre- and post-grip strength recordings, thus resulting in no muscular fatigue being seen.

Another interesting finding is that there was very little neck or back pain reported by the participants in this study. Subjects 1 and 5 were the only subjects to report experiencing any pain throughout the day. Subject 1 experienced pain in the sacrum and right upper pelvic region throughout the entire course of the day as well as some onset of pain in the lower back and right side at time point three (1:00pm) and time point 4 (end of their shift) respectively. Subject 5 experienced some pain the left shoulder for the entire duration of the day. This is a common occurrence for this subject. Neither of these subjects experienced significant increases in pain or discomfort throughout the day.

There are numerous studies showing that long periods of standing and MMH tasks are associated with lower back pain and fatigue: Robinovitch (2015) looked at lifting/standing and back pain. Gallagheret al. (2014) looked at the influence of sitting breaks on prolonged standing induced back pain. Gallagher et al. (2011) looked at postural differences for indiviuals who develop low back pain as a result of standing versus for those who do not. Gregory, & Callaghan (2008) looked at prolonged standing as a precursor to low back pain. All of these studies showed that long periods (2-4 hours) of standing resulted in the onset of low back pain. However, even though the participants in this study were standing for longer periods of time (~3 hours between seated breaks) there are very few reports of onset of pain experienced by these subjects throughout the day.

An explanation for this could be that previous studies looked at simply standing and back pain whereas the participants in this study were in a constant state of motion. Perhaps there was no onset of pain because of the continuous movement compared to the static nature of previous research. Another possibility as to why no discomfort was reported is because the men in this occupation tend to be concerned with appearing tough. Even if they were experiencing discomfort, they may not have reported it for fear of looking weak.

Considering what has been discussed so far, with the pre- and post-results showing no significant differences in posture and no instance of fatigue, the question now is: is refuse collection a demanding occupation that requires further investigation?

WorsafeNB classifies refuse collection as a high-risk industry and states that “Waste collection workers are three times more likely to be hurt on the job than the average New Brunswick worker" (WorkSafeNB, 2015). Given this, the answer is arguably yes.

Looking at the postural and biomechanical data we can see that this occupation is a very demanding one. The participants spent a lot of time in non-neutral postures. During all three lifts workers placed themselves in non-neutral trunk postures. However, the bag lift is deemed to be the most harmful to the trunk due to the much higher percentage of time spent in awkward postures when compared to the can and dolly lifts (Table 4.6). Previous research has also found the bag lift to be the most detrimental lifting task associated with refuse collection (Cakit, 2015; Frings-Dresen et al., 2007; De Looze et al., 2007; Kuijer et al., 2004; Kuijer & Frings-Dresen, 2004; Kuijer et al., 2003; Kuijer et al., 1998).

Can lift was deemed most detrimental for shoulders due to the increased amount time spent in severe left shoulder flexion when compared to the bag and dolly lifts (Table 4.6). This agrres with previous research that found dumping tasks (can) to be more harmful for the wrist/shoulders (Cakit, 2005). This makes sense due to the lifting technique used by refuse collectors when disposing waste from a can. They will often lift the can over their heads to dump the waste into the truck, thus putting their shoulders into compromising positions.

For mild right shoulder flexion, the dolly drag was found to be significantly different compared to the bag lift or can dump. This is due to the drivers pulling the lever on the bar loader of the truck to operate the dolly arm.

The highest peak compression came from the dolly lift. This lift also had the lowest cumulative compression. This makes sense because the dollies have a larger load than both the bags and cans, however, drivers are not required to manipulate all of that weight every time they dump a dolly. A refuse worker will occasionally need to partially lift the dolly to maneuver an obstacle, resulting in a high peak load at that instance. However, this does not occur during every instance of dumping a dolly.

The second-highest peak compression was seen during the bag lifts. This lift also recorded the highest cumulative compression. The bag lift also had the second-highest instance of peak joint anterior sheer and easily had the highest cumulative joint anterior sheer.

The bag lift is deemed to be the most detrimental lift of the three lifts for this study. It has the highest cumulative compression and cumulative joint anterior sheer as well as the second-highest instances of peak loads for both compression and joint anterior sheer. This, along with having the highest percent of time spent in awkward trunk postures, leads to this conclusion. This finding agrees with previous research findings (Cakit, 2015; Frings-Dresen et al., 2007; De Looze et al., 2007; Kuijer et al., 2004; Kuijer & Frings-Dresen, 2004; Kuijer et al., 2003; Kuijer et al., 1998).

The second most harmful task in this study was the can dump. It had a higher cumulative compression than the dolly as well as a higher instance of peak joint anterior sheer. These loads, along with the awkward shoulder postures associated with the can dump, make it the second most harmful lift of the three. This also agrees with previous research findings (Cakit, 2005; Frings-Dresen et al., 2007).

5.1- Limitations and Future Research

There were many limitations associated with this study which may be one of the reasons why there is so little research done in this area. The first is trying to find participants who are willing to take part in a study such as this. Finding a company that will allow a researcher to interrupt the regular work of its employees is difficult enough. Convincing the employees that this research is important research and that they should all participate was challenging. All participants volunteered for this research; however, there was still some level of frustration/annoyance when they knew that it was their day to be tested. The pessimistic attitude displayed by some of the participants was difficult to manage as the researcher of the project, and can also skew results if participants are not trying during strength tests (hand grip) or being truthful about discomfort (ROPD) or any other questions asked over the course of the study.

Another limitation of this study was the environment. Field work is a much more challenging and unforgiving environment than lab work. This became evident from the very first day when the truck was being fitted with all of the equipment. In a lab, there is ample space to set up and organize all necessary equipment. In a truck cab, where the only available space is a little bigger than a milk crate, creative organizing techniques need to be employed so that all necessary equipment can fit safely into the space. Furthermore, the inside of the truck is constantly vibrating and, when the cab starts to fill up with the smell of the collected garbage, it creates an unpleasant environment in which to research and to work daily.

On top of environmental issues inside the truck, there were many environmental issues that occurred outside of the truck as well. The actual environment was constantly changing throughout the course of this study. The testing began in early December and finished in early January; thus, the researchers and participants had to deal with snowfall, ice, melting snow (wet conditions), and unsafe driving conditions at times. The cold also caused issues for some equipment that was used in this study.

