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-synopsis on relevant-issues were-also-given, such-as on: Work-related MSDs (WRMSDs) and their-prevalence; Working in neutral-posture; Awkward-posture, its-effects, and relevance to WRMSDSs; 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 is 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 fulltime-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' compensatecosts (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 'presenteeizm', 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 WRMSDSs

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-shoulder; (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) (Occhipinti, 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; Desky (2010)--on the-ointment-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-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. Materials and Methods.

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 by 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-angels, 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-moment, the-photo was-taken, and also due-to-unintended human-error. The-errors, however, presumed to-be-negligible.

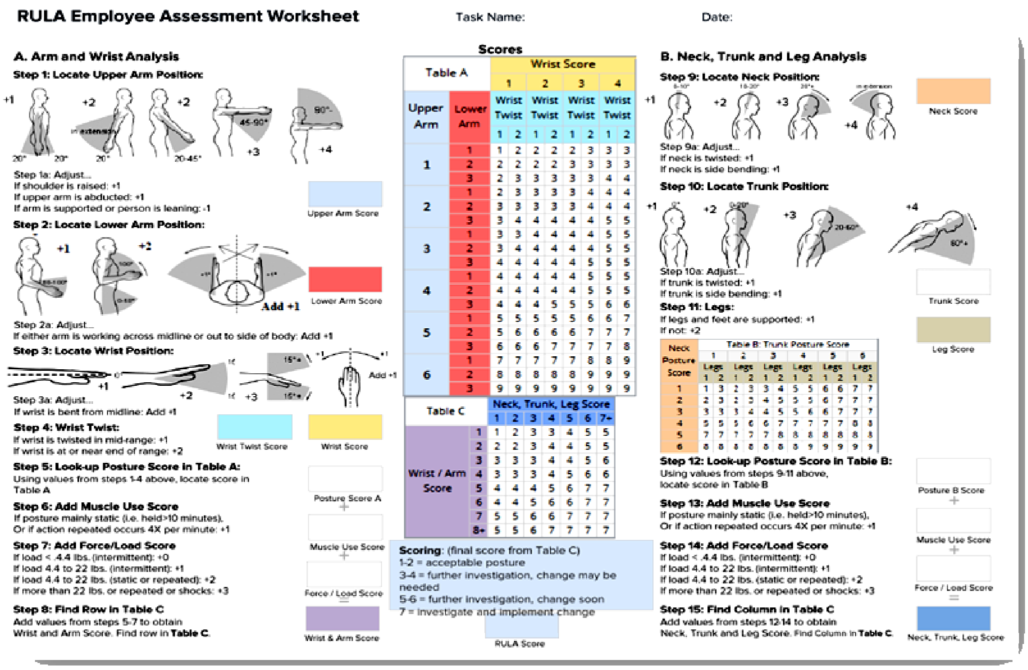

Figure 1: Standard procedure of RULA (McAtamney & Corlett, 2004).

Action level	RULA score	Interpretation
1	1-2	***Negligible risk, no action required*** (the-person is working in the-best-posture with *no* risk of injury, from their-work-posture).
2	3-4	***Low-risk, change may-be required*** (the-person is working in a-posture, that could-present some-risk of injury, from their-work-posture (at-least one-part of the-body being in an-awkward-position, so this should-be investigated and corrected).
3	5-6	***Medium risk, further investigation, change soon*** (the-person is working in a-poor-posture, with risk of injury, from their-work-posture, and the-reasons for-this need-to-be investigated, and changed, in the-near future, to-prevent an-injury).
4	7+	***Very high risk, implement change now*** (the-person is working in the-**worst**-posture with an-immediate-risk of injury, from their-work-posture, and the-reasons for this need-to-be investigated, and changed, **immediately**, to-prevent an-injury).

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.

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

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

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

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.

