# Operator Work-Related Musculoskeletal Disorders during forwarding operations in South Africa: An ergonomic assessment

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## Abstract

Forest machine operators are still experiencing Work-Related Musculoskeletal Disorders (WMSD's) despite extensive mechanisation and modernisation of harvesting systems. However paucity of local ergonomics research and technology transfer problems may affect the use of mechanised systems in South Africa. Consequently this study was a field- based ergonomic assessment of local forwarding operations. PG Bison's North East Cape Forests (NECF), Eastern Cape operations and Komatiland Forests (KLF), Mpumalanga operations were studied. The main aim of the study was to carry out an ergonomic assessment on local forwarder operator tasks, using Tigercat 1055 forwarders. The study specifically assessed WMSD prevalence and risk factors, investigated the frequency of awkward head postures and evaluated work organisation.

A modified Nordic musculoskeletal questionnaire was used to survey WMSD prevalence and work organisation factors. Operators reported hourly, localised work-related musculoskeletal discomfort experienced during the shift. A video camera mounted in the cab was used to capture footage of awkward head postures. The video footage was also used for

the WMSD risk assessment using the Health and Safety Executive (HSG60) upper limb disorder assessment worksheets.

Operators reported having experienced WMSD's during the last 12 months mainly in the lower back, neck, shoulders and upper back. The studied operators reported lower repetition strain symptoms and higher lower back disorders than in previous studies. Twenty three percent of the awkward head postures adopted were extreme. The study results support the assertion that causal pathways of WMSD's are complex and multifactorial. Repetition, awkward head posture, duration of exposure, vibration, psychological factors and individual differences were identified as the main WMSD risk factors.

## Introduction

Forestry mechanisation and modernisation has led to a radical change in work methods. Extensive development of harvesting machines has resulted in a much enhanced and more comfortable operator workstation. Such improvements over the years have contributed to fewer accidents and fewer problems owing to vibrations and working with levers and machines are now being used for longer hours (Komatsu Forest, 2011; Jack & Oliver, 2006). However, many machine operators still experience WMSDs (Hansson, 1990; Axelsson & Pontén, 1990; Jack & Oliver, 2006; Gerasimov & Sokolov, 2009; Hagen et al., 1998; Komatsu Forest, 2011).

There is dire need for local ergonomics research output in order to sustainably support the mechanisation drive and to optimise existing mechanical harvesting systems. Ergonomics research efforts in South Africa have focused on jobs requiring heavy manual labour (Scott,

2006), such as timber hand rollers (James, 2006), manual peelers, stackers and chainsaw operators (Scott et al., 2004). Ergonomics guidelines or research output produced in the developed countries may not reflect the biomechanical, physiological and socioeconomic conditions of the South African work environment Todd (2011). However, many ergonomics studies have been done in the developed countries.

Occupational driving (such as operating a forwarder) has been associated with the prevalence of back pain. Factors contributing to the pain are diverse and might include prolonged sitting, poor postures, exposure to whole body vibration and other non-driving factors such as heavy lifting, poor diet and other psychosocial factors (Robb & Mansfield, 2007; Bridger, 2003; Hanse & Winkel, 2008; Magnusson & Pope, 1998; Marras, 2012).

The main occupational factors associated with musculoskeletal conditions are force, posture, repetition, duration, fatigue, work organisation (shifts and rest breaks), psychosocial factors and work environment (i.e. vibration and lighting) (Bridger, 2003; HSE, 2002). Owing to the complex nature of human work systems, causes of musculoskeletal conditions are therefore multifactorial; exposure to more than one factor increases the prevalence of the disorder (Kee & Karwowski, 2007; Bridger, 2003; Kumar, 2001). While acknowledging the complex multifactorial (Kee & Karwowski, 2007; Kumar, 2001; Marras, 2012) interaction of musculoskeletal risk factors to injuries, this study investigated operator exposure to biomechanical and work organisational factors.

Body posture is a major physical factor associated with occurrence of musculoskeletal disorders (Qu et al., 2012; Bridger, 2003). The human body moves and works more efficiently when joints are in the neutral range and the muscles are around mid-length (Scott et al., 2010). Little is known about which postures are optimal. However, the human body is quite adaptable (Kumar, 2001) and can work in a wide range of postures, but poorly designed work systems force individuals to adopt awkward postures. Although little is known of which

postures are optimal, the ErgoWood & EC (2006) stipulates that the head should not be turned more than 30° to the side or tilted more than 5° up or 25° down. According to Harstella (1990), work postures often contribute to strains that have long-term far-reaching effects, but have no immediate impact on the worker's behaviour or injury rates.

In a study comparing a convectional harvester cab to a self-levelling swivelling cab, Gellerstedt (1998) found that the amount of time the harvester operators spent with their heads rotated beyond 22.5° was reduced by 10 to 28 minutes per hour in the self-levelling swivelling cab. Although the head rotation may still be within the ErgoWood & EC (2006) guidelines of 30°, any reduction in the repetition of postures at the extremes of the range of motion is likely to reduce the risk of WMSDs (Kumar, 2001). This demonstrates that operator postures can be improved through cab design. Similarly, Eklund et al. (1994) assert that rotatable and movable driver cabins improve head postures and viewing angles substantially.

The optimal utilisation of technology depends on an appropriate system of work organisation that determines the social organisation of the workforce and the relations and interdependencies between individuals. Organisational aspects of work are difficult and complex to operationalise, owing to different operational definitions (Hanse & Winkel, 2008). Østensvick et al (2008), in a comparative study between Norwegian (n=19) and French (n=18) male operators, noted that the Norwegians reported higher levels of pain/disorders in the right side of the neck in the morning, noon and afternoon compared with the French. Significant organisational factors related to diagnosis in the neck, shoulder and wrist. Both duration and frequency of non-value-adding hand activity were related to rotator cuff syndrome. Hagen et al (1998) reported that an increasing level of psychological demands was significantly associated with increased prevalence of lower back disorders.

This study was a field based ergonomic assessment of the forwarding task in South Africa, using Tigercat 1055 forwarders. The study specifically assessed WMSD prevalence and risk

factors, investigated the frequency of awkward head postures and evaluated work organisation factors.

## Materials and Methods

### Study design

The study was a field-based ergonomic assessment on forwarding operations in South Africa. The study was conducted in the provinces of Eastern Cape and Mpumalanga. In the Eastern Cape, PG Bison's NECF Ugie harvesting operation was selected. In Mpumalanga, the KLF, Jessievale and Witklip harvesting operations were selected. Both operations were using Tigercat machines at the time of the study. PG Bison's NECF Ugie estates are located between the longitudes 30°47′ S and 31°27′ S and between latitudes 27°58′E and 28°26′E. KLF Jessivale plantations are located in the Highveld region of Mpumalanga, between longitudes E/W 30°32′35 and latitudes N/S -26°17′04. The Witklip plantation is located in the escarpment region between longitudes E/W 30°55′04 and -25°13′20 latitude.

All operations investigated were using the cut-to-length harvesting method (CTL). The NECF Ugie clearfell operation was done mechanically using a combination of Tigercat LH822C harvesters and Tigercat 1055 forwarders. The NECF operated a 24-hour harvesting operation. KLF operations had two harvesting systems in use, a mechanised CTL system using a Tigercat LH822C harvester, and a Tigercat 1055B forwarder in clearfelling and a semi-mechanised CTL system. The semi-mechanised system involved felling and manual stacking and then extracting mechanically with a Tigercat 1055 forwarder. The Jessivale operations used the semi-mechanised system in thinnings, and one Witklip team also used the semi-mechanised system in clearfell operations. The study followed compartments that were scheduled to be harvested at the time of data collection. These compartments were flat with

good underfoot conditions. All compartments were clearfell, with the exception of Jessivale D13, which was a second thinning (refer to Table 1). Owing to the field nature of the study, direct observations were done during daylight working hours from 0600 hrs. to 1700 hrs.

