Hazards and Risks at Rotary Screen Printing (Part 2/6):
Analysis of Machine-operators’ Posture via Rapid-Upper-Limb-Assessment (RULA)

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Abstract
Musculoskeletal-disorders (MSDs) are one of the most noticeable global problems, ergonomists come across, in the workplace. To prevent MSDs, their root causes, particularly, poor/awkward postures, should be identified, first. This study examined such postures, at printing-section of finishing-department, at textile-mill, via numerical-rating ergonomic-assessment tool, namely Rapid-Upper-Limb-Assessment (RULA). In addition, ISO 11226: Ergonomics, evaluation of static-working-postures (2000); and EN-1005-4: Safety of machinery, human-physical-performance, and evaluation of working-postures, in relation to machinery, were used, as a reference. The RULA analysis, on the two-chosen highest-risk postures (#1 and #2), identified 2nd and 3rd action-level of danger of musculoskeletal injury (MSI), necessitating further investigation, and possible change/correction. These investigations revealed the following-risks of MSDs or MSIs, for the posture #1: (1) awkward-back posture--trunk-bending-forward, at the waist, with 46 degrees deviation, from neutral-posture; (2) visually-demanding-operation (risk of eye-strain); (3) contact-pressure; (4) stress on lower-extremities; and (5) standing-static-posture. For the posture #2, the risks were: (1) awkward-neck, and head-posture, with 38 degrees-deviation, from neutral-posture; (2) risk of eye-strain; (3) stress on lower-extremities; and (5) standing-static-posture. Several-tailored recommendations, to control, or prevent, the identified hazards, were offered, including: engineering, work-practice/administrative, and PPE-approaches. In addition, 3 areas, for further research, were identified. Moreover, informative-synthesis on relevant-issues were also given, such as: Work-related MSDs (WRMSDs) and their prevalence; Working in neutral-posture; Awkward-posture, its-effects, and relevance to WRMSDs; Upper-limb-MSDs; RULA; Spine and awkward-back-posture; Visually demanding-operation and eye-strain; Printing-defects; Digital-image-processing-techniques; Contact pressure; Standing-static-posture; Stress on lower-extremities; and GSE-automatic-dispensing systems, among others. The study is important, for textile-printing-industry, particularly the management of the textile-printing-section, at the textile-mill, as it provides specific recommendations, for consideration-to-implementation, to reduce and control the risks of WRMSDs. It also adds (in its small way) to the body of knowledge on WRMSDs.

Keywords: textile industry, MSDs, WRMSDs, awkward-posture, printing defects, machine operator.

1. Introduction
1.1. Work-related Musculoskeletal-Disorders (WRMSDs) and their prevalence
WRMSDs are a widespread health-concern, and a main cause of occupational-illnesses, worldwide (Eurofound, 2007). Currently, MSDs are one of the most noticeable global problems, ergonomists come across, in the workplace (Choobineh et al., 2007).

In 2005, 107.7 million U.S. adults reported, that they experienced a MSD, for three-months, or longer (i.e., the condition was chronic) at some point, in the preceding-year; this is almost-twice, as many people, as reported any other medical-condition (BMUS, 2008). According to the United States Department of Labor (2014), WRMSD-cases, per, 10,000 full-time workers, were: 45.3, 52.7, and 33.5 cases, for state government, local-government, and private-sectors, respectively. In 2013, 35.8 days, away from work cases, were reported, per, 10,000 full-time workers, due to MSDs, which was one third, of all the reported cases of days away from work (Bureau of Labor Statistics, 2014). The Bureau of Labor Statistics, in America, also reported 246,700-cases of WRMSDs, accounting for 66% of workplace-illnesses; 128,000 professional and administrative-workers missed at least one day of work, due to musculoskeletal, or ergonomics-related disorders, or injuries (Dale, 2004; Lester, 2003). 35% of sick days, away from work, are due to musculoskeletal-injuries (MSIs), and 33% of workers compensation-costs are spent on ergonomic-injuries (US Bureau of Labor Statistics, 2014); these compensation-costs classified-as-high, by HSE (2006).

Moreover, large-scale study by IBI (2014) on 99,558 employees, revealed, that in a population of 100 working people: (1) 28% report at least-one musculoskeletal-condition; (2) 11% had treatment for osteoarthritis; (3) 8% had treatment for back problems; (4) 6% had treatment for lupus, and other connective-tissue-disorders; and (5) 2% had treatment, for other-bone and musculoskeletal-diseases.

Along with the health risks, associated, the monetary loss, due to such disorders affects not only the individual, but also the organization, and the society, as a whole (Lee & Park, 2007). In particular, WRMSDs result in high costs, to employers, due to absenteeism; lost productivity; disability, and workers’ compensate-
costs (Arnetz et al., 2003). Annual-report on WMSDs, by United States Department of Labor, in 2014 revealed, that WMSD-incidents cost about USD 20 billion, in the-year 2013, as direct-cost, and five-times to that-amount, as indirect-cost (OSHA, 2014). MSDs are also-linked-to so-called ‘presenteeism’, early-retirement, and economic-inactivity (Summers et al., 2015). ‘Presenteeism’, is being, at-work, while-unwell, thus compromising productivity, and safety.

WRMSDs correlate-with physical-workload-factors, as-follows (IFA, 2014): (1) Manual material handling, e.g. lifting; holding; carrying; and pulling and pushing (can-lead-to low-back-pain; Inter-vertebral lumbar-disc-disorders/injuries (e.g. protrusion, prolapse); and lower-limb-disorders (e.g. osteoarthritis of the hip and knee-joints; and neck-shoulder-MSDs); (2) Working in awkward-postures, can-be both; overload or under-load (e.g. awkward-trunk-postures; crouching; kneeling; squatting; working, with-arms above-shoulder-level; and lack of physical-movement in sitting, standing, or lying); (3) Repetitive work (can-lead-to Carpal-Tunnel-syndrome; wrist-tendinitis; and lateral-epicondylitis); and (4) Work involving high-exertion and/or exposure-to-force, e.g. climbing, knocking, and hammering (low-back-pain; and upper-limb-MSDs).

1.2. Working in neutral-posture

Manual-tasks, in-different-industries, are-performed, in-a-variety of ways; the-main-ones, being: standing-posture, sitting-posture, and a-combination of previous-two, sit-stand-posture.

A good-working-posture is a-prerequisite, for preventing WRMSDs. A good-posture is one, that is comfortable, and in which the-joints are naturally aligned — the-neutral-body-posture. Neutral-postures are postures, where the-body is aligned and balanced, while either sitting, or standing, placing minimal-stress on the-body, and keeping-joints-aligned. Neutral-postures minimize the-stress, applied to-muscles, tendons, nerves, and bones, and allow for maximum-control, and force-production. When standing-correctly, the-spine has a-natural ‘S’-curve, where ears, shoulders, hips, knees, and ankles, are aligned with-the-spine, in-this-natural ‘S’-curve.

According to Halim & Omar (2011), good-posture is also-important, because it helps body-function, at-top-speed. It promotes movement-efficiency and endurance, and contributes to an-overall-feeling of well-being. Good-posture also-contributes to good-appearance; the-person with-good-posture projects self-confidence, and distinction.

In-contrast, poor-posture can affect the-position, and function, of one’s vital-organs, particularly-those, in the-abdominal-region. Working, with the-body, in-a-neutral-position, reduces stress and strain, on the-muscles, tendons, and skeletal-system, and, therefore, reduces the-risk of workers, developing MSDs (European-Agency for Safety and Health, at-Work). Maintaining the-neutral, or standing-shape of the-lumbar, is therefore imperative.