One of the final limitations to my study is around Grip Strength. This measure was taken to try and determine whether the participants fatigued throughout the day. A limitation with this measurement was that it was only taken before and after the shift. I would recommend that future researcher measure grip strength at various points throughout the day as this will give a better representation of fatigue over the course of the day.

Lastly, watchfulness is a limitation to this study. The participants knew that they were being watched/videotaped which could have caused them to behave differently then they normally would have. This could cause them to use proper lifting techniques not because that is what they normally do, but rather due to fear of being ridiculed for any poor habits.

Limited space, challenging participants, and constantly varying environmental conditions made this a difficult study to complete, especially with the amount of information this study attempted to examine. Because there is little to no research done in this area up to this date, this study aimed to lay the foundations for future researchers. This means that some of the data collected were unable to be processed. An example of this was the EMG that was collected throughout the day (while the participants were working). It was not examined because the researchers were unable to stop/start the EMG for each stop as this process would have added hours onto an already long work-day for the participants. Furthermore, the EMG was found almost impossible to match up with the video meaning that even though EMG data was collected throughout the day, it is impossible to match up the proper lift (bag lift, can dump, dolly drag) to its corresponding EMG signal.

Knowing some of the limitations that there were going to be when commencing the investigation, it was still crucial that this study was completed. There has been almost no previous research done in this field but hopefully future researchers can learn from this study so that this occupation can be examined more thoroughly, as it is currently an occupation that often goes overlooked both professionally and socially.

5.2- Ergonomic Suggestions

Suggestions for the employer:

- Inform your employees on proper lifting techniques.
- Inform the public about hazards of bag lift and ask to use cans or, preferably, dollies whenever possible.
    - Perhaps set a bag limit per week to encourage use of cans and dollies.
- Set weight restrictions for bags/cans and enforce them. Do not force employers to pick up refuse if it is too heavy.
- Perform a warm-up and stretch program with employees prior to shift.
- Introduce job rotation if possible (Kuijer et al., 2005; Kuijer et al., 2004; Kuijer et al., 1998)
    - have a driver and a "lifter" on each truck to allow proper work/rest ratios with same amount of work getting done (kuijer et al., 2004).

    - Will decrease perceived exertion and MSI risk (Kuijer et al., 2005)
- Reduce/eliminate bag use where possible and replace with mechanical lifting.
- Grouping dollies in a central location when possible has been shown to reduce MSI risk and improves work efficiency (Kuijer et al., 2000).

Suggestions for the workers:

- Use Dolly arm to assist in the lifting of heavy bags/cans.
- Throw refuse from both sides (left/right) so as not to fatigue muscles on one side.
- Get education on proper lifting techniques.
- Use both hands to lift as there are increased musculoskeletal risks associated with one-handed lifting.

References

Alperovitch-Najenson, D., Santo, Y., Masharawi, Y., Katz-Leurer, M., Ushvaev, D., & Kalichman, L. (2010). Low back pain among professional bus drivers: ergonomic and occupational-psychosocial risk factors. *The Israel Medical Association Journal : IMAJ*, *12*(1), 26–31. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20450125

Bonato, P., Ebenbichler, G. R., Roy, S. H., Lehr, S., Posch, M., Kollmitzer, J., & Della Croce, U. (2003). Muscle Fatigue and Fatigue-Related Biomechanical Changes During a Cyclic Lifting Task. *Spine, 28*(16), 1810-1820. doi: 10.1097/01.BRS.0000087500.70575.45

Cakit, A. (2015). Assesment of the physical demands of waste collection tasks. *Global Nest*, *17*(2), 426-438.

Colombini, D., Occhipinti, E., Alvarez-Casado, E., Waters, T. (2013) Manual Lifting: A Guide to the Study of Simple and Complex Lifting Tasks. Brooklyn, New York: CRC Press

De Looze, M.P., Stassen, A.R.A, Markslag, A.M.T., Borst, M.J., Wooning, M.M. & Toussaint, H.M. (2007). Mechanical loading on the low back in three methods of refuse collecting. *Ergonomics*, *38*(10), 1993-2006.

Frings-Dresen, M.H.W., Kemper, H.C.G., Strassen, A.R.A., Crolla, I.F.A.M., Markslag, A.M.T. (2007). The daily work load of refuse collectors working with three different collecting methods: a field study. *Ergonomics,* 38(10), 2045-2055.

Gallagher, K. M., Nelson-Wong, E., & Callaghan, J. P. (2011). Do individuals who develop transient low back pain exhibit different postural changes than non-pain developers during prolonged standing? *Gait & Posture*, *34*(4), 490–5. http://doi.org/10.1016/j.gaitpost.2011.06.025

Gallagher, K. M., Wong, A., & Callaghan, J. P. (2013). Possible mechanisms for the reduction of low back pain associated with standing on a sloped surface. *Gait & Posture*, *37*(3), 313–8. http://doi.org/10.1016/j.gaitpost.2012.07.020

Gallagher, K. M., Campbell, T., & Callaghan, J. P. (2014). The influence of a seated break on prolonged standing induced low back pain development. *Ergonomics*, *57*(May 2015), 555–62. http://doi.org/10.1080/00140139.2014.893027

Gregory, D. E., Brown, S. H. M., Callaghan, J. (2006). Trunk muscle responses to suddenly applied loads: Do individuals who develop discomfort during prolonged standing respond differently? *Journal of Electromyography and Kinesiology*, *18*(3), 495-502. http://dx.doi.org.proxy.hil.unb.ca/10.1016/j.jelekin.2006.12.005

Gregory, D. E., & Callaghan, J. P. (2008). Prolonged standing as a precursor for the development of low back discomfort: an investigation of possible mechanisms. *Gait & Posture*, *28*(1), 86–92. http://doi.org/10.1016/j.gaitpost.2007.10.005

Johannsen, D.L.; Calabro, M.A.; Stewart, J.; Franke, W.; Rood, J.C.; & Welk, G.J., (2010). Accuracy of armband monitors for measuring daily energy expenditure in healthy adults. Medicine and Science in Sports and Exercise. 42(11), 2134-2140. https://doi.org/10.1249/MSS.0b013e3181e0b3ff

Kuijer, P.F.M., van der Beek, A.J., van Dieen, J.H., Visser, B., & Frings-Dresen, M.H.W. (2005). Effect of job rotation on need for recovery, musculoskeletal complaints, and sick leave due to musculoskeletal complaints: a prospective study among refuse collectors. *American Journal of Industrial medicine, 47,* 394-402.