**Table 1:** Compartments worked during study

| Plantation | Cpt | Species | Vol/ tree m³ | Age | Slope class | Ground condition | Ground roughness |
|---|---|---|---|---|---|---|---|
| GlenCullen | F9 | *Ppatula* | 0.43 | 18 | 0–19.29° | very good | smooth |
| GlenCullen | G16a | *Ppatula* | 0.41 | 17 | 0–19.29° | good | slightly uneven |
| GlenCullen | G17c | *Ppatula* | 0.43 | 19 | 0–19.29° | good | slightly uneven |
| GlenCullen | F8 | *Ppatula* | 0.43 | 18 | 0–19.29° | very good | smooth |
| Witklip | F40a | *Ppatula* | 0.51 | 18 | 0–19.29° | good | slightly uneven |
| Witklip | K28 | *Ppatula* | 0.42 | 17 | 0–19.29° | good to moderate | slightly uneven |
| Witklip | K18B | *Ppatula* | 0.27 | 16 | 0–19.29° | good | slightly uneven |
| Jessievale | D13 | *Ppatula* | 0.37 | 15 | 0–19.29° | very good | smooth |

*Subjects*

All male forwarder operators employed by NECF in the Eastern Cape Ugie operations and KLF in the Mpumalanga operations were approached for participation in the study (n=20). This was done to limit participant variability (David, 2005). All twenty operators approached agreed to participate. Participation was anonymous, and operators were identified by random numbers, given at the beginning for data management only. Twelve NECF operators participated, of whom two were supervisors with experience in operating forwarders and who would sometimes operate the machines when an operator is unavailable. The two supervisors

took part in the survey only, and were not observed operating a forwarder. Eight KLF operators participated in the study.

*Study Methods & Data Collection*

A survey using a modified Nordic musculoskeletal disorder questionnaire (Kuorinka et al., 1987; Corlett, 2005) was carried out to assess prevalence of WMSDs. The modified Nordic musculoskeletal questionnaire (Corlett, 2005) was translated into isiZulu in order to assist operators to interpret the questionnaire. To assess localised musculoskeletal disorders during the forwarding task, the operators were issued with a perceived musculoskeletal discomfort scale, together with a human body template (Corlett, 2005), which showed 27 human body parts with distinct body-part boundaries for precise identification (Figure 1). The operators were asked to record hourly the location and intensity of discomfort on a scale of 0–7 (0 = no discomfort and 7 = extremely strong discomfort). The operators were requested not to undertake any strenuous activities during the test week. This was done to minimise the influence of external factors on the results. The researcher measured the individual operator's weight to the nearest 0.1 kg and height to the nearest 1 mm, using a digital bathroom scale and stature measuring tape measure. This was done with the operators in their work clothes without shoes and hard hats.

A Kodak ZM1 Mini Video Camera with a window suction mount was mounted on the right cab window of the forwarder, level with the seated operator's head (rear facing loading position). The operator was recorded during the first quarter of his shift for at least 40 minutes doing normal forwarding work (Gerasimov & Sokolov, 2009). This was done once for each participant. Owing to the nature of the shift systems, which overlap between day and night, the first quarter of the shift was selected in order to utilise daylight hours (video recording and direct observation) for two shifts per day. A parallel time study was also done alongside the video recording.

0= Neck
1= Upper back-a
2= Left Shoulder
3= Right Shoulder
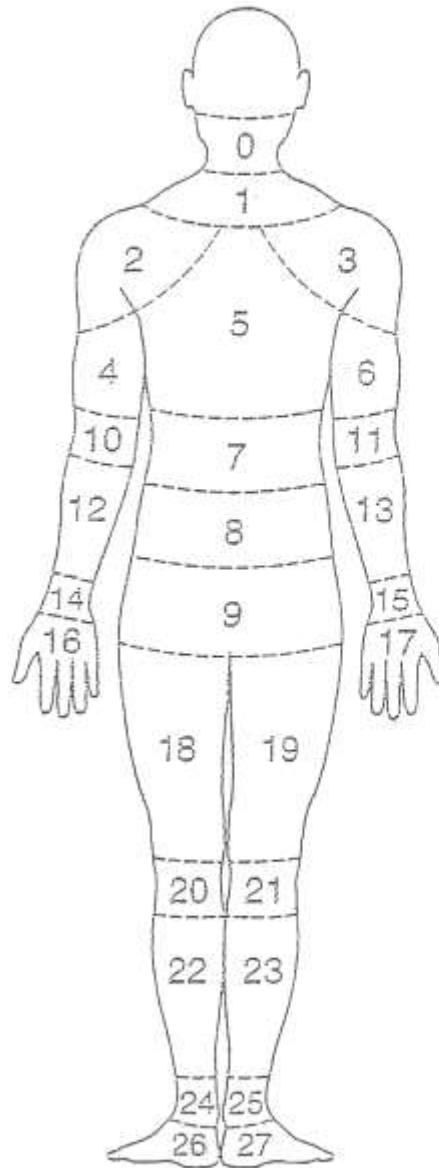5= Upper back- b
7= Lower back- a
8= Lower back- b

**Figure 1:** Body template (adapted from Corlett, 1995)

A digital stopwatch was used to record the forwarding task cycle times in centi-minutes. The video recording was later used to assess operator head postures (Figure 2) during the forwarding task. Only the frequency, and not the time spent in each of the awkward head

**Figure 2:** Postures assessed in study a) Extreme lateral head rotation to the right (elr); b) Minor lateral head rotation to the right (mlr); c) Extreme lateral head rotation to the left (ell); d) Minor lateral head rotation to the left (mll); e) Extreme head flexion (ef); f) Minor head flexion (mf); g) Extreme head extension (ee); h) Minor head extension (me)

postures that were adopted during each task (travel empty, loading, travel loaded and offloading) were assessed. The head postures were visually assessed using the Ergowood & EC (2006) optimum forest machine operator head posture guidance; minor (<30°) and

extreme (>30°) head rotation in the transverse plane, minor (<25°) and extreme (>25°) flexion and minor (<5°) and extreme (>5°) head extension. All video analysis and interpretation was done by the researcher and captured manually onto worksheets.

Forwarding task time elements (weekly working hours, number of rest breaks, and length of rest breaks) and operator psychological profiles were regarded as the work organisation parameters. Both the forwarding time elements and psychological profiles were reported by the operators through the modified Nordic musculoskeletal questionnaire. The operator psychological profile was based on the modified Nordic musculoskeletal questionnaire 12 general health questions. The recorded videos were later used to assess the forwarding task WMSD risk profile. The survey results reflected higher incidence of disorders in the upper body extremities. This prompted the decision to use the HSE guidance tool to assess upper limb disorders in the workplace (HSE, 2002). A two-stage assessment was conducted. NECF data were collected in July 2012 and KLF data were collected in May 2013.