During-work, however, sometimes-subconsciously, workers tend-to-accept, and get-used-to unsatisfactory working-conditions, and have to-perform, required-for a-task, movements, in-deviated-from-neutral, positions. Deviations from neutral-posture, toward the-extremes in-range of motion, lead to-abnormal or awkward-posture, which is a-complete-opposite of a-neutral-posture. Workers-may not realize, that their-body is under-strain, until they feel actual-pain, and even-then, they may not understand the-exact-causes, behind such-pain.

1.3. Awkward-posture, its-effects, and relevance to WRMSDs

Awkward-postures refer-to-positions of the-body (limbs, joints, back), that deviate, significantly, from the-neutral-position, while job-tasks are-being-performed. Awkward-postures occur, when joints are not in-neutral-positions. The-following-examples of awkward-postures, may-involve range of movement, near-extreme-positions (Soytas, 2006): (1) bending-neck-forward, greater than 30 degrees; (2) raising the-elbow, above the-position; (3) bending the-wrist-downward, with palm facing-downward, greater than 30 degrees; (4) bending the-back-forward, greater than 45 degrees; and (5) squatting, among-others.

Other-joint-postures, not necessarily involving extreme-range of motion, are known-to-be-associated with increased-risk, of discomfort, and MSDs. These-include: twisting the-trunk; bending the-trunk, to-either-side; leaning-backward; turning the-head, to-either-side; bending the-neck, to-either-side; bending the-neck-backwards; bending the-wrist-upward, with palm facing-downward; bending the-wrist-outward, with palm facing-downward; rotating the-forearm, or resisting-rotation, from a-tool; and kneeling, among-others. There are other-awkward-postures, which occur, because of the-orientation of the-body, with respect-to gravity, and do not necessarily involve extreme-ranges of movement. For-example, extended reaches, that are beyond an-arm-length (above, forward, or below), where the-upper-part-of the-body has-to-bend-forward, to-reach.

When a-joint is not in its-neutral-position, its-muscles are either-shorter or longer, than resting-length. When joints are exposed to-postures, near the-extreme-positions, the-tissues-around-the-joint are stretched, or compressed. Ligaments, in-particular, are stretched, in-extreme-postures, and if such-exposure is prolonged, the-ligaments do not immediately-return to-their-resting-length. Tissue-compression may also-occur with-extreme-postures. For-example, extreme-flexion, or extension, of the-wrist, increases the-pressure, within the-carpal-tunnel, resulting in-compression of the-median-nerve, as it passes-through the-carpal-tunnel (Keir et al., 2007).
When a-muscle is in-its-neutral-range of postures, it can produce the-greatest-amount of force, that is, a-muscle is strongest, when in-a-neutral-posture. When-doing a-task, which-requires a-specific-amount of force, exerting that-force, with the-joint and muscles, in-a-neutral-posture, will-result in the-muscles using a-lower-percentage of its-maximum-capability. In-contrast, when a-joint is in-an-awkward-posture, the-muscles have-less-strength. Accordingly, if they have-to-produce the-same-amount of force, the-muscles will-be-working closer to-their-maximum-level. Fatigue will-occur, more-quickly, increasing the-risk of injury (Chaffin et al., 2006).

According to Gangopadhyay et al (2010), a-person, working in-an-extreme or awkward-posture will-have to-use more-force, to-accomplish the-same-amount of work, compared to-using a-neutral-posture, which in-turn affects muscle-loading and compressive-forces, on the internal-vertebral-disc. The-forward-bent-posture and the-techniques of work are influencing the-compressive-force, on the vertebral-discs, and the-electromyography, of erector-spine-muscles.

The-stress on-the-muscles, and tendons, in-a-particular-area (say, shoulder), can cause-irritation, and inflammation of the-tendons, and the-shoulder-joint. This, in-turn, may place increased-pressure, on-nerves and blood-vessels, reducing the blood-supply-to the-affected-muscles and tendons (Anderson et al., 1986).

Awkward-body-postures place excessive-strain on human-bodies, posing a-risk of injury (hazard), if held for-extended-periods of time, without stretching. If not addressed, timely and appropriately, more-serious and chronic-manifestations of the-symptoms can emerge, severely-affecting the-quality and duration of a-person’s working-life (Harcombe et al., 2009; Compensation Commission, 2004).

Many-painful-afflictions, of musculoskeletal-system, known-as Cumulative Trauma Disorders (CTD), MSDs, or MSIs, in-manufacturing-industry, are associated-with these-working-postures (Harcombe et al., 2009; Jonsson et al., 1988; Kilbom & Persson, 1987; Armstrong et al., 2000). WRMSDs, such-as: neck, upper-limb, and back-disorders, are widely-recognized, for their-adverse-impact, upon employee- productivity, and well-being (Parker & Mackie, 2002; Roelofs & Straker, 2002).

Present-study is focused on assessing the-work-posture of personnel, engaged in-different-activities, involved, during fabric-printing, assuming, that workers are operating, largely, at awkward-postures.

1.4. Upper-limb-MSDs

According to HSE (2002), the-term ‘upper limb’ (UL) refers-to: (1) the-part of the-body (the-arm and hand, covering a-region, extending-from-the-tips of the-fingers to the-shoulder, and expanding, into-the-neck; and (2) the-tissues: the-soft-tissues, muscles, and connective-tissues (tendons and ligaments), and the-bony structures, as-well-as the-skin, along-with the-circulatory, and nerve-supply, to-the-limb.

There-are established-associations-between many-types of UL-disorders, and work-tasks, or specific-risk-factors, within these-tasks (Bernard & Putz-Anderson, 1997). Evidence comes from: (1) reports, which have historically-linked specific-occupations and particular-conditions (Hunter, 2000; (2) clinical-case-studies, and reporting-schemes, for occupational-diseases (Cherry et al., 2001; 2000); (3) workplace-surveys of symptoms (Mackay, 1998); (4) epidemiological-reviews (WRULD, 1998; Bernard & Putz-Anderson, 1997); (5) population-surveys (Jones & Hodgson, 1998); and (6) laboratory-studies, of the-physiological-impact, of experimentally-imposed physical-stresses (Chaffin & Andersson, 1999; Whiting & Zernicke, 1998).

Tanaka et al. (2001) estimated that about 40% of all upper-extremity MSDs, in the-total U.S.A. employed-population, were attributable to-occupational-exposures, representing over 500,000 people, affected, per-year.

This-study focused on upper-limb-MSDs. Specific-tools, to-measure the-exposure to-MSDs-risks, include, but are not limited to: Rapid-Upper-Limb-Assessment (RULA) (McAtamney & Corlett 1993); Rapid-Entire-Body-Assessment (REBA) (Hignett & McAtamney, 2000); Strain-Index (Moore & Garg, 1995); Occupational-Repetitive-Actions-Index (OCRA) (Occipinti, 1998); and TRAC (van der Beek et al., 1992), among-others. Posture is a-key-input, in these-analysis-tools, in which the-analyst classifies a-body-segment-position, which is partitioned into posture-categories. The-risk is especially-pronounced, when a-job includes exposure-to a-combination of two or more of these-risk-factors.

Moreover, study by Strine & Hootman (2007) found-out that, among-individuals, with low-back and/or neck-pain, the-following co-morbidities were-significantly more-likely: respiratory, cardiovascular, gastrointestinal, chronic-pain, other-musculoskeletal-conditions, and other-chronic-conditions.