Kuijer, P.F.M., & Frings-Dresen, M.H.W. (2004). World at work: refuse collectors. *Occupational and environmental medicine, 61*, 282-286.

Kuijer, P.F.M., Frings-Dresen, M.H.W., de Looze, M., Visser, B., & van der Beek, A.J. (1998). Work situation and physical workload of refuse collectors in three different time periods. *International Journal of Industrial Ergonomics, 26,* 509-519.

Kuijer, P.F.M.,Hoozemans, M.J.M., Kingma, I., van Dieen, J.H., de Vries, W.H.K., Veeger, D.J.H.E.J., van der Beek, A.J., Visser, B., & Frings-Dresen, M.H.W. (2003). Effect of redesigned two-whelled container for refuse collecting on mechanical loading of low back and shoulders. *Ergonomics, 46*(6), 543-560.

Kuijer, P.F.M., Sluiter, J.K., Frings-Dresen, M.H.W. (2010) Health and safety in waste collection:towards evidence-based worker health surveillance. *American Journal of Industrial Medicine, 53,* 1040-1064.

Kuijer, P.F.M., de Vries, W.H.K., van der Beek, A.J., van Dieen, J.H., Visser, B., & Frings-Dresen, M.H.W. (2004). Effect of job rotation on work demands, workload, and recovery of refuse truck drivers and collectors.

Kuijer, P.F.M., de Vries, W.H.K., van der Beek, A.J., van Dieen, J.H., Visser, B., & Frings-Dresen, M.H.W. (2000). Effect of the number of two-wheeled containers at gathering point on energetic workload and work efficiency in refuse collecting. *Applied Ergonomics*,*33,* 571-577.

Marshall, P. W. M., Patel, H., & Callaghan, J. P. (2011). Gluteus medius strength, endurance, and co-activation in the development of low back pain during prolonged standing. *Human Movement Science*, *30*(1), 63–73. http://doi.org/10.1016/j.humov.2010.08.017

Mifflin, M.D., St. Jeor, S.T., Hill. L.A., Scott, B.J., Daugherty, S.A., Koh, Y.O., (1990). A new predictive equation for resting energy expenditure in healthy individuals. *The American Journal of Clinical Nutrition, 51*(2), 241-247.

Nelson-Wong, E., & Callaghan, J. P. (2010). Is muscle co-activation a predisposing factor for low back pain development during standing? A multifactorial approach for early identification of at-risk individuals. *Journal of Electromyography and Kinesiology : Official Journal of the International Society of Electrophysiological Kinesiology*, *20*(2), 256–63. http://doi.org/10.1016/j.jelekin.2009.04.009

Nelson-Wong, E., Howarth, S. J., & Callaghan, J. P. (2010). Acute biomechanical responses to a prolonged standing exposure in a simulated occupational setting.

Ergonomics, *53*(May 2015), 1117–1128. http://doi.org/10.1080/00140139.2010.500400

Okunribido, O. O., Magnusson, M., & Pope, M. H. (2006). Low back pain in drivers: The relative role of whole-body vibration, posture and manual materials handling. *Journal of Sound and Vibration*, *298*(3), 540–555. http://doi.org/10.1016/j.jsv.2006.06.007

Potvin, J.R., Norman, R.W. (1993). Quantification of erector spinae muscle fatigue during prolonged, dynamic lifting tasks. *European Journal of Applied Physiology and Occupational Physiology, 67*(6), 554-562. doi: 10.1007/BF00241654

Poulsen, O.M., Breum, N.O., Ebbehoj, N., Hansen, A.M., Ivens, U.I., van Lelieveld, D., Malmros, P., Matthiasen, L., Nielsen, B.H., Nielsen, E.M., Schibye, B., Skov, T., Stenbaek, E.I., & Wilkins, C.K. (1995). Collection of domestic waste. Review of occupational health problems and their possible causes. *The Science of the Total Environment, 170*, 1-19.

Presser, A.M., Zhou, L., Garrido, M.V., Harth, V. (2016). Measured by the oxygen uptake in the field, the work of refuse collectors is particularily hard work: Are the limit values for physical endurance workload too low? *International Archieves for Occupational and Evironmental Health, 89,* 211-220.

Reddy, E.M., Yasobant, S. (2015). Musculoskeletal disorders among municipal solid waste workers in India: a cross-sectional risk assessment. *Journal of Family Medicine and Primary Care, 4*(4), 519-524.

Shetty, P., (2005). Energy requirements of adults. *Public Health Nutrition, 8*(7A), 994-1009.

Sutherland, C.A., Albert, W.J., Wrigley, A.T., & Callaghan, J.P. (2008). A validation of a posture mathing approach for determining 3D cumulative back loads. *Applied Ergonomics*, *39,* 199-208.

Sutherland, C.A., Albert, W.J., Wrigley, A.T., & Callaghan, J.P. (2007). The effect of camera viewing angle on posture assessment and cumulative spinal loading. *Ergonomics, 50*(6), 877-889.

Richards, L., Palmiter-Thomas, P. (1996). Grip Strength Measurement: A Critical Review of Tools, Methods, and Clinical Utility. *Critical Reviews™ in Physical and Rehabilitation Medicine, 8*(1-2), 87-109. doi: 10.1615/CritRevPhysRehabilMed.v8.i1-2.50

Robinovitch, S.N. (2015). *Biomechanics of Lifting and Lower Back Pain* [PowerPoint slides]. Retrieved from http://www.sfu.ca/~stever/kin380/lecture_outlines/Biomechanics_lifting_p1_1pp.pdf

Tudor-Locke, C. & Basset Jr, D.R., (2004). How many steps/day are enough? *Sports Medicine*, *34*(1), 1-8.