*Data analysis*

All analysis was done with the statistical software SAS® V9.3 under Windows XP (SP3). Non-parametric statistics were performed using BMDP 7.01.2009 software and specifically the 3S program. The Fisher's exact test was used to test for significance between the mean neck, shoulders, elbows, wrists, upper-back and lower back disorders frequency reported by the operators, during the last 12 months, 7 days and prevention from carrying out normal duties, for company, age group and experience groups. Friedman's non-parametric test was performed with multiple comparisons for the following means of the variables: lower back, neck, shoulders and upper back operator disorders during the last 12 months, 7 days, and prevention from carrying out normal duties. The Kruskal-Wallis non parametric test was used to test for significance between the means of the following variables; WMSD prevalence, awkward head posture, work organisation, company, age and experience group.
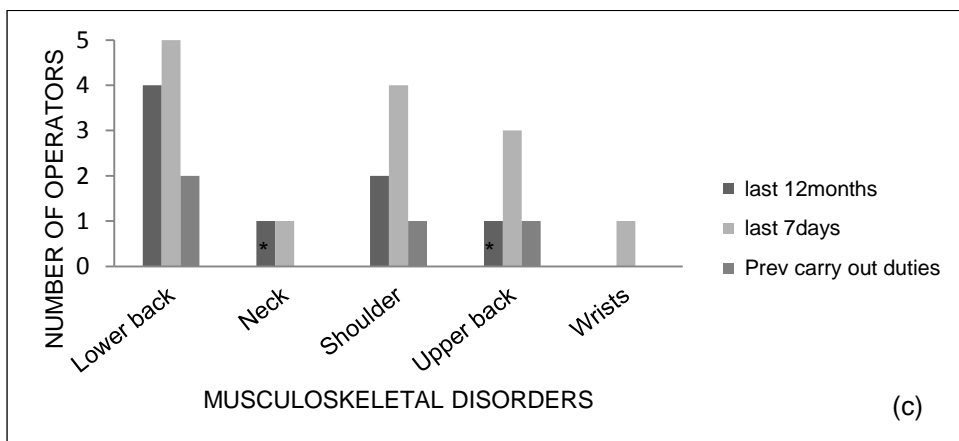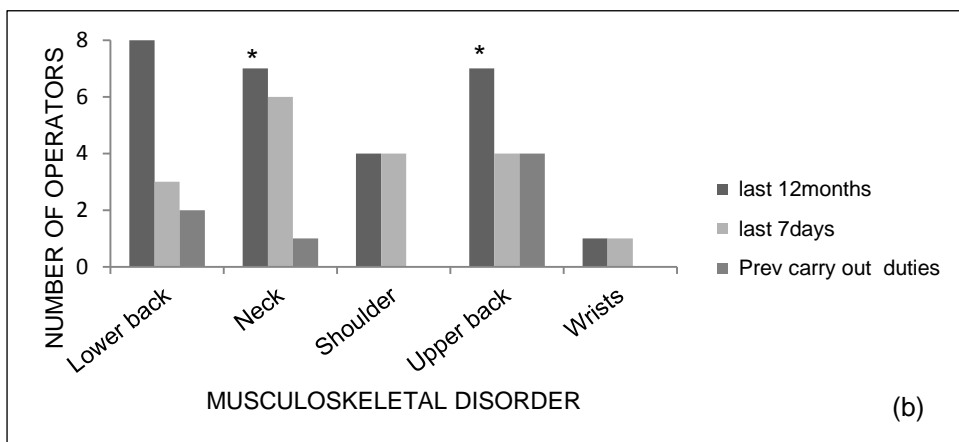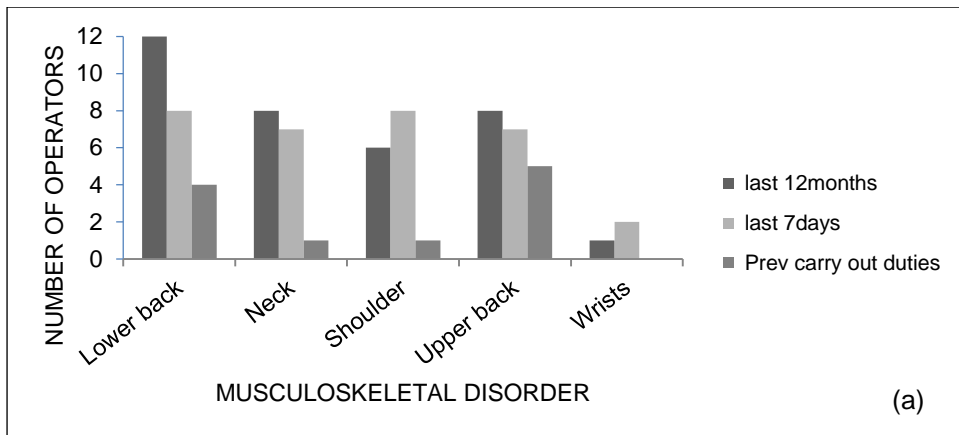
**Figure 3**: Number of (a) all (b) NECF and (c) KLF operators reporting musculoskeletal disorders and number of operators prevented from carrying out 'normal duties' *(p<0.05)

**Results**

The mean age for NECF and KLF operators was 27.5 years and 43.38 years, respectively (Table 2). Figure 3 shows the prevalence per body site of WMSDs experienced by all, NECF and KLF operators, during the last 12 months, 7 days, and whether the disorders experienced in the last 12 months had prevented them from carrying out normal activities. NECF operators reported significantly higher prevalence of neck and upper disorders in the last 12 months than KLF operators (Figure 3). For musculoskeletal disorders, there was a significant difference in reporting lower back disorders during the last 12 months, 7 days, and prevention from carrying out duties by all operators  and NECF ($p < 0.05$) operators with forwarding experience of >36-60 months. Elbow disorders did not occur.

**Table 2:** Operator demography and anthropometric characteristics

| Demography | N | Mean | Std dev | Std error | Range |
|---|---|---|---|---|---|
| Total sample | 20 | | | | |
| Age | | 33.85 | 9.66 | 2.16 | 22 – 50 |
| Weight (kg) | | 77.36 | 13.44 | 3.01 | 51.1 – 98 |
| Height (cm) | | 172.70 | 8.56 | 1.91 | 154 – 185 |
| Experience (months) | | 46.80 | 30.44 | 6.81 | 6 – 120 |
| NECF | 12 | | | | |
| Age | | 27.50 | 4.19 | 1.21 | 22 – 37 |
| Weight (kg) | | 73.32 | 15.20 | 4.39 | 51.1– 98 |
| Height (cm) | | 171.25 | 7.82 | 2.26 | 154 – 178 |
| Experience (months) | | 42.40 | 20.38 | 5.88 | 11 – 61 |
| KLF | 8 | | | | |
| Age | | 43.38 | 7.27 | 2.57 | 28 – 50 |
| Weight (kg) | | 83.49 | 7.52 | 2.66 | 75.6 – 96 |
| Height (cm) | | 174.87 | 9.69 | 3.43 | 154 – 185 |
| Experience (months) | | 53.40 | 42.20 | 14.92 | 6 – 120 |