1.5. Rapid Upper Limb Assessment (RULA).

RULA-method, was developed, by Dr. Lynn McAtamney and Prof. Nigel Corlett, ergonomists, from-the University of Nottingham, in-England. RULA is a-postural-targeting-method, for estimating the-risks of work-related upper-limb-disorders. The-method provides a-complete and detailed-assessment, on each-body-parts, there-are: group A (upper-arm, lower-arm, wrist, and wrist-twist) and group B (neck, trunk, and legs), muscle-use (static or repetitive), and force/load (Hignett & McAtamney, 2005). Overall, this-tool considers biomechanical and postural-load-requirements of tasks-demands on the-neck, trunk and upper-extremities.
Based on the results of a survey, conducted by Dempsey et al. (2005), RULA method is the most widely used, by the international ergonomic experts, because its procedure is appropriate and easy to use. RULA method has been widely applied to study various types of industrial tasks, for example: Sartika (2010) conducted an analysis of working postures, using RULA method, in boiling-palm-oil operators; Deský (2010) on the oatmeal-packaging operators; Abdillah (2013) on fruit posters, in a traditional market; and Pangaribuan (2009) on employees, working in a university library.

This study used standard RULA method.

1.6. Research-purpose

Hankin & Killian (2004) reported, that chronic pain, associated with WRMSDs and work-related injuries, has a significant economic impact on society, in terms of health care costs, disability compensation, and days lost, from work. As a result, everyone loses, when workers are injured, or disabled, for long periods of time. The insurer, employer, and society suffer the economic losses, while the employee suffers pain, and discomfort, and in severe prolonged cases, decreased income, costly medical bills, and deprivation of quality of life.

Preventing WRMSDs and injuries starts with understanding them. Knowledge of the context and type of working postures is necessary, in order to examine the associations with health related outcomes (Taylor et al., 2005). According to Da Costa & Vieira (2010), it has become a priority, to prevent WMSDs, in many countries. For example, 2% of the annual budget, of the National Institutes of Health, was awarded to research, investigating MSDs (BMUS, 2008).

According to Da Costa & Vieira (2010) some frequently reported risk factors/hazards, for WRMSDs, have not been studied, in sufficient detail, to confirm, whether they do, indeed, represent a risk. There are also ongoing methodological debates, and inconsistencies, among current studies, about how to measure, best occupational exposures; making difficult, to reach a consensus, on the subject matter (Gerr et al., 2014). Besides, Summers et al. (2015) points out, on significant gaps, in understanding, and knowledge, when it comes to WRMSDs, and their relationship to employment. Besides, upper extremity MSDs are highly prevalent in manual intensive occupations, such as clerical work, postal service, cleaning, industrial inspection, and packaging (Rempel & Punnett, 1997). Statistics on UL-MSDs (for any sector) for Kenya, however, are not yet found.

Besides, HSE (2002) identifies textile manufacturing jobs, as having tasks, with recognized risk factors to MSDs. Moreover, Punnett & Wegman (2004) classified textile manufacturing as high risk sector. Textile manufacturing, however, is exceedingly versatile, consisting of many different specialties and equipments, hence, it is paramount, that specific sectors, and particular equipment, be assessed, to avoid generalization.

Recent study, by Starovoytova (2017a), at the same textile-mill, recommended: to research on machine operator’s postures, during printing, and possible work related MSDs, due to such postures. Yet, another study by Starovoytova (2017b) concluded, that: ‘The highest number (60%) of sick leave days, attributed to MSDs, among factory workers, was due to hand, wrist, and forearm pain or injury’. In addition, one of the main recommendations was to identify postures and working practices, leading to WRMSDs, at the finishing department, of the mill.

To prevent MSDs, their root causes, such as awkward postures, should be identified, first. In this regard, the current study is to examine such postures, at printing section of finishing department, of textile-mill, via numerical rating ergonomic assessment tool, namely Rapid Upper Limb Assessment (RULA). In this study, MSDs are considered, in the context of workforce association; work is assumed as ‘paid employment’, simply put, the focus of this study is exclusively on occupational MSDs.


2.1. Preparatory observations, for the RULA analysis

The assessment started, by interviewing the workers, being evaluated, to gain an understanding of the job tasks and demands, and observing the worker’s movements and postures, during several work cycles, at the printing section, of the finishing department.

While the operators were performing their routine tasks, working on their machines, or workstations, pictures of them were taken, from lateral angles on the 5th, 10th, 15th, 16th, 17th, 18th and 20th minutes of observation, to identify the worst posture, captured over the period of 20 minutes, according to (McAtamney & Corlett, 2004). Afterwards, the pictures with worst posture, for each participant, were selected.

The overall highest risk postures, due for RULA analysis, was chosen, based on (ErgonomicsPlus): (1) the duration of the posture (e.g. longest held); (2) the degree of postural deviation (e.g. worst posture); (3) the highest force loads (most physically demanding); and (4) the overall difficulty postures. The first three were obtained from observations and from the photographs, taken; while fourth, by interviewing the printing machine operators.
2.2. RULA-method

RULA is a postural targeting-method, for estimating the-risks of work-related upper-limb-disorders. The method uses photos of body-postures and three-scoring-tables, to provide evaluation of exposure to risk-factors. The-analysis of occupational postures followed the standard RULA procedure, which is shown in Figure 1, as a single-page, 16 steps-explanations.

Briefly, RULA worksheet (Figure 1) is used to assess body posture, force, and repetition. Based on the evaluations, scores are entered for each body-region, in Table A, B, and C. After the data for each-region is collected, and scored, a single score, that represents the overall-level of MSD risk, is obtained, according to (McAtamney & Corlett, 2004). The RULA checklist measures postures on a scoring-system-scale from 1 to 7. The action-level is then determined, from the overall level of MSD risk, obtained, and guidance table, shown in Figure 2. In addition, ISO 11226: Ergonomics, evaluation of static-working-postures (2000); and EN-1005-4: Safety of machinery, human-physical-performance, and evaluation of working-postures, in relation to machinery, were used, as a reference.

The following tools were utilized, during the study: (1) Digital-camera Canon EOS T5, to capture the postures of the participants while doing observation; (2) Measuring-tape, to measure viewing-distance; and (3) a regular ‘protractor’, for measuring the deviation-angles, from neutral-postures.

After observing the workers, it was decided, to limit the study to one side (right), only, as right-hand was dominant, in majority of working-operations, performed, and all observed-workers were right-handed.

RULA scores were measured from photographs, taken. Slight errors might be present, in establishing the angles of deviation, from neutral-postures, due to possibility of slight movement of a worker, at the same time, the photo was taken, and also due to unintended human error. The errors, however, presumed to be negligible.

Figure 1: Standard procedure of RULA (McAtamney & Corlett, 2004).
Figure 2: RULA action-levels with their-interpretation (McAtamney & Corlett, 2004).

3. Results and Analysis.
3.1. Postures chosen
Two-high-risk-postures were chosen, posture #1(awkward-back-posture) for a-printing-machine-operator, visually-monitoring quality of printed-fabric; and posture # 2(awkward-neck-posture), for printing-machine operator, manually-preparing printing-paste, in color-kitchen. This-findings are in-accord with-studies by Lombardo & Eyre (2011), who stated, that the-back was the-most-frequently affected-region, among garment-workers, while Deyyas & Tafese, (2014) pointed-out, that awkward-neck-posture was the-most prevalent posture, leading to MSDs.

3.2. Demographic-data of the-participants
The-mean-age of the-workers was 32.1±4.2 years; the-duration of their-employment (by the-time of this-study) ranges from 2.3 to 4.7years. The-body-height, and body-weight, was 160.7±7.9 cm, and 59.6±6.3 kg, respectively. The-workers, in-printing-section of the-finishing-department, worked for 9.5 hours, per-day, including one-hour-lunch-break, and 30minutes-tea-break.

3.3. Analysis of posture#1
Figure 3 (left) shows the-posture #1, chosen, based-on: extreme-angle of posture, static-posture, and longest-duration of operation, among other-reasons.

Figure 3: Operator visually-inspecting printed-fabric for defects (left); and Extreme angles and the-actual-deviation from neutral-position.
Table 1 shows summary of the-analysis of upper-arm, lower-arm, and wrist (Table A); Neck, trunk and legs (Table B); and Neck, Trunk, leg, and wrist/arm (Table C), for the-posture#1.