WorksafeNB. (2015). WorkSafeNB aims to make waste collection safer in New Brunswick. Retrieved from: http://www.worksafenb.ca/worksafenb-aims-to-make-waste-collection-safer-in-new-brunswick

APPENDIX-A

SUBJECT INFORMED CONSENT FORM

CONSENT

The purpose of this study has been explained to me by __________________________. I have understood the information, including the risks of participation, and agree to participate in the study. I have been given a copy of the Study Information sheet and the Consent form, which I have read and understood. I have been given an opportunity to ask questions about the study and my participation, and I understand that I may ask questions at any time.

By signing this form, I agree to participate in the study to be observed and recorded during a manual material handling task using a technique of my own selection, with the understanding that I may withdraw from it at any time, without penalty.

____________________	____________________	________
Name of Participant (Print)	Signature of Participant	Date
____________________	____________________	________
Witness (Print)	Signature of Witness	Date

::

If you wish to be informed of the research results, please provide contact information.

Name:

Address:

Telephone #:

Email address:

APPENDIX-B

Health and Lifestyle Questionnaire(HLQ)

SECTION A – GENERAL INFORMATION

Age	
Gender	
Height	
Weight	
Years (or months) with Police Force	

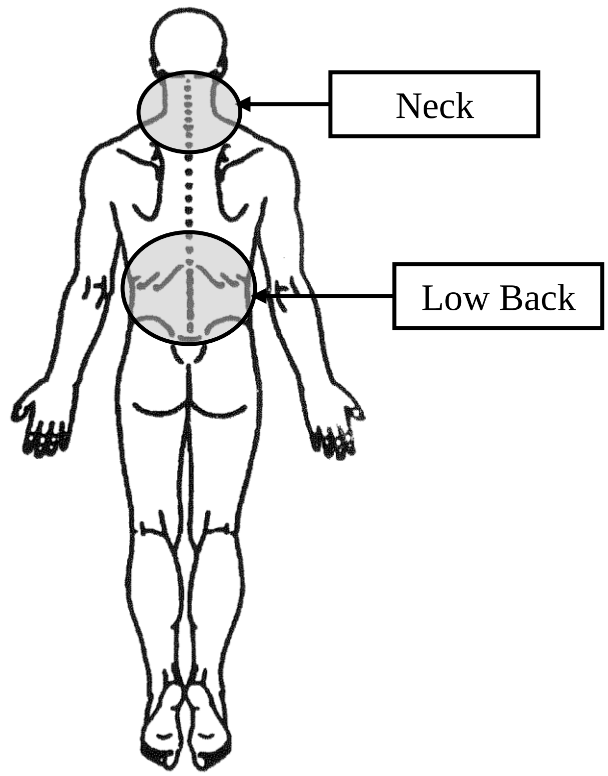
How often do you participate in:

	Never	**Occasionally (1/month)**	**Frequently (1/week)**	**Every Day**
Household Activities (e.g., cleaning, mowing lawn)				
Organized Sports				
Fitness routines (e.g., gym or oter)				

Has a doctor ever told you that you suffer from any of the following?

□ Stroke. What age? _______________________
□ Hypertension
□Diabetes
□ Parkinson’s
□Lupus
□ Sciatica
□ Degenerative disc disease
□Herniated disc; (level)________________
□Osteomyelitis
□Osteoporosis
□Current fracture/sprain/strain; ________________________
□ Previous fracture/sprain/strain; _______________________
□ Arthritis;_______________________________
□ Tendonitis / Epicondylitis
□ Bursitis;____
□ Carpal tunnel, Thoracic outlet or Cervical syndrome (please circle)
□ Previous surgery;__________________________________
□ Others;____

In this picture you can see the approximate area of the parts of the body referred to as "neck" and "low back".



Neck pain can be defined as ache, pain or discomfort in the neck region. The pain may be described as aching, stiffness, burning, numbness or tingling.

Low back pain can be defined as ache, pain or discomfort in the low back whether or not it extends from there to one or both legs. The pain may be described as aching, stiffness, burning, numbness or tingling.

SECTION B - LOW BACK

1. Are you **currently** experiencing any **low back pain**?
   †□Yes □†No If 'no', proceed to **Question 5**

2. How long have you experienced this **low back pain**? _______ months/years

3. Mark an **X** on the line to indicate how much **low back pain** is normal for you.

No Pain |————————————————————| Greatest amount of pain possible

4. Do you attribute this **currentlow back pain** to work?
   † □Yes † □No †
   □Unsure

5. How often do you have **low back pain**?

Mild		Moderate		Severe	
Never	†	Never	†	Never	†
Sometimes	†	Sometimes	†	Sometimes	†
Occasionally	†	Occasionally	†	Occasionally	†
Often (at least 1/week)	†	Often	†	Often	†
Constantly	†	Constantly	†	Constantly	†

6. Over the **past 12 months**, have you ever experienced Mild/ Moderate/ Severe pain in the **low back**? If yes, what was the total duration of that pain for all episodes?

Mild: □Yes†□ No†
If 'yes':†1 week
†2 weeks
†1 month
†3 months
†6 months
†9 months
†1 year (every day)

Moderate: □Yes†□ No†
If 'yes':†1 week
†2 weeks
†1 month
†3 months
†6 months
†9 months
†1 year (every day)

Severe: □Yes†□No†
If 'yes':†1 week
†2 weeks
†1 month
†3 months
†6 months
†9 months
†1 year (every day)

7. Do you attribute this **low back painexperienced over the past 12 months** to work?
□Yes □ No □Unsure

8. Do or did any of the following make your **low back pain** worse? (Please check all that apply)

Lifting	□	Running	□	Lying down	□
Bending forwards	□	Leaning backwards	□	Coughing/sneezing	□
Standing for long periods of time	□	Sitting for long periods of time	□	None of these make pain worse	□
Walking	□	Twisting	□	I don't remember	□

9. In the last year have you changed your normal work or home activities because of your **low backpain**?
□Yes
□No

10. Did your **low back pain** result in any of the following? (Please check all that apply)

□Days off from work?
Number of days? _______________
□Temporary reassignment of duties to accommodate injury
Number of days? _______________
□Accident reports at work
□Worker's compensation claim filed
□ None of the above