The mean localised disorders for the neck (Figure 4a), lower back-a (Figure 4b), lower back-b (Figure 4c), upper back-a (Figure 4d), upper back-b (Figure 4e) right shoulder (Figure 4f), and left shoulder (Figure 4g) were recorded. The mean localised discomfort was recorded for the total sample of operators (all), and for those operators who reported some discomfort at least once during the shift (nonzero). The discomfort scale was from 0 to 7 (0 = no discomfort and 7 = extremely strong discomfort). The majority of the operators did not report
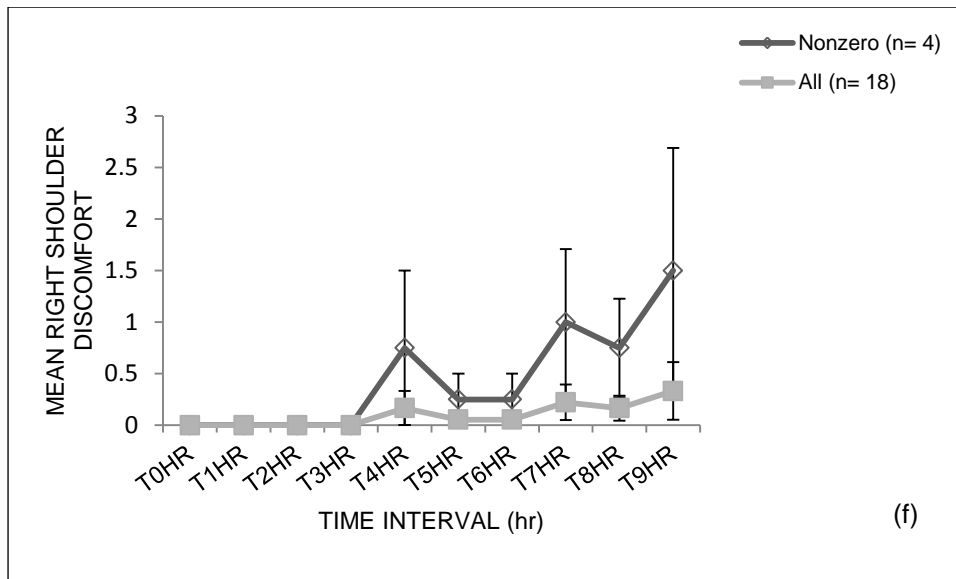
(a)



(b)



(c)

(d)



(e)



(f)
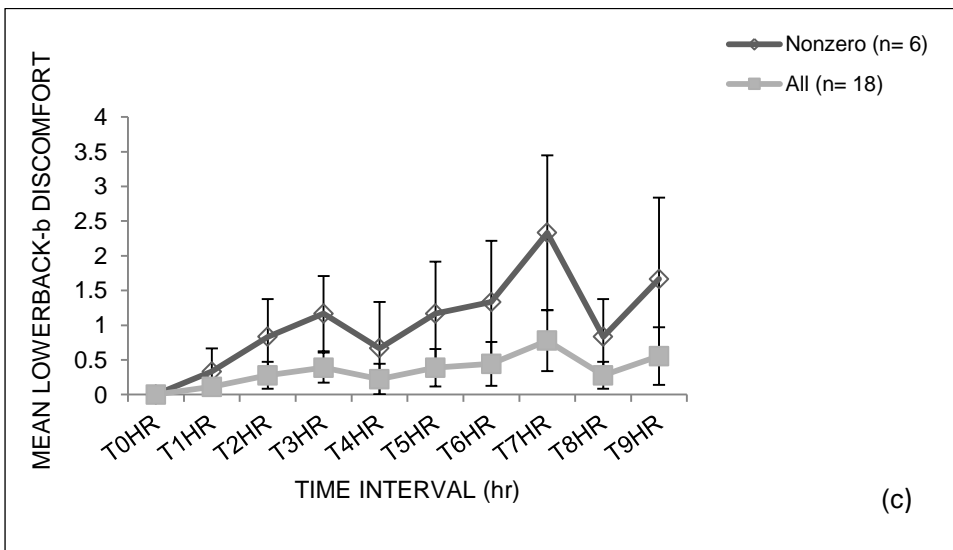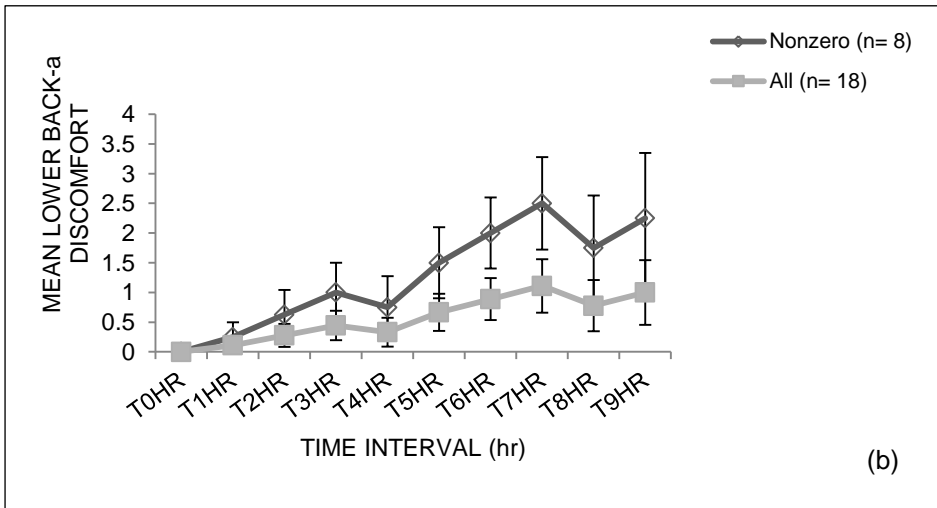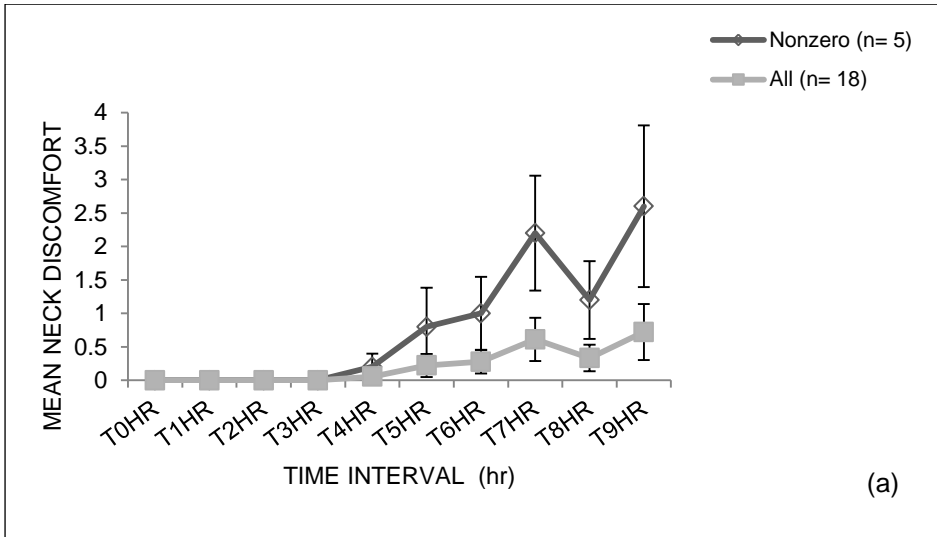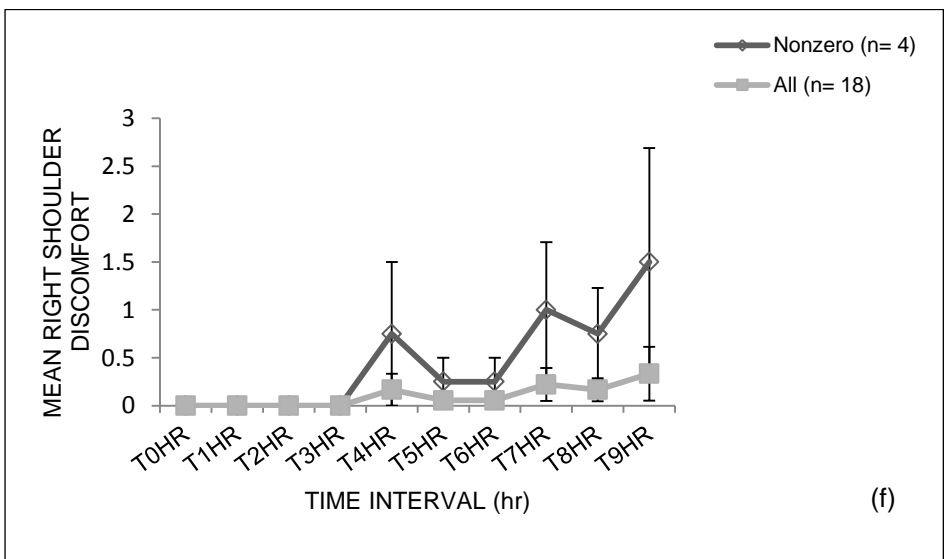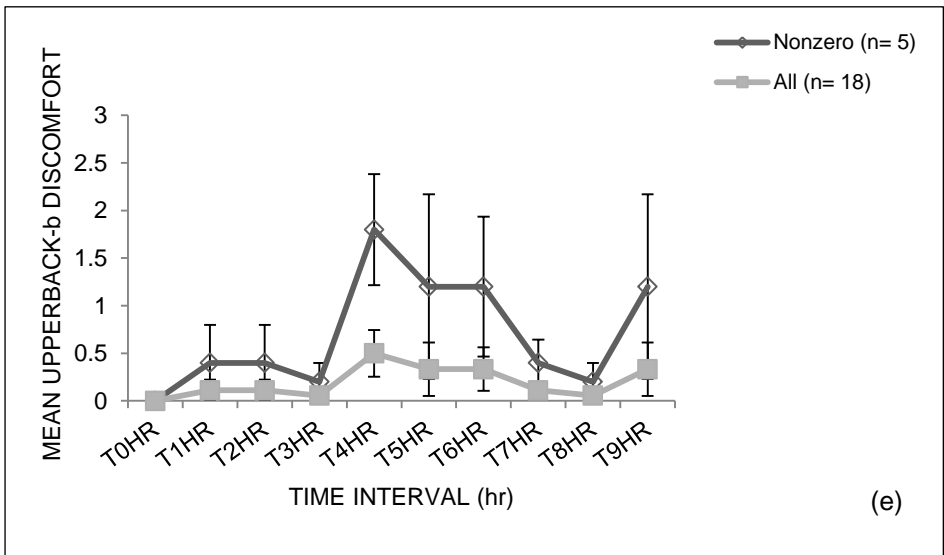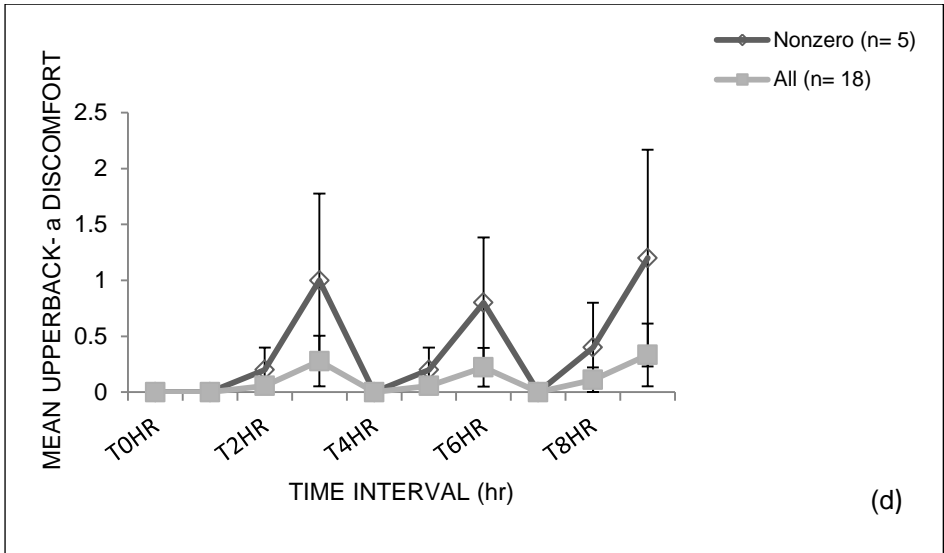
**Figure 4:** Mean discomfort reported by operators during a working day in (a) neck (b) lower back-a (c) lower back-b (d) upper back-a (e) upper back-b (f) right