Table 1: Summary of the-RULA-scores (Table A, B, and C) for posture #1.

3.4. Analysis of Posture#2

The-operator was manually-preparing ingredients, for printing-paste; the neck-position deviation-angle is shown, in Figure 4 (left), while Figure 4 (right) shows the neck-flexion and extension zone of operations, showing actual-degree of deviation, for posture #2.

Figure 4: Operator, measuring chemicals (left); and Extreme angles, and the-actual-angle of deviation
Table 2 shows scores for the-posture #2.

Table 2: Summary of the-RULA-scores (Table A, B, and C) for the-posture #2.

<table>
<thead>
<tr>
<th>Upper Arm</th>
<th>Lower Arm</th>
<th>Neck Score</th>
<th>Wrist Score</th>
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<td>1</td>
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For-the-posture # 1, total-score of 4, corresponded to 2\(^{nd}\) action-level (see Figure 2). The-person is working in a-posture, that could-present some-risk of injury; from their-working-posture (at-least one-part, of the-body, is in-awkward-position). This should-be investigated and corrected.

For-the-posture # 2, total-score of 6, corresponds to 3\(^{rd}\) action-level. The-person is working in a-poor-posture, with risk of injury. The-reasons should-be-also-investigated, and changed, in-the-near future, to-prevent injury.

Both-findings call-for further-investigations, on the-two-postures, which follow under the-discussion-section.

4. Discussion.

Evaluating working-conditions greatly-contributes to the-recognition and prevention, of occupational- hazards, and risks. The-following-sections cover further-evaluations of the-two-postures, and corresponding tailored-recommendations, on how to-improve the-current-practice, and protect the-operators, from MSDs and occupational-injuries.

4.1.1. Posture#1
The-printing-machine-operator was in-awkward-back-posture; the-angle of deviation was 46\(^{\circ}\), which from Figure 3(right) is in the-extreme-end of the-red-zone of movement, meaning that it-is a-high-risk-posture, which can-lead to-MSDs, or injury. The-operator was standing, in-this-position, with almost no movement, for the-large-part of his-shift, pointing at-another-MSDs-risk—standing-static-posture. The-operator was also-visually inspecting printed-fabric, which was moving, on a-rubber-blanket, at the-approximate-speed of 50m/minute. He was continuously-observing the-fabric, for any-visible-defects, meaning that his-eyes were fixated, in-the-same-direction, and in-addition, the-operator was constantly processing information (comparing the-moving-printed-fabric with known-printing-defects), this makes the-job visually demanding, adding another-risk of MSDs. The-operator was also-leaning on his-elbows, on the-metal-surface of the-machine, leading to yet-another-risk—contact-pressure. His-legs were also under-stress, as he was standing all-the-time, and in-addition there was a-limited leg-room, for any-movements. In-summary, five-aspects of the-operator’s-job, were considered as MSDs-risk-factors: (1) awkward-back-posture (trunk-bending-forward, at the-waist); (2) visually-demanding-operation (risk of eye-strain); (3) contact-pressure; (4) stress on lower-extremities (see Figure 5 for the-fist-four-aspects); and (5) standing-static-posture.

Besides, according to Ndung’u & Kiplangat (2007) chances of injury increases, when two or more MSD-risk-factors, combined in one-job. One-factor, alone, is unlikely-to-cause a-high-risk of injury. For-example, performing a-forceful-lift, once, places a-worker at-less-risk, than performing a-forceful-lift, several-times an-hour.
Figure 5: MSDs risks identified for the-posture #1.

To-reduce the-risks of MSDs and injury, each of these-risks were looked-at, individually, and presented below, in-the-same-order.

4.1.1.1. Awkward-back-posture

To-understand the-possible-damage, of back-awkward-posture, first, it-is-beneficial to-comprehend the-complex-system of human-spine, and the-elements, involved in the-back-movement.

Human-back is a-flexible-curved-column, composed of a-series of bones (vertebrae), separated by shock-absorbing-discs. The-structure is held-together by a-large-number of muscles and ligaments. Acting-together, they give the-spine the-ability to-move, bend, and twist. The-spine also-encapsulates, and protects the-spinal-cord, and acts-as a-distribution-center, for the-nerves.

Structural-components, of the-spine, involve: (1) Bones (the-bone-portion of the-back consists of 24 vertebrae, stacked, one-on-top of another, to-form a-long and stretched ’S-shaped’-curve, with interchanging, and hence, balancing, forward and backward-curves) see Figure 6 (right); (2) Discs (the-discs positioned between two-vertebrae, to-absorb-shock, and keep the-vertebrae from rubbing, against-each-other); (3) Facet-Joints (each-vertebra has a-facet-joint, that allows to-bend and move the-back; they are held-together, by ligaments; and (4) Ligaments (these-bands, of tough-tissue, support the-spine, and help to-keep-it in-place).

Moreover, supportive-components enable for the-back to-move and to-function (see Figure 6 left), namely: (1) Spinal-Cord and Nerves (the-spinal-cord is located within the-spinal-column. It composed of nerve-bundles, that transmitting messages, to-the-brain, and throughout the-body); and (2) Muscles (support the-vertebrae of the-spine, from all-sides. The-following four-muscle-groups are involved in the-back-movement, and support of the-spine: Back; Stomach; Hip-Flexor; and Side-muscles.

Figure 6: Structural-components (to-the-right of the-diagram), and supportive-components of the-spine (left).

The-existence of the-relationship, between awkward-postures and the-occurrence of low-back-pain, leading to MSDs, or injury, has long been-recognized (Bridger et al., 2002; Black et al., 2001; Johanning, 2000). When
parts of the-body are near the-extremes, of their-range of movements, such-as, in the-case of the-posture #1, stretching and compression, of tendons and nerves, occur. The-longer an-awkward body position is used, the-more likely it-is, that an-injury will-develop.

According to Key (2000) back-pain remains pandemic; it filter-through all-nationalities, all-age- groups, and all-professions; and, currently, is second, only to-the-common-cold and flu, as a-cause of time-off. However, lower-back-problem is more-frequent in-people, with-predominantly bent-over work-posture (Twomey & Taylor, 2000). Furthermore, Messing (2004), points-out, that the-working-posture and task, should-be-designed, to-avoid strain and damage, to any-part of the-body, especially the-back.

Continuous-awkward-back-postures can-lead to-MSDs, such-as: Lumbar-inter-vertebral-disc prolapse ("slipped-disc"); Degenerative-disc-disease; Fatigue-strains (muscle, tendon) and sprains (ligaments); Facet joint-syndrome; Vertebral-Arch-stress-fracture (spondylolysis); Acute-nerve-root-compression; Spinal-Canal Stenosis; Lumbar-muscle-strain; and Lumbar-instability, among-others (NCP, 2007).

To-prevent such MSDs, usually, any (or a-combination) of the-three-standard-approaches can-be-used, namely: (1) Engineering-controls (redesign of workstations, tools, facilities, materials, equipment, and processes); (2) Administrative-controls (employee-rotation, job-task-enlargement, alternative-tasks, employer-authorized-changes in work-pace, and training); and (3) provision and use of Personal Protective Equipment (PPE).

Ideally, work should be done, in a-neutral-body-position, however, this-is not always possible. For-the-posture #1, the-operator had to-bend, to-see any-printing-defect, clearly. Hence, different-approach to-reduce the-risks of MSDs, should-be assessed. According to Twomey & Taylor (2000), there-are demonstrated-benefits, from-stretching the-soft-tissues (the-muscles, ligaments, and tendons) around the-spine. The-spinal-column and its-surrounding-muscles, ligaments, and tendons, are all designed to-move, and limitations, in-this-motion can bring-out pain. Specifically-designed back-stretching-exercises can-be viewed via Twomey & Taylor (2000), however, for the-operator (in-this-study) to-do the-regular-stretching-exercises, the-printing-machine must-be stopped, which will-reduce its-productivity. Rotation of the-task will also necessitate the-machine-stoppage. These-two-recommendations, therefore, are subject to-the-employer-authorized-changes in work-pace.