11. Have you had to change jobs as a result of your **low back pain**?
□Yes □No

12. Have you sought medical treatment because of **low back pain** in the last twelve months (doctor, physiotherapist, chiropractor or other such person)?
□Yes □No

If you answered no, skip to **Section C**

13. If you sought medical help, were you given a diagnosis?
□Yes Please describe: ___________________________________
□No ___________________________________
____

14. How often did you visit a health professional and/or go for treatment? (Please indicate total number of visits in the last twelve months, OR average number of visits per month over the last twelve months.)

a. ________ total visits, last twelve months
b. ________ average visits per month, last twelve months

SECTION C – NECK

1. Are you currently experiencing any **neck pain**?
   □ Yes □ No If 'no', skip to **Section D**

2. How long have you experienced this **neck pain**? ______ months/years

3. Mark an **X** on the line to indicate how much **neck pain** is normal for you.

No Pain |————————————————————| Greatest amount of pain possible

4. Do you attribute this **neck pain** to work?
   □Yes □No □Unsure

5. Over the past 12 months, have you ever experienced Mild/ Moderate/ Severe pain in the **neck**? If yes, what was the total duration of that pain for all episodes?

Mild: □Yes □ No	**Moderate**: □Yes □No	**Severe**: □ Yes □No
If 'yes': 1 week	If 'yes': 1 week	If 'yes': 1 week
2 weeks	2 weeks	2 weeks
1 month	1 month	1 month
3 months	3 months	3 months
6 months	6 months	6 months
9 months	9 months	9 months
1 year (every day)	1 year (every day)	1 year (every day)

6. How often do you have **neck pain**?

Mild		Moderate		Severe	
Never	†	Never	†	Never	†
Sometimes	†	Sometimes	†	Sometimes	†
Occasionally	†	Occasionally	†	Occasionally	†
Often (at least 1/week)	†	Often	†	Often	†
Constantly	†	Constantly	†	Constantly	†

7. Do or did any of the following make your **neck pain** worse? (Please check all that apply)

Lifting	□	Running	□	Lying down	□
Looking up	†□	Look Down	†□	Coughing/sneezing	□
Turning the head to the right	†□	Turning the head to the left	□	None of these make pain worse	□
Walking	□	I don't remember	†□		

8. In the last year have you had to change your normal work or home activities because of your neck pain?

□Yes † □No †

9. Did your **neck pain** result in any of the following? (Please check all that apply)

□ Days off from work?
†Number of days? _______________
†□Temporary reassignment of duties to accommodate injury
† Number of days? _______________
†□ Accident reports at work
†□Worker's compensation claim filed
†□ None of the above

10. Have you had to change jobs as a result of your **neck pain**?

□ Yes † □No †

11. Have you sought medical treatment because of **neck pain** in the last twelve months (doctor, physiotherapist, chiropractor or other such person)?

□Yes † □No †

If you answered no, skip to **Section D**

12. If you sought medical help, were you given a diagnosis?

□Yes † Please describe: ___________________________________
□No † ___________________________________
____

13. How often did you visit a health professional and/or go for treatment? (Please indicate total number of visits in the last twelve months, OR average number of visits per month over the last twelve months.)

a. ________ total visits, last twelve months
b ________ average visits per month, last twelve months

SECTION D - HEALTH, LIFE STYLE and JOB SATISFACTION

Part 1: Previous Driving Experience

1. Before working Waste Management Industry, have you had previous occupations requiring some driving?

☐ Yes ☐ No

2. If you answered "yes," please state the driving occupations you have had and years of experience.

Driving Occupation	Time (Years)
1.	
2.	
3.	
4.	

3. Does the stress you feel while driving/working come home with you at night?

□ Yes □ No □ I have no stress

4. While at home do you ever experience any of the following:

□ Flashbacks of negative work related events
□ Nightmares
□ Persistent startled responses
□ Enduring fatigue

5. How satisfied are you with your job?

☐ completely satisfied ☐ somewhat dissatisfied
☐ somewhat satisfied ☐ completely dissatisfied

Part 3: Health and Lifestyle

1. In general, **compared to other persons your age**, would you say your health is ...
   - ☐ excellent
   - ☐ very good
   - ☐ good
   - ☐ fair
   - ☐ poor
2. How **satisfied** are you with your health?
   - ☐ completely satisfied
   - ☐ somewhat satisfied
   - ☐ somewhat dissatisfied
   - ☐ completely dissatisfied
3. On average, how many **hours of sleep** do you get each night? __________ hours
4. How often do you **get enough sleep**?
   - ☐ always
   - ☐ usually
   - ☐ seldom
   - ☐ never
5. How long have you been doing **physical activity in your leisure time**, which increases your heart rate and breathing, and causes you to sweat?
   - ☐ I don't do an activity each week
   - ☐ For less than 3 months
   - ☐ From 3 to just under 6 months
   - ☐ 6 months to just under 1 year
   - ☐ 1 year to just under 3 years
   - ☐ 3 years to just under 5 years
   - ☐ five or more years
6. In general, **compared to other persons of your own age and sex**, would you say you are:
   - ☐ more fit
   - ☐ less fit
   - ☐ as fit

END OF SURVEY

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

APPENDIX-C

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ____________________

SIGNATURE OF PARENT ________________________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...

APPENDIX-D

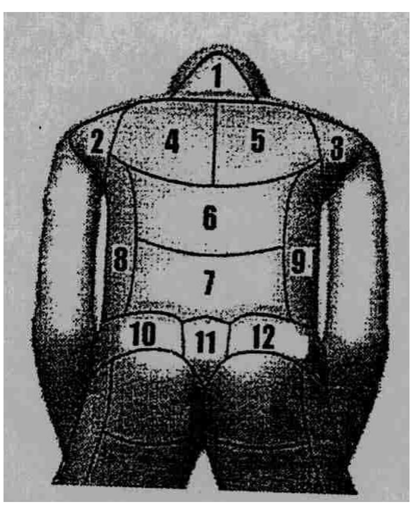
Body Part Discomfort Questionnaire (BPQ)

*To answer each question, place a vertical dash (|) **through the corresponding line**.*

Your answers should reflect how you feel during a typical shift.You are encouraged to answer each question, however, you may decline to answer any of the following questions should you feel uncomfortable or are unable to answer them. If you have any questions regarding any of the items listed below, a research assistant will be available to assist you.