experiencing discomfort during the shift. Those who reported some discomfort experienced it mainly in the lower back (Figures 4b and 4c).

Figure 5 shows mean head postures adopted in the sagittal plane for all, NECF, and KLF operators. Figure 6 shows mean head postures adopted in the transverse plane for all, NECF, and KLF operators. Most of the sagittal and transverse plane awkward head postures were adopted mainly during loading and offloading tasks. The observed operators assumed awkward head postures on average 180.6 times to complete the forwarding task (travel empty, loading, travel loaded and offloading) and 42.4 (23%) of these were extreme awkward postures. For all operators observed, 3% (Figure 5a) and 27% (Figure 6a) of the postures adopted in the sagittal and transverse planes were extreme. NECF operators adopted significantly more frequent extreme transverse plane lateral head rotation to the right during travelling empty than KLF operators (Figure 6). KLF operators adopted significantly more frequent extreme sagittal plane head flexion during loading (Figure 5) and minor transverse
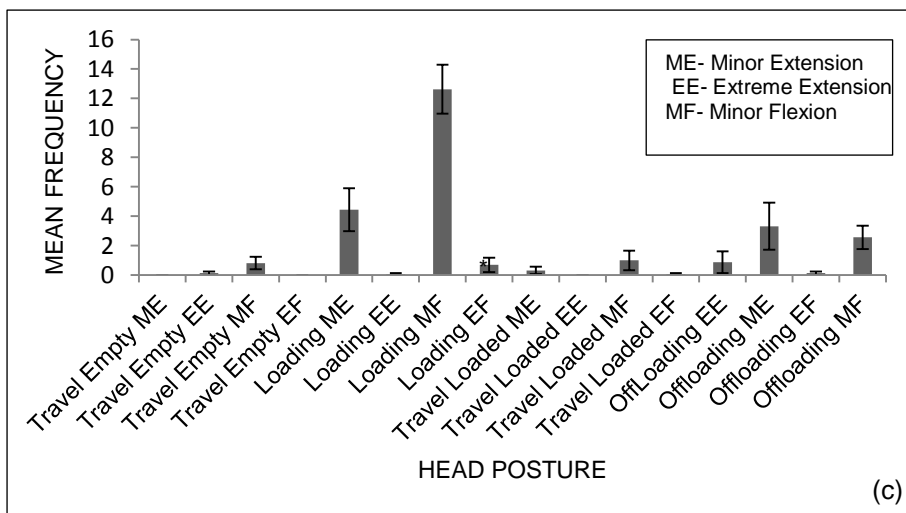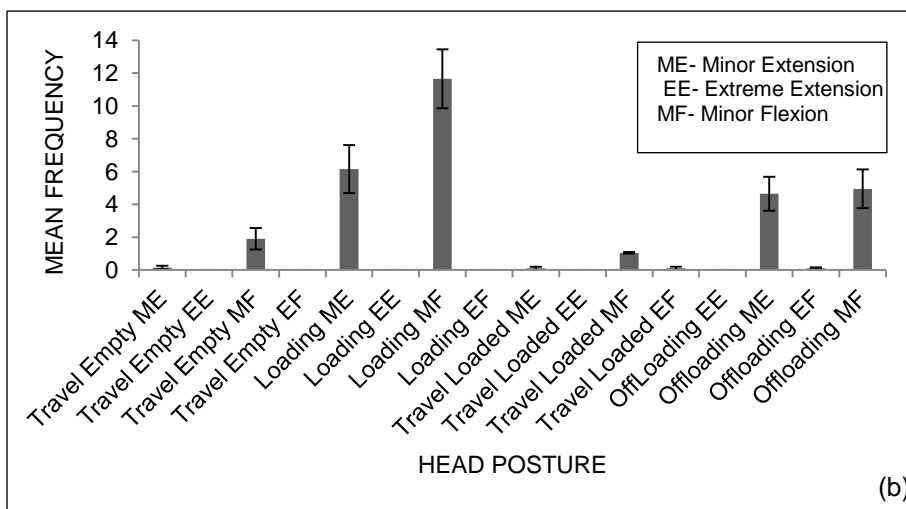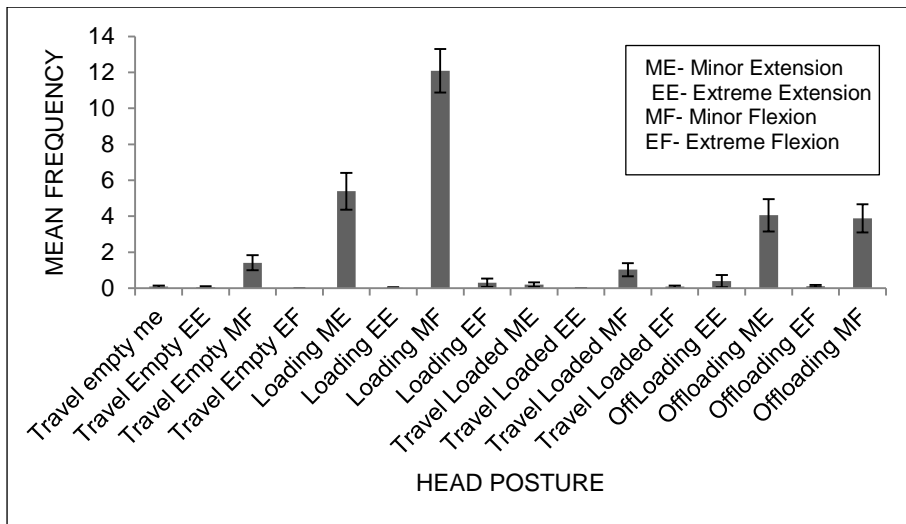
**Figure 5:** Mean sagittal plane head posture frequency adopted during forwarding tasks by (a) all (b) NECF (c) KLF operators (p*<0.05)
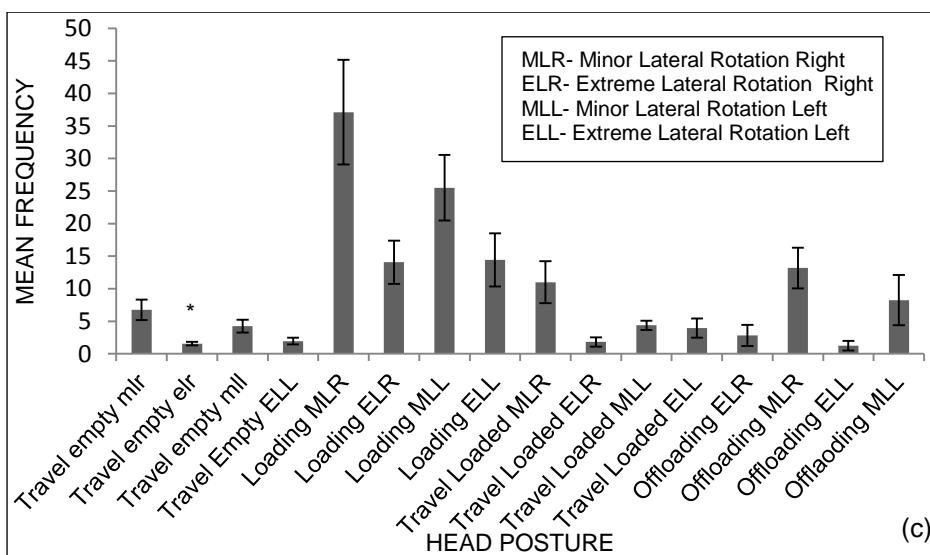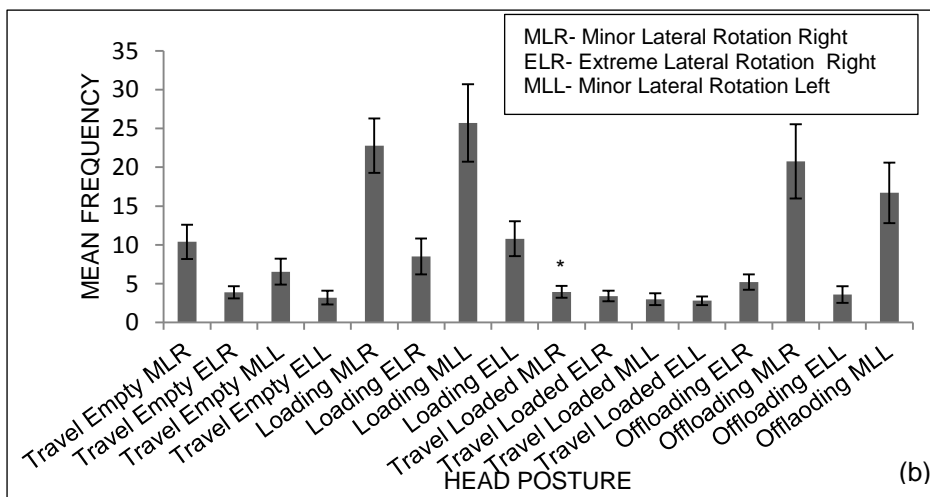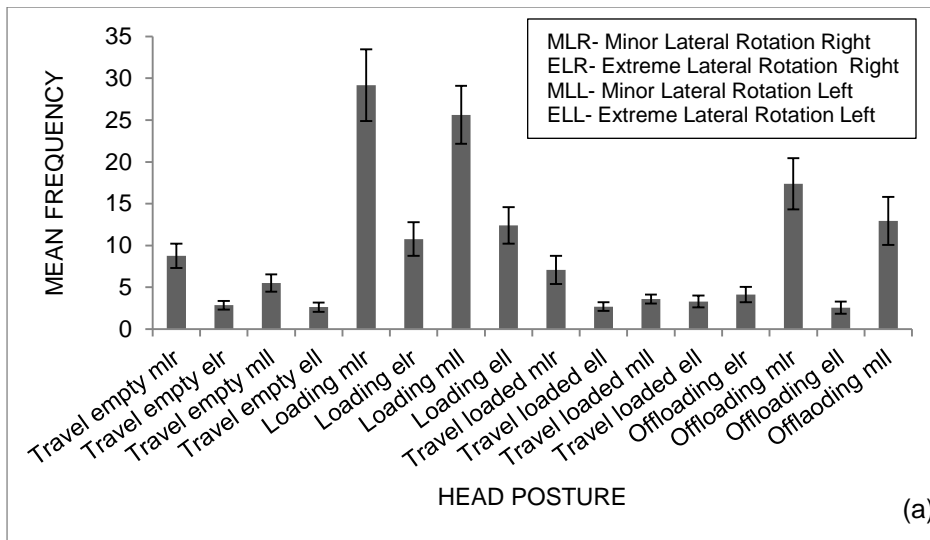
**Figure 6:** Mean transverse plane head posture frequency adopted during the forwarding tasks by (a) all (b) NECF (c) KLF operators (*p<0.05)