4.1.1.2. Visually-demanding-operation (risk of eye-strain)

The-work of an-observer, of the-quality of printed-fabric, is very-monotonous and time-consuming. They have to-detect tiny-details, in a-wide-area, that is moving-through their-visual-field. A-clear-distinction, have to-be made, between dimensional-inspection and surface-inspection. Dimensional-inspection may-be carried-out to-check the-item’s-size and shape, while surface-inspection is more-like a-detailed-scrutiny, of surface-properties, such-as color-distribution, and texture (Davies, 2001). In-this-task, the-operator conducted surface-inspection of printed-fabric, looking for any-abnormality or defect.

On-the-other-hand, a-visually-demanding-task involves some, or all of the-following-conditions: (1) near-work—distances of less-than 500 mm, for periods of several-hours, with few-breaks; (2) text and graphics, less than 3mm-high; (3) crowded and complex-visual-material; (4) accuracy, sustained-attention, sustained-work, at-speed, or sustained-cognitive-processing; and (5) less-than-optimum workplace ergonomics (Health and Safety Executive, 2006; Cole, 2001). The-work of the-printing-operator, hence, is qualified as visually-demanding. Over-time, such-a-job might lead to-eye-strain, and other-associated-conditions.

For-example, eye-strain or fatigue, also-known-as asthenopia, is an-eye-condition, that manifests itself through nonspecific-symptoms, such-as: fatigue; pain, in or around the-eyes; blurred-vision; headache; occasional-double-vision; burning, itching or tearing-eyes; loss of focus; and temporary-change in-ability to-see-colors. Besides, dry-eye-syndrome (keratoconjunctivitis sicca) is also-very common, among-workers, constantly-performing visually-demanding-tasks. Nonocular-symptoms, such-as: tension-headaches; difficulty concentrating; and shoulder, neck, or back-pain; may-also-result from over-correction or accommodation-postures, that aim to-reduce eye-strain (e.g., in-this-study, bending forward, to-view the-moving-fabrics, more-clearly).

Visual-impairment can-diminish health and wellbeing, affect a-person’s ability to-work, drive, and perform-normal-everyday-activities, such-as: reading, or watching TV. The-effects of visual-impairment, or injury, can-reduce mobility, increasing the-risk of falls, and injury, and distress a-person’s independence. This-can contribute, over-time, to-isolation, and depression, affecting both; the-worker’s performance, and social-relationships (Vansa et al., 2008). To-prevent visual-impairment, it would-be-useful, to-understand the-system of vision, starting from the-eye, itself.

The-ability to-see is one of the-most-remarkable and complicated-human-senses. Moreover, analogous to the-human-spine, the-structure of the-eye is complex. The-human-eye is not designed for prolonged-fixation in one-direction, with no movement, such-as inspecting fabric, which moves, at high-speed, for prolonged-periods; the-ciliary-muscles tightens. Ciliary pertains to various-anatomical structures, in and around-the-eye, namely the ciliary-body and annular-suspension of the-lens of the-eye. Muscles play a-very-important-role in the-process of vision; they are known as the extra-ocular muscles, responsible for the-movement of the-eyes (see Figure 7).
Vision-Dysfunction also-known-as Vertical Heterophoria (VH), where the two-eyes have difficulty keeping in vertical-alignment. This can lead to double-vision, and the brain does not interpret such-input. Besides, sometimes, one-eye is physically-higher, than the-other. Moreover, operators might simply-have poor-vision. Whatever the-scenario, poor-eye-sight can result in low-defect-detection, and even, can-lead-to an-accident. The study, hence, recommends the factory-management, to-ensure that the-workers undertake necessary-eyesight-screening. During the-examination, any-eye-problems can-be-discussed with an-eye-professional, eye-problems, identified-early, and preventative-strategies, developed. The results of each examination, should be recorded, for-ease of reference, during subsequent yearly-eye-examination.

In addition, it was also observed that the department, where the printing-machine is situated, was illuminated by overhead-fluorescent-lights, fixed at a height of around 5 meters. From the observers' point of view, the illumination, just above the observation-area, was not sufficient. Good-workplace-lighting, however, is paramount, especially for visually-demanding-work, to avoid unnecessary-straining the-eyes, or, even, an injury. Insufficient-lighting may also increase the risk of accidents, as awkward-positions, obstructing-to-see, clearly (EFILWC, 2005).

In this regard, the study made two more recommendations: (1) to provide workers with adjustable task-lighting; and (2) further studies should be conducted to examine whether the intensity and the type of light, in the printing-section, is adequate and appropriate.

On the other hand, the printing machine-operator is looking for any defects, in printed-fabric; knowledge of printing-defects is, therefore, an important step, in order to reduce or eliminate them. To appreciate the complexity of visual-defect-detection, Table 3 shows common defects of printed-fabrics.
Moreover, for the rotary-screen-printing, in-particular, several major-types of defects, are identified, as follows (Ferreira et al., 2015): (1) **Out of register**: when the-printing of each-color is not synchronized; (2) **Color exchange**: when the-ink is placed in-the-wrong screen; (3) **Insufficient dyestuff in the fabric**: when in-some-part of the-pattern, there is-a lack of color, meaning that the-color gets duller; (4) **Color drift**: along the-printing process, the-color changes, or becomes toned-down; and (5) **Color blots**: color-spot, marking the-tissue; among-others. After detection of defects, they-are graded. Defects graded based-on (Ullmann, 2008) : (1) severity, as: **Major**--a-defect severe-enough, if exposed, to-place an-end-item in 'seconds' (second-quality-item); **Minor** –an-imperfection, that may, or may not, cause a-second, depending-upon its-location, in the-end-item and/or its-chance of being-lost, in-fabrication; and (2) **Point-Value of Major and Minor**: Major—one-point, for each-increment of nine-inches or part-thereof; Minor-one-quarter-point, for each-increment of nine-inches, or part-thereof.

Fabric-faults, or defects, are responsible for-nearly 85% of the-defects, found in-the-textile garment-industry. Manufacturers recover only 45-65% of their-profit, from seconds, or off-quality-goods (Ullmann, 2008). It-is imperative, therefore to-detect, to-properly-identify, and to-prevent these-defects, from reoccurring. Above-narrative illustrated, that there-are, indeed, many-kinds of printed-fabric-defects. Much of them is caused by machine-malfunctions, and should-be timely-detected, to-correct machine-malfunction. For-example, Jing et al. (2012) pointed-out, on one-of such-machine-malfunctions:

The registering accuracy is a key factor which affects the fabric printing quality. In order to guarantee the printing accuracy, and to ensure that there is no off-pattern-appearance, all cylinders of rotary screen printing-machine must keep the same pace with the conduction band precisely. In the actual production process, as the rotary-screen-printing-machine is affected easily by the wear of transmission parts, gear loose and fabric deformation and other factors, the relative position between the cylinders and the bands changes easily. And if it is not adjusted timely, the off-pattern phenomenon will appear. To solve this problem, the manufacturers of rotary screen printing machine at home and abroad, do continuous improvements on the textile registering link.

Most of the-strategies they take are-about the-improvement, of the-mechanical-structure, and updating of electrical-actuators; or detecting the-register-error, by color-mark-method (Li et al., 2008). Overall, this problem,
it still remains in the-manual-judgment and adjustment-phase, and the-closed-loop-control is yet to be implemented (Gang & Junfeng, 2009).