No Discomfort Extreme Discomfort

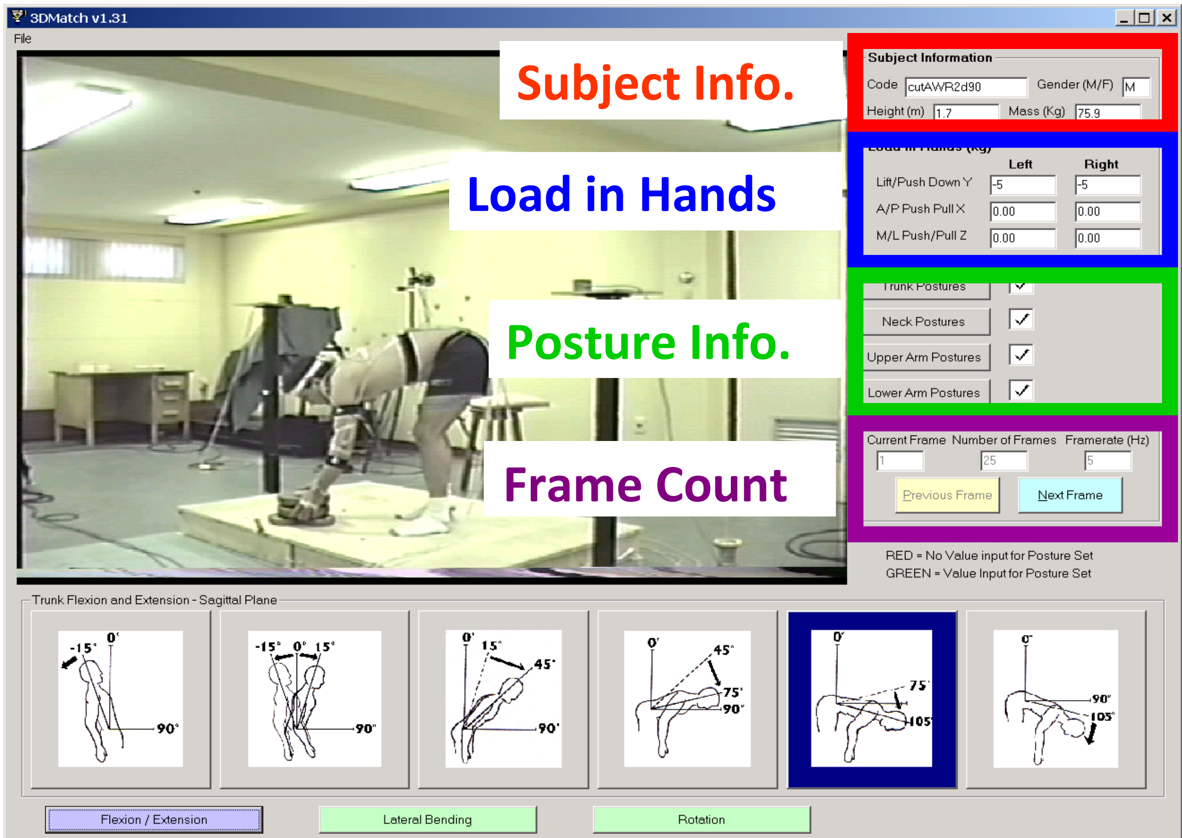
1. Neck
2. (L) Shoulder
3. (R) Shoulder
4. (L) Upper Back
5. (R) Upper Back
6. Middle Back
7. Lower Back
8. (L) Side of Body
9. (R) Side of Body
10. (L) Upper Pelvis
11. Sacrum/Tail Bone
12. (R) Upper Pelvis