**Table 3:** Work organisation time elements (*p<0.05)

| Work variable | N | | Mean | Std dev | Std error |
|---|---|---|---|---|---|
| Total sample | 20 | | | | |
| Weekly working (hrs) | | | 50.00 | 7.66 | 1.81 |
| Number of breaks/day | | | 2.15 | 1.23 | 0.27 |
| Length of break(min) | | | 12.25 | 13.95 | 3.12 |
| Actual machine (hrs)/shift | | | 5.83 | 1.49 | 1.02 |
| NECF | 12 | | | | |
| Weekly working (hrs) | | * | 44.80 | 5.99 | 1.90 |
| Number of breaks/day | | | 1.92 | 1.38 | 0.40 |
| Length of break(min) | | | 14.58 | 17.35 | 5.01 |
| Actual machine (hrs)/shift | | | 5.30 | 1.68 | 1.24 |
| KLF | 8 | | | | |
| Weekly working (hrs) | | * | 56.50 | 3.07 | 1.09 |
| Number of breaks/day | | | 2.50 | 0.93 | 0.33 |
| Length of break (min ) | | | 8.75 | 5.68 | 2.01 |
| Actual machine (hrs)/shift | | | 6.50 | 0.83 | 0.75 |

plane lateral head rotation to the right during travelling loaded (Figure 6) than NECF operators. KLF operators reported working significantly more hours per week than NECF operators (Table 3). Based on actual production reports for the test days, the operators spent on average 5.83 machine hours per shift (Table 3). The answers to the general health questions in the WMSD questionnaire were scored on a scale of 1–4 (1 = better than normal condition, 2 = normal/usual, 3 = worse than normal and 4 = much worse than normal condition). All operators had a worse than normal mean psychological profile (Table 4).

**Table 4:** Mean operator psychological profile score

| Operator sample | N | Mean | Std dev | Std error |
|---|---|---|---|---|
| All | 20 | 3.34 | 0.35 | 0.08 |
| NECF | 12 | 3.24 | 0.25 | 0.07 |
| KLF | 8 | 3.48 | 0.44 | 0.15 |

Repetition, working head/neck posture, duration of exposure, psychological factors and individual differences were identified as the main WMSD risk factors of the local forwarding job. The duration of awkward posture exposure was highest during the loading task (Table 5).

**Table 5:** Upper limb Work-Related Musculoskeletal Disorder risks of the local forwarding tasks assessed

| Task-related factors | |
|---|---|
| Repetition | Loading and offloading involved repetitive shoulder, arm, and finger/thumb action. More than 50% of the task involved performing a repetitive sequence of motions |
| Working posture | All forwarding tasks involved repetitive twisting of the neck. Visual demands of the task result in operators adopting awkward head and neck postures |
| Duration of exposure | Operators worked on the machine for prolonged periods, greater than 2 hours without break. Loading constituted 55% of the work time on average 3.78hrs per day |
| Environment-related factors | |
| Vibration | Operators were exposed to low-level whole body vibration and jerky actions. The jerks and shocks were mainly experienced as the operator drove over stumps and uneven ground conditions in the compartment |
| Psychological factors | The forwarding work was characterised by shift systems, and task work was usually common. Operators tended to skip breaks in order to meet targets. Occasional unplanned overtime was worked. This was mostly owing to the tight mill volume demands. In general, forwarding work required high levels of concentration |
| Individual differences | Operators of different competencies and skill sets were often required to work together within a harvesting system |

## Discussion

Operator reports on the location of WMSDs experienced during the last 12 months, are consistent with the location of WMSD symptoms reported by forestry machine operators in previous studies (Hansson, 1990; Axelsson & Pontén, 1990; Jack & Oliver, 2006; Gerasimov & Sokolov, 2009; Hagen et al., 1998; Hanse & Winkel, 2008). However, the studied operators reported higher 12-month WMSD prevalence in the back and lower prevalence in the neck, shoulder, wrist and elbow than that reported by operators in previous studies (Hanse

& Winkel, 2008; Jack & Oliver, 2006; Hansson, 1990 Axelsson & Pòten, 1990; Hagen et al., 1998).

The higher WMSD prevalence for the neck and upper back by the younger NECF operators is a rather unexpected trend compared to previous studies (Hagen et al., 1998; Axelsson and Potén, 1990) where WMSD prevalence increased with age. One would also have expected the more experienced and older KLF operators to have increased pain sensitisation owing to a centralised biochemical response (Marras, 2012) and therefore being more susceptible to this type of disorders. Marras (2012) stresses that tolerance limits vary throughout the lifespan of the worker because of controllable (exposure) and uncontrollable (genetic) factors. These factors of tissue loading and tolerance exist in a fine balance that is different between individuals. Consequently, the unexpected age trend observed in the present study emphasises the difficult and complex process of trying to establish the causal process of WMSDs. At best there is need to seek a balance that minimises the tissue load, as well as optimising the tissue tolerance and the resulting risk of WMSD for an individual (Marras, 2012).

The incremental trend of discomfort with time observed in the current study may be the result of inadequate recovery time during the shifts. Based on the actual machine hours recorded during the test days, studied operators spent less time on the machines than they reported in the survey (Table 3). Non-machine time constituted mainly machine breakdowns and other operational delays. These unplanned operational delays could have created more production pressure in that when the machines were operational, operators tended to work overtime or to skip mandatory breaks in order to catch up on lost production. These 'unplanned breaks' may have reduced the exposure time and increased the variation of activities for the operators. Similarly, Attebrant et al (1997) argued that in the past, machines were less durable, therefore more breakdowns were experienced, resulting in such breaks

offering variability and less exposure time. Today machines are more durable and hence operators are working longer hours, thus WMSD risks are more prevalent. This might not have been the case in the present study; operators were using modern durable machines, but may not necessarily have worked long machine hours per shift owing to the unplanned breaks. This may be the result of sub-optimal application of these systems in South Africa compared with the more experienced and developed regions.

Extreme head postures were adopted mainly in the transverse plane. This was owing to the visual demands of the forwarding task in this plane, as operators were trying to view the operating zone and follow the boom and attachment movements. Operators who spend 23% of their working time adopting extreme postures, might run the risk of WMSDs. Any intervention that reduces the amount of time spent by operators adopting these extreme postures is likely to reduce the risk of WMSDs (Kumar, 2001). Previous studies reported that rotatable and movable driver cabins improved head postures and viewing angles substantially (Gellerstedt, 1998; Eklund et al., 1994; Gerasimov & Sokolov, 2009). The present study forwarders had fixed driver cabins with a rotating seat. This demonstrates that cab design and/or machine selection might have an influence on improving operator visibility.

Although the operators reported working 50 hours a week, actual hours on the machines were observed to be much lower owing to a variety of factors, including machine breakdowns and shift-change delays. The operators' work pace was generally driven by production needs, and the tendency was to work intensively for four to six hours without breaks during the delay-free time of the shift. The reasons for operators not taking the mandatory breaks are complex and may be driven by the enormous production pressure placed on the operators. This production pressure may have been escalated by unplanned breaks owing to breakdowns and/or other operational delays in the systems. This is consistent with Attebrant et al (2007)'s observation that work organisation in forestry machine work is generally guided by

production needs and only to a minor extent by ergonomics. The incremental mean localised WMSD trend for all body sites (Figure 4) might be explained by the lack of adequate recovery time during intensive machine work.

All operators had a worse than normal mean psychological profile. The increased incidence of back pain reported by operators in this study may be related, among many other factors, to this. This is consistent with reports from a previous study in which Hagen et al. (1998) found that increasing levels of psychological demands were significantly associated with increased prevalence of lower back disorders. Marras (2012) concurred that physical and mental work factors can greatly influence the loading of spine tissues. It is possible that operators faced similar work demands, and despite differences in experience, age and company, all the operators may have found it increasingly difficult to cope with the demands.