In-addition, if the-auto-registering detection-system, based-on machine-vision (Binjie et al., 2010; Li Yong et al., 2009; Hyung et al., 2009), replaces the-manual-detection, it will not only eliminate the-human-errors, and improve registering-accuracy, but also-reduce the-labor-load, raise the-per-unit-quality and productivity. In-study by Chaoli & Jianxi (2008), a-theoretical-model of rotary-screen printing-machine automatic-registering-detection-system, based-on machine-vision, was presented. Besides, Ergonomics Unit (2006), proposed the-color textile-image segmentation-algorithm, based on MeanShift, and the-block-matching-algorithm, based on Harris-corner-detection. The-extended MeanShift-algorithm was used to-segment the-textile-image, and then different-color-regions were extracted, from the-segmented-standard-image; then the-feature-points were-detected by Harris-operator, and with these-feature-points, as the-centers, the-standard matching-blocks were-selected; finally, the-best matching-block, in the-dealt target-image, were-found to-calculate register-errors.

On-the-other-hand, one of the-imperative-aspects, of textile-fabrics, is quality. The-price of fabrics is relentlessly-affected by the-defects of fabrics, which represents a-major-threat to-the-textile-industry, wishing to-preserve its-reputation. Moreover, a-very-small-percentage of defects is, actually, detected, by the-manual-inspection, even with-highly-trained-inspectors, which is time-consuming and not accurate enough. The-identification-rate is only about 70% (Henry et al., 2011). Moreover, the-effectiveness of visual-inspection decreases-quickly, with-fatigue. The-fabric-defects-inspection process is carried-out with human-visual-inspection, and thus, largely, unsatisfactory, and costly. An-automatic defect-detection system can increase the-defect-detection, while maintaining the-fabric-quality.

For defect-detection, most-visual-inspection-systems fall-into one of three-categories, depending on the-defect-detection-approach: (1) image-reference (or Template-Matching); (2) design-rule; or (3) some-combination (hybrid-approach) (Vansa et al., 2008). Moreover, there-are four-main-categories of techniques, used to-inspect textural-abnormalities: statistical-approaches, structural-approaches, filter-based methods, and model-based-approaches (Li et al., 2013; Xie, 2008).

Digital image-processing-techniques have been progressively-more and more applied to-textured sample-analysis. In-essence, the-images are-acquired, pre-processed, and normalized, and then a-structural-feature is extracted. The-Artificial Neural-Network (ANN) is used, as-defect identification-model. The-extracted-features are given as-input to-the-ANN, and it-identifies the-defect. For-instance: (1) Niskanen (2003) described a-system for automatic, on-line visual-inspection and print-defect-detection, for Variable-Data-Printing (VDP). The-system automatically stops the-printing process, and alert the-operator to-problems; (2) ViDi Suite is automatic-inspection of complex-pattern fabrics, via the-software-algorithm, which trains-itself on a-set of known-good-samples, to-create its-reference-model (Xie, 2008); (3) Independent Component-Analysis (ICA) is another-proposed-method, that solves the-problem of defect-detection, in patterned-fabrics, prior to-Regular-Bands (RB) method, based-on-periodicity. Patterned-fabric is built on the-repetitive-unit of its-design. The-proposed-method ICA, along-with RB method tries to-improve the-efficiency and quality of the-fabric, at much-less-time (Rao et al, 2012); (4) Nasira1 & Banumathi (2014) also-proposed a-new fabric-defect-detection-system, based on BPN-identifier, giving a-success-rate of defect-identification of 93%; (5) Peng Li et al., (2009); and Xiaochun, et al. (2008), pointed-out, that in their-systems, the-print-pattern location-information was-extracted, by-hardware, and was-compared with the-standard-image, and the-error-information was-obtained; but in most-cases it is difficult to-extract the-complete-print-image; and (6) The-goal of yet-another-development by Ferreira et al. (2015) was to-build a-prototype, capable of detecting and classifying defects, in real-time, meaning an ‘on-line’ inspection, during the-textile printing-process, and to-implement it, in a-textile printing-plant.

The-attempts to-automate the-detection of printing-defects-process, are ever-growing, however, they are relatively-costly, particularly for a-developing-country. Nevertheless, this-study brought-forward the-recommendation to-consider automation, of the-process of defect-identification.

4.1.1.3. Contact-pressure
According-to OSHA (2014), contact-stress results-from continuous-contact, or rubbing, between hard or sharp-objects, or surfaces, and sensitive-body-tissue, such as: soft-tissue of the-fingers, palms, thighs, and feet. This-contact creates localized-pressure, for a-small-area of the-body, which can-restrain blood-supply, nerve-function, or movement of tendons, and muscles. Examples of contact-stress include: resting-wrist on the-sharp-edge of a-desk, or workstation, while-performing-tasks; pressing of tool-handles, into the-palms, especially when they cannot be-put-down; tasks that require hand-hammering; and sitting, without adequate-space, for the-knees, among-others. The-sides of fingers, palms, wrists, and forearms, elbows, and knees, are most-susceptible to-contact-stress, because in-those-areas the-nerves, tendons, and blood-vessels, are close to-the-skin and underlying-bones.

When one rests, some, or most of their-body-weight, on a-small-portion, of their-forearms, elbows, knees, or thighs, the-resulting highly-concentrated-forces may-be-enough, to-restrict the-movement of tendons, and cause inflammation, restrict the-flow of nutrient, and oxygen-carrying-blood, in the-blood vessels, or bruise the-
muscles. In this study, the contact-stress, was concentrated on forearms and elbows. The elbow is actually two different joints (see Figure 8). It raises and lowers the arm (flexion and extension) and also acts as the pivot-point, for forearm-rotation (pronation and supination). There are also numerous vulnerable soft tissues, such as: tendons, nerves, blood vessels, that pass through the elbow, to reach the forearm and hand. Contact-stress, on this particular region, can lead to MSDs, such as: lateral and medial-epicondyritis; radial-tunnel-syndrome; and cubital-tunnel-syndrome, among others.

To protect the operator, PPE, such as, for example, Sartorius-Elbow-Pad (shown in Figure 8 right) can be used. The visco-elastic material, of the pad, relieves contact-stress, pain, and discomfort, underneath the elbow. It is useful for working-in, leaning on the elbows; elbow pads should fit, comfortably, but should not compromise blood circulation, in the arm. In addition, they are affordable, and hence, recommended, as one form of personal protection, at the department.

Figure 8: Elbow muscles (left) and Sartorius-Elbow-Pad (right) on (OSHA’s website).

In addition, the hard metallic surface of the printing machine can be covered with soft padding.

4.1.1.4. Stress on lower extremities

A standing workstation is defined as a workstation, where a task is performed with the employee, standing in a relatively stationary position, and without much leg movement (Summers et al., 2015). In the standing position, the body is held upright, by the big muscles, of the trunk and lower limbs. Since the printing machine operators have to accomplish tasks, in standing position, the postural muscles, and lower limb muscles, get fatigued. Lower limb muscle Soleus, the peripheral heart of the body, also becomes weak, and more prone to varicose veins (Karthikeyan, 2014), while other muscles, such as: Calf, Hamstring, and Quadriceps muscles, can be also fatigued. This can lead to MSDs, namely: plantar-fasciitis; tarsal-tunnel syndrome; and Tailor’s Bunion (ErgonomicsPlus official website).

In the case of printing machine workstation, it provides no or limited knee, or foot clearance, and therefore, the task cannot be performed, in a seated position, using an ordinary chair or stool. To protect the operator, two suggestions were made: (1) to provide adjustable ergonomic footrest (see Figure 8 right); it has 6 degrees of increments of height, and angle adjustment, and it is covered by the carpet; and (2) another recommendation is for the factory administration, to provide employees with shoe insoles, or anti-fatigue floor mats, when standing for prolonged periods of time.

