The impact of a change in work posture from seated to stand-up on work-related musculoskeletal disorders among sewing-machine operators

Susan H. Grobler Masters (Physiotherapy)[1,2,*], Karien Mostert PhD[2], Piet Becker PhD[3,4]

[1] Physiotherapy Private Practice, Pretoria, South Africa

[2] Department of Physiotherapy, University of Pretoria, Pretoria, South Africa

[3] Research Office, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa

4 Biostatistics Unit, South African Medical Research Council, Pretoria, South Africa

* Correspondence: Susan H. Grobler, Masters (Physiotherapy), Physiotherapy Private Practice 8 Myrtle street, Clydesdale, Sunnyside, Pretoria, 0002, South Africa.Email: grobler.physio@gmail.com

Abstract

Background: Work-related postural change could lead to improved musculoskeletal health.

Method(s): In a quantitative, retrospective, longitudinal study, data of work-related musculoskeletal disorders of 123 sewing-machine operators were captured for 4.5 years, and analysed using Poisson regression.

Results: Stand-up work posture (SUWP) reduced the incidence for spinal disorders (SD) to 0.29 fold the incidence for sitting work posture (SWP) ($p < 0.001$). Morbid obesity had significantly increased ($p=0.04$) incidence of upper limb disorders (ULD), 3.35 times that of normal body mass index (BMI) (regardless of work posture). SUWP was associated with increased IRR

(1.49) for lower limb disorders (LLD). LLDs were associated with obesity (overweight (IRR=2.58; p=0.08), obese (IRR=2.45; p=0.09), and morbidly obese (IRR=6.24; p=0.001)).

Conclusions: The protective benefit of the SUWP was statistically significant for SDs incidence. Owing to high mean BMI, SUWP had a negative impact on the incidence of LLDs for the first 2 months.

Keywords: obesity, sewing, sitting work posture, stand-up work posture, work-related musculoskeletal disorders.

1. INTRODUCTION

Work-related musculoskeletal disorders (WRMSDs) are costly to employers and employees, and to balance productivity and health, occupational healthcare needs well-researched evidence.(1,2) Since 2010, a controversial body of evidence reported on the adverse health outcomes of prolonged sitting.(3-5) Reducing sitting time can be one strategy to improve occupational health, but scientific literature lacks population-specific implementation guidelines, as individual risk factors are involved.(6)

Traditionally, sewing is performed in a seated work posture. Studies indicate a higher prevalence of spinal and upper limb disorders among seated sewing-machine operators (operators) (7) compared to the general working population; a high prevalence of upper limb disorders associated with obesity (8) and leg discomfort associated with standing.(9) Although studies mention that sitting compromises spinal biomechanical function (10) and vertebral disc nutrition (11), a myriad of personal, ergonomic and psychosocial risk factors (12-15) are associated with WRMSDs among these operators.

Operator-specific risk factors to WRMSDs are threefold. First, the association of personal risk factors, that is. gender, age, and marital status/parenting (14,15) to WRMSDs among operators, is inconclusive in literature. For musculoskeletal disorders (MSDs), length of employment (13-16) and musculoskeletal history (14,17) are risk factors; and systemic illnesses (including obesity) (7,15) might contribute to the prevalence of operator-specific MSDs. Second, causative ergonomic risk factors to operator-specific MSDs, include a sub-optimal match between sedentary furniture dimensions and individual anthropometric requirements (18); and high muscle-load.(14,19) Operator-specific MSDs are not associated with the implementation of a job rotation policy (12), or working overtime (15,20). The third group of factors, psychosocial risk factors, are excluded from this study.

All ergonomic risk factors, individually and jointly, can play a causative role to the incidence and prevalence of WRMSDs, and should be managed within a workplace health program, that is, an integrated clinical occupational model. The three key determinants of such a program are: first, primary prevention through close association of occupational intervention with clinical care. Second, secondary prevention through early reporting of strains, followed by tertiary prevention (rehabilitation) through aggressive medical/manual management.(2,10,21-25)
A "participatory ergonomics programme with multi-disciplinary representation" was implemented among 250 United States of America (USA)-based operators sewing canvas automobile products in the mid-90s to control and reduce workers' compensation costs. Among other interventions, the program included a change in work posture from sitting to stand-up, and resulted in an 82% reduction in MSDs, and 42% overall reduction in workers' compensation incurred losses.(21) A similar program, including a change in work posture from sitting to stand-up was implemented among operators in a car-seat manufacturing plant of Johnson

Controls Automotive S.A. (Pty) Ltd (company) (25). As personal risk factors to each population, and program components in each country are unique, these USA results cannot necessarily be expected in South-Africa.

This study was conducted to determine the impact of a change in work posture from seated to stand-up on WRMSDs among operators in this South African setting. The aim of the study was to determine the impact of the change in work posture on the monthly count (equivalent to incidence) of WRMSDs (spinal, upper- and lower limb) among operators. Objectives of the study were to describe the incidence of WRMSDs for the study period; to determine the association between individual risk factors (personal and ergonomic) and WRMSDs longitudinal; and to determine the association between work posture and WRMSDs adjusted for influential risk factors.