Table 5 shows the WMSD risks associated with the local forwarding task. This is consistent with forwarding work risks identified in the literature (Attebrant et al., 1997; Jack & Oliver, 2006; ErgoWood & EC, 2006; Axelsson & Potèn, 1990; Harstella, 1990; Østensvick et al., 2008). Owing to the complex nature of human work systems, the causation of musculoskeletal conditions is multifactorial (Kee and Karwowski, 2007; Bridger, 2003; Kumar, 2001; Marras, 2012). Duration of exposure has been identified as an important concept in the assessment of WMSD risk factors (HSG, 2002). This was observed in the two systems. Although all forwarding tasks involved some shoulder, arm, hand and finger repetition and head and neck awkward postures, it was the duration of exposure that was likely to increase the WMSD risk.

**Conclusions**

This study was an ergonomic assessment of the local forwarding tasks. It has shown that local operators experienced WMSDs; operators were affected mainly by back problems. The study

results support the proclamation that causal pathways of WMSDs are complex and multifactorial, therefore any interventions to mitigate them must address physical and mental risk factors and are dependent on individual operator tolerances. Operators are simultaneously exposed to a number of WMSD risks and to varying magnitudes. Therefore it is recommended that WMSD risk management should be incorporated into existing health and safety 'wellness' programmes to ensure early detection and continuous mitigation of WMSD risks. Owing to the small operator sample and the short term nature of the study, the results may not be generalised outside the study scope therefore, a long-term longitudinal study with a larger operator sample on WMSD prevalence and risk factors in South Africa is recommended. Irrespective of the shift systems in place, continuous monitoring and management of operator machine time is recommended, particularly where breakdowns and operational delays result in the disruption of normal scheduled work. In such cases the operator workload balancing is critical and may be achieved through;

- Monitoring and reducing piecework schemes
- Ensuring that mandatory breaks and adequate periodic breaks are taken when they are most beneficial
- Managing overtime effectively

Owners of forwarders in South Africa are encouraged to incorporate periodic lower back medical check-ups in existing operator health and safety programmes

**References**

Attebrant M, Winkel J, Mathiassen SE, Kjeillberg A. 1997. Shoulder-arm muscle

    load and performance during control operations in forestry machines: Effects of

    changing to a    new armrest, lever and boom control system. *Applied Ergonomics*

    28:85–97.

Axelsson S, Potèn B. 1990. New ergonomic problems in mechanised logging

    operations. *International Journal of Industrial Ergonomics* 5:267–273.

Bridger RS. 2003. *Introduction to ergonomics*. (2nd edition). New York: Taylor & Francis.

Corlett NE 2005. Static muscle loading and the evaluation of posture. In: JR Wilson,

    NE Corlett (eds). *Evaluation of human work*. (3rd edition).

    London: Taylor & Francis. pp 454–495.

David GC. 2005. Ergonomic methods for assessing exposure to risk factors for work-

    related  musculoskeletal disorders. *Occupational Medicine* 55:190–199.

Eklund J, Odenrck P, Zettergen S, Johansson H. 1994. Head/posture measurements

    among work vehicle drivers and Implications for workplace design. *Ergonomics* 37:623–639.

ErgoWood, European Commission (EC) 2006. European ergonomic and safety guidelines for

    forest machines: ErgoWood    handbook. Edited by S Gellerstedt, G Eriksson, S Frisk, O

    Hultäker, U Synwoldt, R Tobisch, G Weise. Uppsala, Sweden: Mats Nylinder, Swedish

    University of Agricultural Services.

Gellerstedt S. 1998. A self-levelling and swivelling forestry machine cab. *Journal of Forest

    Engineering* 9:7–16.

Gerasimov Y, Sokolov A. 2009. Ergonomic characterisation of harvesting work in

Karelia. *Croatian Journal of Forest Engineering* 30:159–170.

Hagen KB, Magnus P, Vetlesen K. 1998. Neck/shoulder and low back disorders in

the forestry industry: relationship to work tasks and perceived psychosocial job

stress. *Ergonomics* 41:1510–1518.

Hanse JJ, Winkel J. 2008. Work organisation constructs and ergonomic outcomes among European

forest machine operators. *Ergonomics* 51:968–981.

Hansson JE. 1990. Ergonomic design of large forestry machines. *International Journal of*

*Industrial Ergonomics* 5:225–266.

Harstella P. 1990. Work postures and strain of workers in Nordic forest work, a selective

review. *International Journal of Industrial Ergonomics* 5:219–226.

Health and Safety Executive (HSE) 2002. Upper limb disorders in the workplace (HSG60).

Surrey, United Kingdom. Available at http:// www.hse.gov.uk/pubns/books/hsg60.htn

[Accessed: 17 June 2013].

Jack RJ, Oliver M 2006. A review of factors influencing whole body vibration

injuries in forestry mobile machine operators. *International Journal of Forest*

*Engineering* 19:51–65.

James G 2006. An ergonomic assessment of manual timber extraction. ICFR Bulletin

12/2006. Pietermaritzburg. South Africa. Available at

http://www.icfr.ukzn.ac.za/collaboration/fesa/fesa-publications/

[Accessed: 17 June 2013].

Kee D, Karwowski W. 2007. A comparison of three observational techniques for

assessing postural loads in industry. *International Journal of Occupational Safety and Ergonomics* 13:3–14.

Komatsu Forest 2011. Ergonomics. Available at:

http://www.komatsuforest.fi/ergonomics [Accessed: 5 August 2013].

Kumar S. 2001. Theories of musculoskeletal injury causation. *Ergonomics* 44:17–47.

Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Anderson G

Jørgensen K. 1987. Standardised Nordic questionnaires for analysis of

musculoskeletal symptoms. *Applied Ergonomics* 18:233–237.

Magnusson ML, Pope MH. 1998. A review of the biomechanics and epidemiology

of working postures: it isn't always vibration which is to blame! *Journal of Sound and Vibration* 215:965–976.

Marras WS. 2012. The complex spine: The multidimensional system of causal pathways or

low-back disorders. *Human Factors* 54:881–889.

Østensvik T, Veiersted KB, Cuchet E, Nilsen P, Hanse JJ, Carlzon C, Winkel J

2008. A search for risk factors of upper extremity disorders among forest machine

operators: A comparison between France and Norway. *International Journal of Industrial Ergonomics* 38:1017–1027.

Qu Y, Hwang J, Lee KS, Jung MC. 2012. The effect of camera location on

observation based posture estimation. *Ergonomics* 55:885–897.

Robb MJM, Mansfield NJ. 2007. Self-reported musculoskeletal problems among

professional truck drivers. *Ergonomics* 50:814–827.

Scott PA. 2006. Editorial. *Ergonomics SA* 18(1).

Scott PA, Christie C, James G , Todd A. 2004 Ergonomics report: Forest harvesting.

Ergonomics evaluation for FESA, ICFR. Pietermaritzburg, South Africa.

Available at: http://www.icfr.ukzn.ac.za/collaboration/fesa/fesa-publications/

[Accessed: 5 June 2013].

Scott P, Kogi K, McPhee B. 2010. Ergonomics guidelines for occupational health practice in

industrially developing countries. Darmstadt (Germany): Institute for Ergonomics, University

of Darmstadt.

Todd A I. 2011. Opinion section. Shaping the future ergonomics landscape of SA: A

co-operative co-responsibility. *Ergonomics SA* 23(1).