4.1.1.5. Static posture

Most MSDs, and injuries, are caused by overuse, or straining of the muscles and ligaments, leading to Occupational-Overuse-Syndrome (OOS). Apparently, even a neutral posture, can cause discomfort, and fatigue, if it is maintained, for long periods of time. The musculoskeletal system is designed to move; working for long periods of time, in a static position, will cause the body to fatigue; this is known as static load. Static postures (or static loading) refer to physical exertion, in which the same posture is held throughout the exertion. Static postures result in fatigue, because not moving impedes the normal blood flow, to bring nutrients, to the muscles, and to carry away the waste products of muscle metabolism, hence hampering tissue recovery and slowing down delivery of oxygen, to the muscles, which also diminishes the elasticity in the soft tissues (muscles, ligaments, and tendons, in the affected areas). The longer or more frequently, static loading occurs, the greater the risk of MSDs or injury, due to overuse of muscles, joints and other tissues.

According to CCOHS, the healthy body can only tolerate staying, in one position, for about 20 minutes. Standing in one place, such as standing on a concrete floor, for extended periods of time, as in this study, tends to cause back pain and pain in other parts of the body. There are three main areas of the body, which are affected by static standing posture: neck and shoulders; lower back; and legs and feet. Standing-static posture, in particular, can lead to: joint compression, in spine and hips; Static-Muscle Strain, Plantar Fascitis,
flat-feet, and heel-spurs; postural-muscle fatigue—slouching; stiff-neck and shoulders; compromised-circulation, in-legs, knees, and feet, leading to varicose-veins; deep-vein thrombosis; sore-feet, and stiff-legs (Van Rijswijk, 2005; Tuchsen et al., 2000; Beasley et al., 2005), an-increased risk of oedema, in-the-legs (Zander et al., 2004); back-pain (Hoogendoorn et al., 2000; Xu Xu et al., 1997), and precipitation of rheumatic-diseases of tendons and ligaments (Bridger et al., 2002). Tasks, that involve static-standing-postures lead to rapid-discomfort, and fatigue, especially if combined-with exposure to other risk-factors, such as in-this-study.

To-prevent MSDs and injuries, due to standing-static-posture, the-following-recommendations were put-forward for workers, to: (1) use an anti-fatigue-mat, appropriate to the flooring-type; (2) alternate standing with sitting, by using stand-sit-stool (see Figure 9 (right)); (3) use footwear, with thick-insulating-soles, and shock-absorbing-insoles. According to CCOHS, an operator, for standing-static posture, should-choose shoes with good-support, enabling the heels and toes free-movement, no flat-soles, or heels, higher than 5cm, and good-arch-support. Laced-shoes are the best, as they enable adjustment, according to the size and shape of the operator’s feet; and (4) rest-stool (previously-recommended for prevention of stress on lower-extremities). Training is also paramount; the workers should-be informed about using suitable-working-postures, preferably in a neutral-posture, and changing their-position frequently, if possible.

Figure 9: Stan-sit-chair (left) and rest-stool (right) (ErgonomicOffice official-website)

4.1.2. Posture #2
The-printing-machine-operator is preparing a printing-paste, by measuring ingredients. He is in awkward-neck-posture; the angle of deviation is 38 degrees, which from Figure 10 is in the middle-of-the-red zone of movement, meaning that it is a high-risk-posture, which can-lead to MSDs, or injury. The operator is standing, in-this-position, with little-movement, for long-periods of time, pointing at another MSDs-risk—standing-static-posture. It is also evident, that he is standing on a concrete-floor, wearing ordinary-shoes (stress on lower-extremities). He is using his both-hand, to perform precision-movements, such as: getting chemical-containers, weighing the chemicals, and mixing them. The task is also visually demanding, and in addition, demanding of high-concentration; accuracy, in-following the recipe; and overall-meticulousness, to make appropriate-printing-paste.

Awkward-neck-posture affects many muscles (see Figure 10). Neck-related MSDs and injuries can be serious and can affect ability to walk, stand (normally), and move, with ease. This is because neck injuries may result in damage to the spinal-cord, which connects brain to the rest of the body. Accidents are major causes of neck injury. Sudden jerking of the head-back and forth causes whiplash-injuries. Whiplash is a neck-sprain, in which the ligaments, which connect the spine, are stretched, or torn. Continuing awkward-head and neck-postures, can lead to MSDs, such as: temporomandibular-joint-dysfunction syndrome; cervical-pain-syndromes; cervical-nerve-root-impingement; tension-neck-syndrome; cervical-disc-disease; and thoracic-outlet syndrome, among others (Taylor, 2010). Neck-related MSDs, pain, or injury, can also be due to overuse of the muscles, or nerves, of the neck.

To reduce risk of MSDs, the workstation should be redesigned, so that, the operator will not bend his head, and neck, as much as it was, during this study. This can be done by providing an adjustable height-table, for precision-work and light-weights, by raising table-surface, above elbow-height, and providing upper-extremity weight-bearing-support, when possible. Making the table-higher, or even better, adjustable, so that the operator will not bend his neck so much, as the OSHA recommended neck-posture is to look down or up, slightly, max 15°. The study, hence, recommended an adjustable-workstation (table), appropriate to the operator's height, with toe-space, to avoid bending.
Figure 10: Neck and shoulder-muscles (http://www.injurytreatment.com.au/injury-information/neck/).

On-the-other-hand, when the-arm performs any-controlled-movement, muscles-in-the-neck and shoulder, contract and stay-contracted, for as-long, as-the-task-requires. The-contracted-muscles squeeze the-blood-vessels, which restricts the-flow of blood, all-the-way-down to-the-working-muscles, of-the-hand. As a-result, the-neck and shoulder-muscles, become-overtired, even though, there-is-little or no movement. At the-same-time, the-reduced blood-supply, to-the-rest of-the-arm, accelerates fatigue, in-the-muscles that-are-moving, making them more-prone to-injury. Since the-arm provides a-very-long-lever, holding even-small-loads, in-the-hand, with-the-arm held-away, from-the-body (as in this-posture) will-quickly-result in shoulder-fatigue and discomfort, and place substantial-stress, on-the-tendons, in-the-shoulder. Potential-MSDs are: rotator-cuff-tendonitis; bicipitaltenosynovitis; and frozen-shoulder syndrome, among-others.

Raising-awareness, among workers, on-the-risks of awkward-neck-posture, can-reduce the-incidence of neck-pain (Lyons, 2002). In-addition, adding breaks, has shown to-be-associated with reduced discomfort, and fatigue, in-the-muscles (DeLooze et al., 2005; Balci & Aghazadeh, 2003). For-example, integrating exercise-programs, in-the-daily work-routines of employees, can have-positive-effects, not only on-reduction of MSDs, but-also on-mood-states (Taylor, 2005; Pronk et al., 1995). Moreover, engaging in-sports, for-at-least one-hour, a-week, during-at-least 10 months, a-year is associated with reduced: MSDs-symptoms, and related-long-term sick-absence (Vanden Heuvel et al., 2005).

To-condition the-body and reduce-fatigue, hence, physical-stretching, is vital, as it improves muscular-balance, and posture, and advances muscle-coordination. It-is, therefore, beneficial to-take periodic-stretch-breaks, over-the-course of the-work-day, to-get the-blood-moving, to-restore the-energy.

Training is also-also-important, for prevention and control of WRMSDs; some-workers are exhibiting obsessive-habits, trying to-finish their-task, even if it-is a-lengthy-one, with completely no breaks, as if they are running a-marathon. They rest only when the-task is accomplished. Such-workers, probably, do not fully-understand the-risks, associated with such-habits, of ‘going-nonstop’, and hence, they need to-be-trained, to-take care of their-bodies, by respecting the-pain-signals; recognizing potentially self-destructive-behavior, and simply having small-rest-breaks, when performing long-tasks. In-contrast, to-posture #1, where in-order-to-have a-break, the-machine, has to-be-stopped; in this-task, the-operator has the-prerogative to-plan the-task, by himself, as-long, as it is accomplished, within specified-period. Workers should-limit-time on task, in-one-position, whether sitting or standing, to no more, than 30 minutes, taking regular-breaks, from activities, in-a-single-body-position, and performing activities, involving movement. Being physically-active is also-associated with control and prevention of WRMSDs.