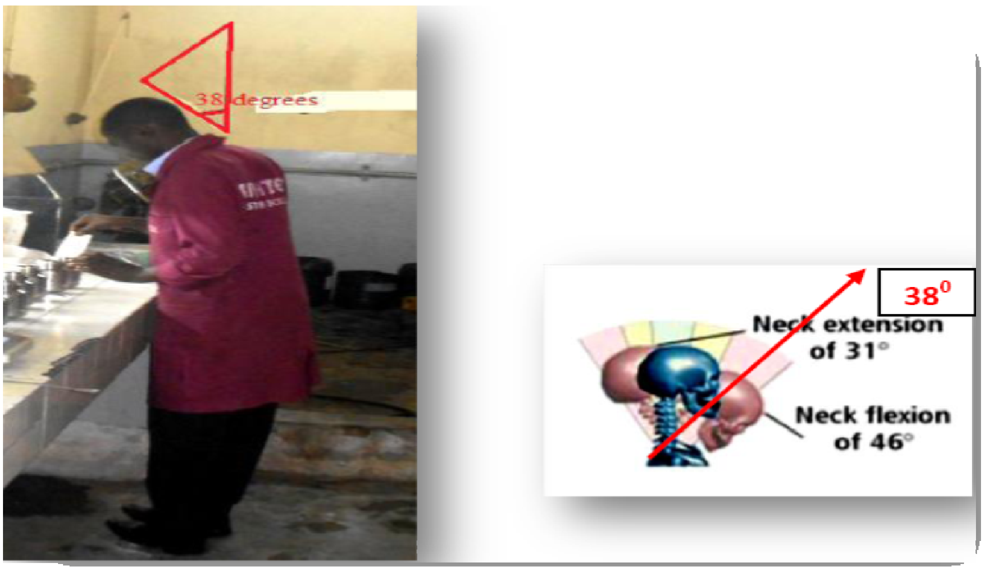

Figure 4: Operator, measuring chemicals (left); and Extreme angles, and the-actual-angle of deviation

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

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

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

For-the-posture # 1, total-score of 4, corresponded to 2nd 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 3rd 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.

4.1. Further assessment of the-two-postures.

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°, 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.

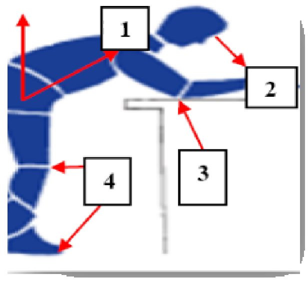

Figure 5: MSDs risks identified for the-posture #1.

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.

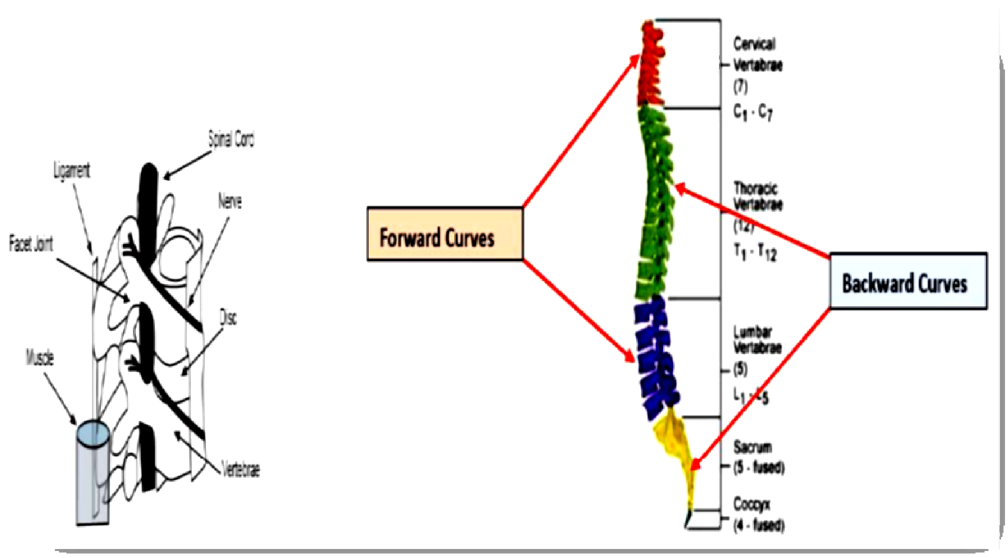

Figure 6: Structural-components (to the-*right* of the-diagram), and supportive-components of the-spine (*left*).

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).

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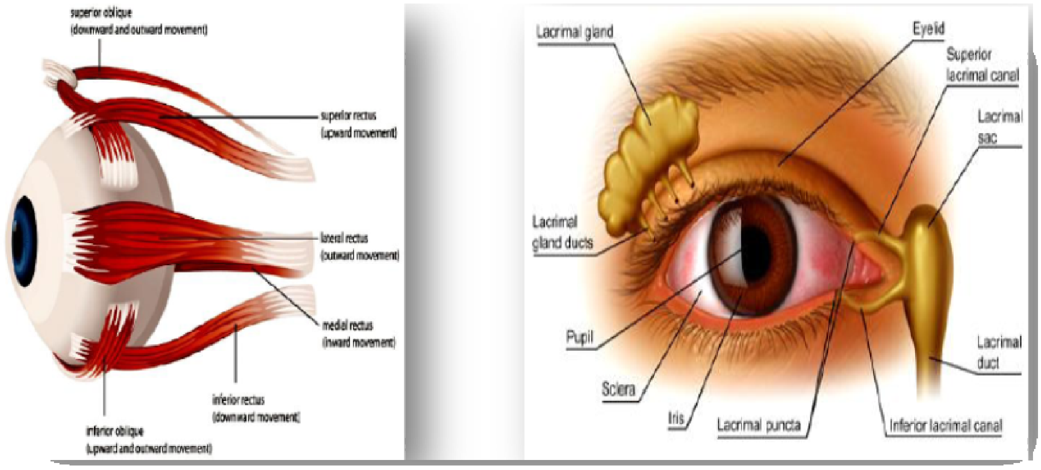


Figure 7: Muscles (*left-side of the-diagram*) and Anatomy (*right*) of the-eye.
(http://humananatomylesson.com/human-eye-muscle-anatomy/)

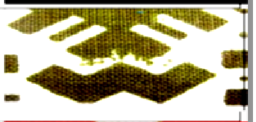
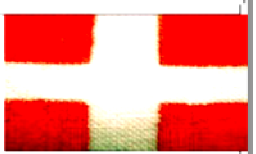
To-detect defects an-operator *must* have adequate-vision (20/20). The-study, however, revealed, that *no* eye-check-up was done on any of the-printing-machine-operators (including initial and yearly- examinations). Workers, however, may-have a-pre-existing eyesight-problem, that has *not* been resolved, e.g., Binocular-Vision-Dysfunction also-known-as *Vertcal 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 5meters. 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.