APPENDIX-E

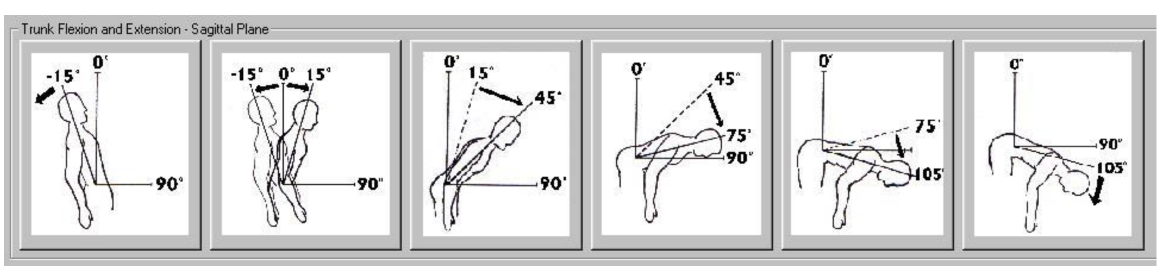
3D Match

Screen shot of 3DMatch analysis screen

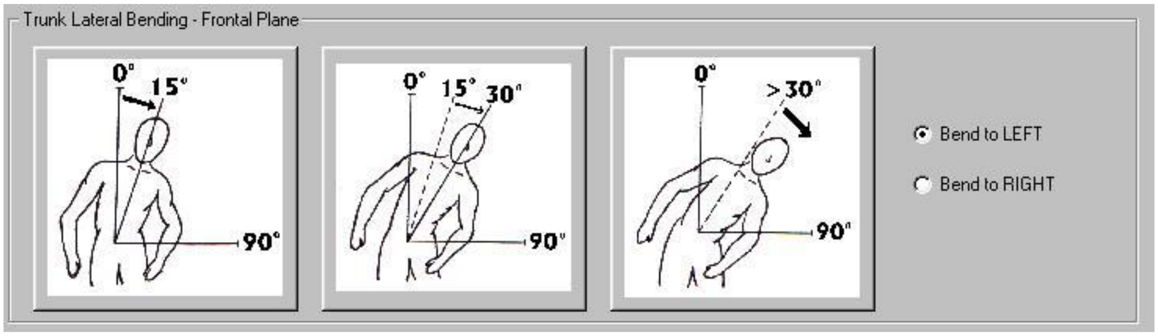


3DMatch – Posture Categories

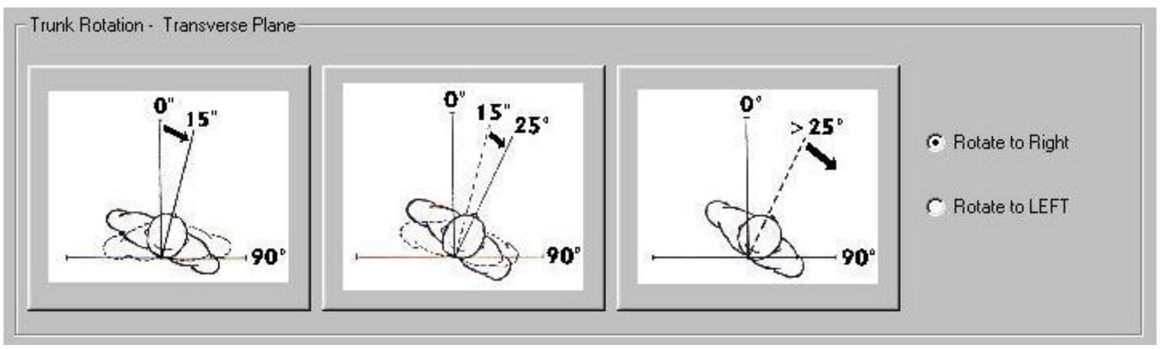
1) Trunk Flexion Categories – Sagittal Plane



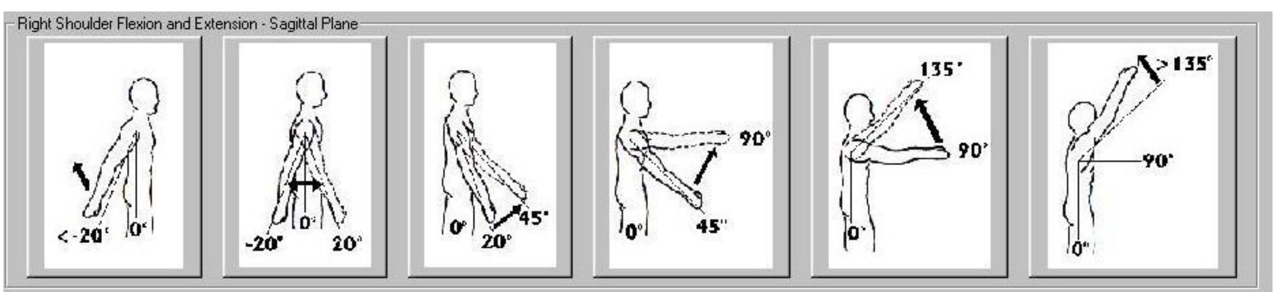
2) Trunk Lateral Bend Categories – Frontal Plane



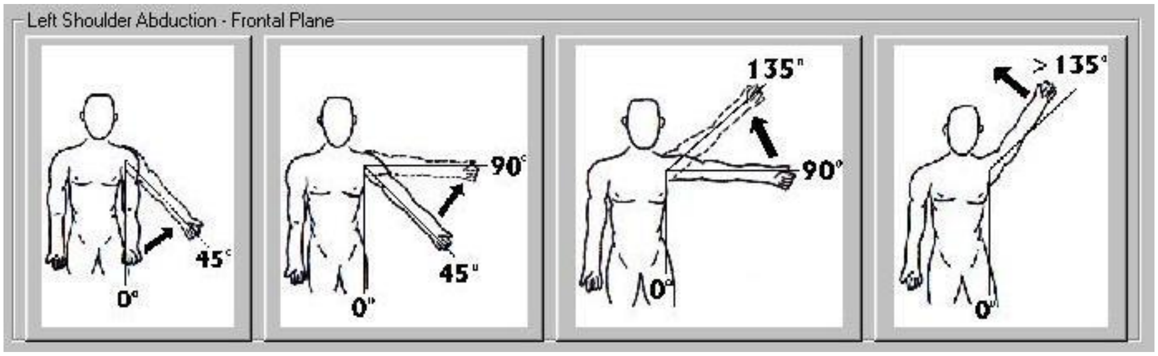
3) Trunk Rotation Categories – Transverse Plane



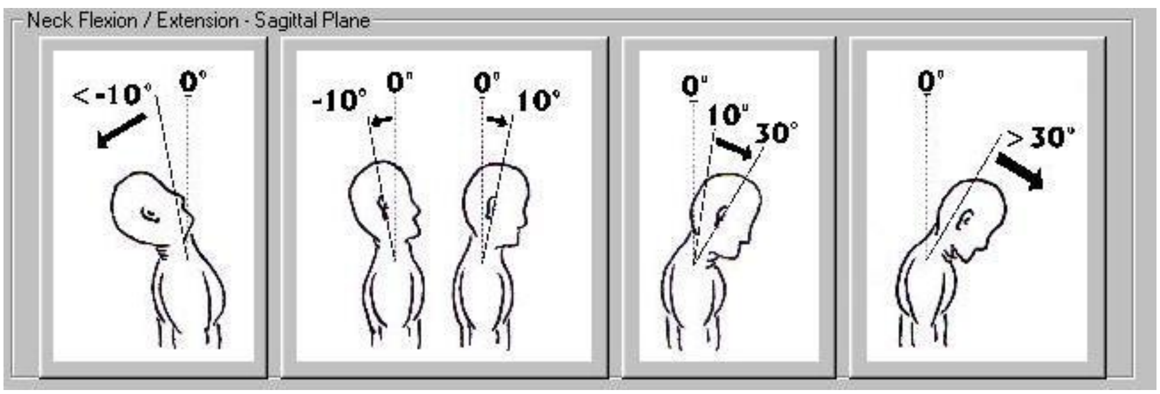
4) Shoulder Flexion Categories – Sagittal Plane