At REAL, the-printing-paste was prepared manually, which is time-consuming-process, prone to-human-error. Automation is yet, another-approach, used-to-reduce MSDs. Although, this-approach, could-be costly, it-is still worth-to-mention it here, to-give a-full-picture on-addances in the-subject-area. For-example, the-authors come-across, a-new-advanced-system to-provide fully-automated-process of printing-paste-preparation.

According to GSE-dispersing-company, their-automatic-dispensing-systems provide greater-efficiency, through ‘on-demand paste-production’. They are characterized by: minimal-machine-downtime, better reuse of printing-paste, lower-maintenance-costs, and high-equipment-reliability. They are also-compact; straightforward, to-install; and easy-to-operate. They also-incorporate: a-unique-valve-design, and a-self learning-software, to-ensure rapid, accurate, and splash-free-dispensing—even-with-fluctuations, in-viscosity. Other-standard-features include: automatic-valve-cleaning, after every-dispensing-cycle, to-maintain color-integrity; circulation-control, to-minimize dyestuff-setting; and air-operated-valves and pumps, which require little-maintenance. In-addition, the-thickening-preparation-system (TPS) ensures smooth, consistent printing-paste, which thickens every-time; the-advanced Textile-Management-Software (TMS) package optimizes printing-paste-production. The-Return-
Paste-Module (part of the-TMS), reduces waste of printing-paste to an-absolute-minimum, by tracking buckets, with return-paste. When a-new-order is entered, the-module automatically-checks, for stored-return-paste, and calculates how-much can-be-reused, then informs the-operator.

For-instance, their-IPS-epsilon-model is ideal, for-use with small-quantities, such-as in-the-case of the-printing-section of REAL. It-can operate stand-alone, or in-combination with a-production-system, accommodating up-to 64 valves, and is available with manual-bucket-handling, or automatic-bucket handling/mixing, with or without a-separate cascade-dispensing-unit, for-thickening. The IPS-epsilon is suitable for using typical 1 kg, 5 kg and 15 kg buckets, geared towards producing accurate-samples. Readers, interested in more-details can-refer to-the-official website of the-company (www.gsedispensing.com).

This-study focused only on-the-printing-section of the-finishing-department, and the recommendations, made, were-specifically-tailored, for the-identified-scope. The-mill, however, has many-departments, hence, it-would-be beneficial, to-conduct all-inclusive WRMSDs Risk-assessment, as-an-important-part of the-risk-management-process. According to EU-OSHA (2008), such-assessment comprises a-multistep approach, to-improve workplace-health, safety, and productivity The-general five-steps of the-risk assessment-procedure involve: (1) identifying hazards, and those at-risk; (2) evaluating and prioritizing risks; (3) decisions on-preventive-actions; (4) executing actions; and (5) monitoring, and reviewing the-progress, at-regular-intervals.

Moreover, for-the-management of ULD-risks HSE (2002), outlines 7 stages. The-stages are-as-follows: (1) Understand the-issues and commit-to-action; (2) Create the-right organizational environment; (3) Assess the-risks of ULDs, in-workplace; (4) Reduce the-risks of ULDs; (5) Educate and inform the-workforce; (6) Manage any-episodes of ULDs; and (7) Carry-out regular-checks on program-effectiveness.

Besides, the-assessments of MSDs-risks, were limited, in this-study to-observations-methods, including RULA; these-methods bear typical-limitations of this-category. The-main-drawback of these-methods is that they only approximately-classify workload-categories, and, often, do not adequately-reflect the-complexity of work-processes (Li & Buckle, 1999). Therefore, the-advanced-level of research is recommended, such-as: the-CUELA (‘computer-aided recording and long-term-analysis of musculoskeletal-workloads’) measuring method (see Ellegast, 2009).

5. Conclusion and Recommendations.

5.1. Conclusion

This-study evaluated two-high-risk-postures of the-machine-operators, during their-routine-tasks of rotary-screen-printing-machine. The-study identified numerous-risk-factors, which often go-unnoticed, measured that-risks with an-objective-ergonomic-evaluation-tool, and proposed several-tailored recommendations, to-reduce, or control the-risks. The-recommendations relied, largely on-common-sense, and on-the-established-Ergonomic-approaches.

Ergonomic-approaches can-be very-simple and inexpensive, such-as, for-example, proving a-rest-stool, to-prevent stress to-lower-extremities. Other-ergonomic-approaches can-be sophisticated and rather-costly, e. g., Digital-image-processing-equipment. While the-use of one-recommendation, say anti-fatigue-mats, does not completely-eliminate sore-feet, when combined with sit-stand-chair, rest-stool, and quality footwear, it-should noticeably-improve the-working-conditions, meaning that system-approach would-be the-best.

Ideally, Engineering-controls are preferred, but, they are costly, for a-factory, in a-developing-country, hence, administrative-controls can-be helpful, as transitory-measures, until engineering-controls can-be realized, or when engineering-controls are not technically-feasible. Since administrative-controls do not eliminate hazards, the-necessary precautions and safeguards must-be-followed. The-prerogative of choosing and applying the-most-appropriate-approach(es), remains, however, up-to the-factory-management.

Despite the-limitations of the-study, this-unfunded-research provided valuable-information, for the-factory management, in illuminating the-natures and extents, of exposures to MSDs-ergonomic-risks. The-theoretical-coverage, in-conjunction-with the-diagrams, believed, to-provide more-comprehension, on the-subject-matter, and added to the-body of knowledge.

It-is paramount, however, that awareness and understanding, turn-into a-commitment, to-take-actions, to-manage the-risks, at-the-mill.

5.2. Recommendations

The-tailored-recommendations, indicated previously, are summarized, and grouped, as-follows:

5.2.1. Engineering-controls, such-as:

1) Auto-registering detection-system, to-detect the-machine-malfunctions.  
2) Digital image-processing-techniques, to-automate the-defect-identification-process.  
3) Automatic-dispensing-systems, such-as IPS-epsilon-model, to-automate the-process of printing-paste-preparation.
5.2.2. Work-practice /Administrative-controls:
1) To-provide workers, standing for prolonged-periods of time, with adjustable-task-lighting; adjustable-ergonomic-footrest; adjustable-stand-sit-stool; and anti-fatigue floor-mats.
2) For the-colour-kitchen, to-use an-adjustable workstation (table), appropriate to the-operator’-height, with toe-space, to-avoid-bending.
3) For the-workers, to-take periodic-stretch-breaks, over the-course of the-work-day, to-get the-blood moving, to-restore the-energy.
4) Training is also-paramount; the-workers should-be-informed about using suitable-working postures, preferably in a-neutral-posture, and changing their-position frequently, if possible.
5) The-factory-management, to-ensure that the-workers undertake necessary-eyesight-screening.

5.2.3. Provision and use of Personal Protective Equipment:
To-protect the-operator, PPE, such-as, for-example: Sartorius-Elbow-Pad; and shoe-insoles were recommended.

5.2.4. Areas for further-research:
1) To-examine, whether the-intensity, and the-type of light, in-the-printing-section, is adequate, and appropriate.
2) To-conduct all-inclusive WRMSDs Risk-assessment, for the-entire-mill, as first-step in the-risk management-process.
3) Use of the-advanced-level of research, via the-CUELA measuring-method (‘computer-aided recording and long-term analysis of musculoskeletal-workloads’).

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