Table 3: Selected visual-defects in printing (compiled from Ahmed, TS3B).

Name/ Description	Possible Cause	Classification/ Comments	Photograph
The letter 'a' has a cut off corner and the following z also has a cut on the edge.	The presence of a stray yarn on the fabric during transfer printing caused the design to be printed on the yarn which when later removed caused the defect. A quality check for stray yarns before printing can reduce occurence.	Defects of this type are usually minor. However in some case if the print design is affected such that the variation in design is very easily detectable and reveals a definite non-conformity in the garment the defect may be labeled major	
Overlapping of colors in a print.	Poor registration of screens.	In this case the defect is minor as the character is recognizable and when viewed from a distance the registration problem doesn't seem too obvious. However, depending on the severity and end use the defect can be major or minor.	
Missing patches of color from top left and bottom right corners of the 'X'	Incomplete transfer of design from paper to fabric on transfer printing due to removal of transfer of paper while the fabric was still hot.	The defect is minor as only a very slight portion of the design is missing.	
Unwanted pigment marking on fabric	Screen has holes in it that should have been covered. This could be because of ageing of the screen and eventual damage or just improper exposure to light.	This is a major defect as the design has been foiled. However, in the industry unless there is only minor damage to the screen, it is not used.	
Bleeding of red and its adsorption into the white area.	Prints with reactive dyes need to be washed thoroughly with back flow. Saturation of washing bath with color can lead to the dye adsorbing onto the uncolored fiber surface leading to tint as shown.	This is a major defect. The tint is very obvious. It fouls the appearance of the fabric.	
Flushing on polyester fabric	Low viscosity of print paste	Major as it happens throughout the fabric unless the viscosity is corrected.	

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. Manufactures 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-pattern; 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-wrists on the-sharp-edge of a-desk, or workstation, while-performing-tasks; pressing of tool-handles, into the-palms, especially when they can*not* 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-though the-elbow, to-reach the-forearm and hand. Contact-stress, on this-particular-region, can lead to MSDs, such-as: lateral and medial-epicondylitis; 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.

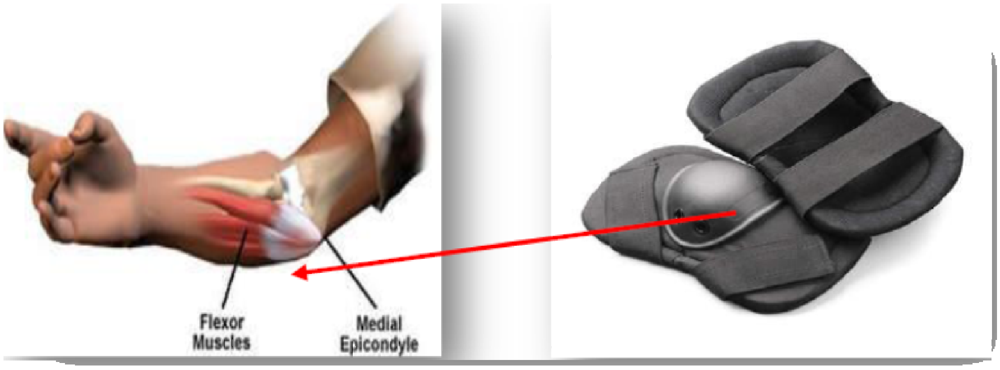


Figure 8: Elbow-muscles (*left*) and Sartorius-Elbow-Pad (*right*) on (OSHA's website).

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 degree-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 pains 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 15^0. The-study, hence, recommended an-adjustable-workstation (table), appropriate to the-operator'-height, with toe-space, to-avoid-bending.

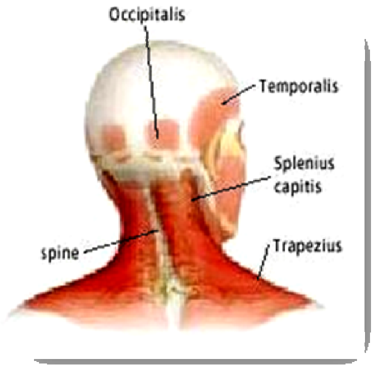


Figure 10: Neck and shoulder-muscles (http://www.injurytreatment.com.au/injury-information/neck/).

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; bicepital-tenosynovitis; 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-advances 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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