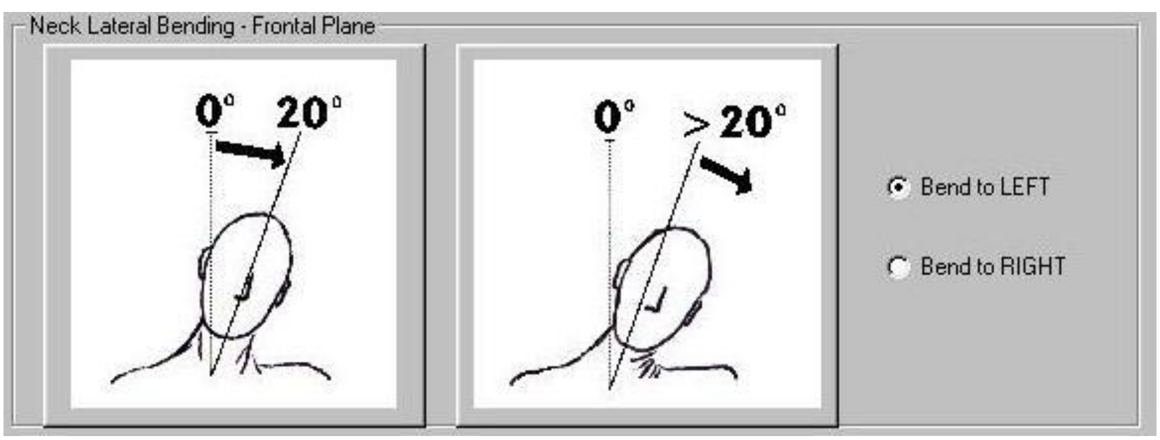
5) Shoulder Abduction Categories – Frontal Plane



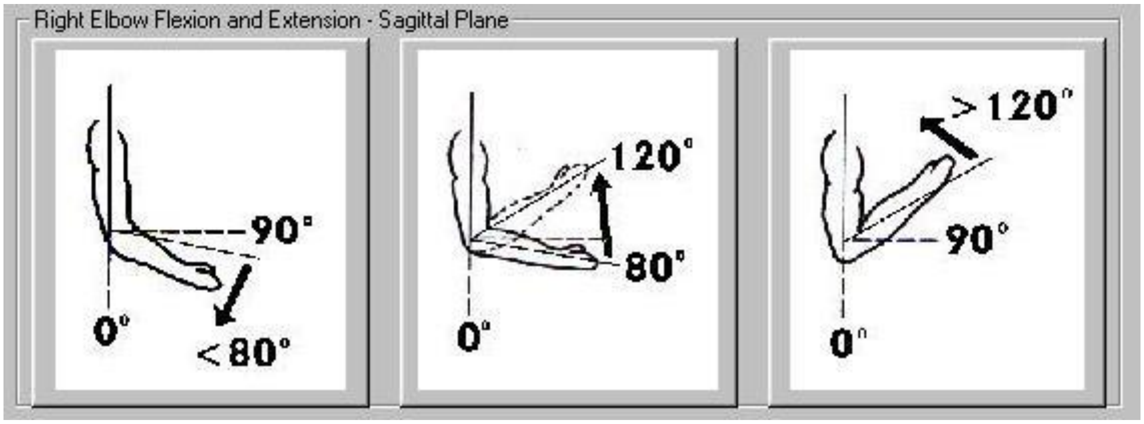
6) Neck Flexion Categories – Sagittal Plane



7) Neck Lateral Bending Categories – Frontal Plane



8) Elbow Flexion Categories – Sagittal Plane



APPENDIX-F
eVAS (ROPD) RESULTS

Subjects 2, 3, 4, 6, 7, 8, 9 reported experiencing no discomfort throughout the day.

Table H.1 Sub001 eVAS

Time Point	1	2	3	4
Neck	0.00	0.00	0.00	0.00
(L) Shldr	0.00	0.00	0.00	0.00
(R) Shldr	0.00	0.00	0.00	0.00
(L) Up Back	0.00	0.00	0.00	0.00
(R) Up Back	0.00	0.00	0.00	0.00
Mid Back	0.00	0.00	0.00	0.00
Low Back	0.00	0.00	0.08	0.00
(L) side	0.00	0.00	0.00	0.00
(R) Side	0.00	0.00	0.00	0.19
(L) Up Pelv	0.00	0.00	0.00	0.00
Sacrum	0.46	0.33	0.34	0.37
(R) Up Pelv	0.28	0.27	0.22	0.30

Table H.2 Sub005 eVAS

Time Point	1	2	3	4
Neck	0	0	0	0
(L) Shldr	0.22	0.20	0.08	0.13
(R) Shldr	0	0	0	0
(L) Up Back	0	0	0	0
(R) Up Back	0	0	0	0
Mid Back	0	0	0	0
Low Back	0	0	0	0
(L) side	0	0	0	0
(R) Side	0	0	0	0
(L) Up Pelv	0	0	0	0
Sacrum	0	0	0	0
(R) Up Pelv	0	0	0	0

APPENDIX-G
CUMULATIVE AND PEAK LOAD STATISTICAL ANALYSIS

Table I.1 ANOVA and t-test p-values for L4/L5 Daily Cumulative Compression

ANOVA	T-Test		
	Bag-Can	Bag-Dolly	Can-Dolly
>0.001	0.960223	>0.001	>0.001

Table I.2 ANOVA and t-test p-values for L4/L5 Peak Compression

ANOVA	T-Test		
	Bag-Can	Bag-Dolly	Can-Dolly
>0.001	0.004452	>0.001	>0.001

Table I.3 ANOVA and t-test p-values for L4/L5 Cumulative Joint Anterior Sheer

ANOVA	T-Test		
	Bag-Can	Bag-Dolly	Can-Dolly
>0.001	0.001727	0.001737	0.655726

Table I.4 ANOVA and t-test p-values for L4/L5 Peak Joint Anterior Sheer

ANOVA	T-Test		
	Bag-Can	Bag-Dolly	Can-Dolly
>0.001	0.007573	0.000798	0.254588

CURRICULUM VITAE

Candidate's full name:

Frederick Carl Fulton

Universities attended (with dates and degrees obtained):

Bachelor of Science in Kinesiology, University of New Brunswick, 2014

Publications:

Conference Presentations:

2015- ACE Atlantic: *Manual Material Handling Demands of Disposal Workers*

2016- Kin Research Day*: The Interdisciplinary Nature of Ergonomics*