2. MATERIALS AND METHODS

Incidence of WRMSDs was assessed in a quantitative retrospective longitudinal study with a convenience sample. Study period: June 2004 to January 2009.

All 123 operators who performed sewing operations of car seats in the company's auto-motive factory were included in the study. These hourly-paid operators were subjected to the same daily working hours, on the same premises with cement floor/paved areas, and had low job control in an organisational climate driven by production targets. Their activity profile during working hours, included the following activities: During working hours, each operator walked 100m twice - from the outer gate to the work station and back. They had their 15 min early morning 'flex-and-stretch' group exercise session from 7h30-7h45 in a standing posture. Sewing was performed from 7h45-9h00, 9h30-12h00, and 12h20-16h00; and should the need for working overtime arise, they worked till 18h00. During their predictable meal breaks from 9h00-9h30, and 12h00-12h20, operators could walk to the well-equipped canteen and toilets, which were 50 m from their work stations. Most operators chose the seated posture in the canteen throughout the study period, although a few operators chose to lay on the floor, with their feet elevated (especially during the early months after they changed their work posture). Operators were allowed to walk to the toilet during working hours. Due to the nature of sewing a car seat with cloth/vinyl/leather, the upper body of the operators constantly exerted forceful actions, while they used their feet to operate the pedals to lift the needle, or adjust the sewing speed. Sitting/standing during working hours, was never static.(26)

Only 70 of these operators self-reported WRMSDs during the study period. An average of 2.7 treatment sessions per operator was provided by the physiotherapist.

The physiotherapist clinically evaluated all WRMSDs; and visited the production lines weekly to evaluate work settings. During physiotherapy sessions, WRMSDs were confirmed. Based on subjective report of the operator and a physical examination performed by the physiotherapist, work-relatedness was determined. Work-relatedness was ascertained by relying on general principles of occupational medicine.(10) 'These general principles of occupational medicine are: relation of symptoms to work, history of workplace exposures to ergonomic factors likely to contribute to the condition, presence of similar conditions among co-workers, presence of prior trauma to the affected body parts, and vocational activities that may cause or contribute to injury.'(27) It is unlikely that WRMSDs were not reported, as team leaders regularly prompted operators to report WRMSDs (without penalty) to the free of charge physiotherapy service. Part of the remuneration package of each operator, was membership of a private medical scheme. The company and operators each paid half of the monthly contributions for limited medical benefits for health management of each operator and his/her family. These lower wage employees, managed their personal medical expenses very conservatively; their monthly contributions covered membership on the basic plans of their schemes, with limited out-of-hospital benefits, specifically for physiotherapy. They tended not to visit personal physicians or physiotherapists often, as depleted medical scheme benefits would lead to co-payments. The fact that the company funded the physiotherapy service in this study 100% in order to manage WRMSDs, made self-reporting of WRMSDs attractive to operators. Only the area of the disorder, that is, spinal, upper limb, or lower limb was documented, and with the operator's consent it was anonymously reported to management. Some operators were employed permanently, and other's as contractors for a minimum period of 6 months. All operators were part of this unionized population, working under similar conditions in the company. The physiotherapy service was unaware of any operator being penalised for reporting a WRMSD over the total study period.

Differentiation between work-related and non-work-related MSD was a prerequisite from the company for funding physiotherapy treatment.

Operators who were employed less than two months by the company (1%); non-sewing occupations, that is, team leaders; and disorders not regarded as WRMSDs, that is, traumatic injuries sustained after hours, were excluded.

2.1 Intervention

Each operator was allocated to a production line and worked in a seated posture until December 2004, where after the company implemented a change of work posture from seated to stand-up.(25) Each of the seven production lines in this company, had an individual predetermined stand-up date. The operator's postural change was abrupt, compulsory and permanent. All operators were working in a stand-up posture by August 2008 till the end of the study period.

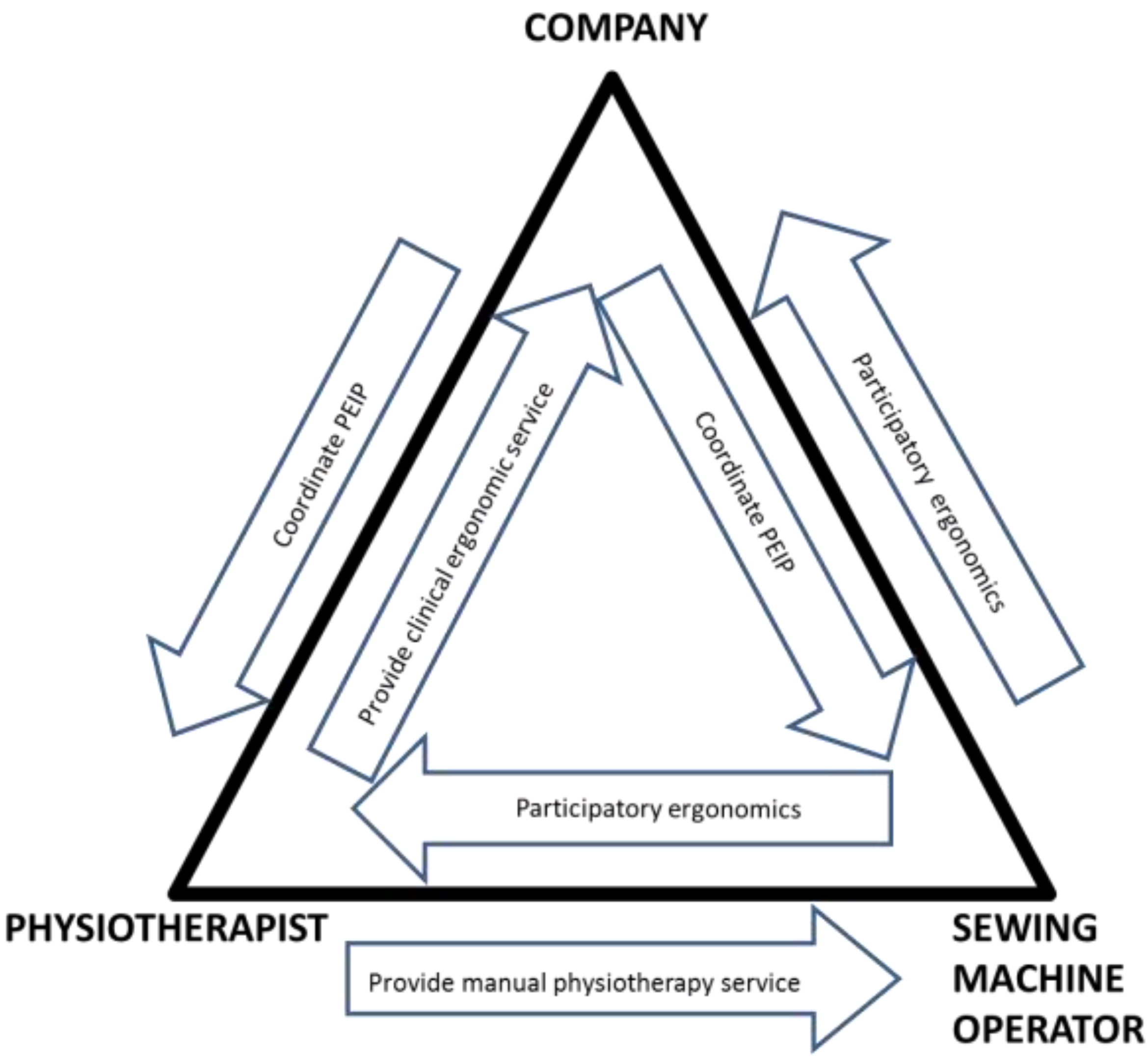

Figure 1 A graphic description of the three role players in the Prevention Early Intervention Programme (PEIP) (Source: Developed by the first author)

2.2 Prevention Early Intervention Program

The company, physiotherapist and operators were the three role players in the workplace health program, that is, the Prevention Early Intervention Program (PEIP) (Figure 1). The intervention was implemented within this participatory ergonomics model.(10) The company coordinated the PEIP and was committed to implementation of budget-approved ergonomic recommendations; and the physiotherapist delivered a clinical ergonomics and manual therapy service. Ergonomic issues were addressed by job redesign, health education and employee selection.

2.3 Job redesign

According to the participatory ergonomics model (10), regular excessive reaching was minimised for all workstations by optimising storage heights and workstation layout (regarding the floor plan and workflow) throughout the study period.

Similarly, for seated workstations, once-off adjustments of pedal position, table- and chair height in relation to individual anthropometric measurements were made within the first few months, and maintained**.** Chairs with fixed backrests were replaced by chairs with adjustable backrests and also maintained.(14,18,28) For stand-up workstations, operators worked in cells, and product transportation was done by conveyor belt throughout the stand-up period.

Due to budget constraints, the self-use height-adjustability feature of stand-up sewing tables was only implemented from 2006, and enabled operators to do job-rotation whilst accommodating individual anthropometric differences. Operators' concerns about the possible negative effects of the stand-up work posture on their lower limbs, were accommodated as pedals encouraging alternative feet-use for sewing-speed and needle-lifting; and a 1x1 m^2 shock-absorbing carpet at each work station (9) were supplied upon installation of stand-up workstations.

2.4 Health education

Due to an initial increase in lower limb discomfort voiced by the operators to the physiotherapist shortly after implementation of the stand-up work posture, health education was prioritised by management as part of occupational interventions to operators in the seated and stand-up work postures.(23) The physiotherapist designed and presented health education sessions during working hours in English to management and operators.(18,23,25,29-32) Managing the impact of the work posture change was addressed individually and in small work groups, and included advice on purchasing supportive footwear,(9) silicone innersoles,(32) compression stockings,(33) and exercise.(29,30)

Prior and during the study period, all operators participated in a 15 min early morning ‘flex-and-stretch’ group exercise session. Exercises were done in a standing posture and focussed on breathing and full-body stretching. Because most operators wore high-heeled shoes while sewing in the seated work posture, prescription of additional exercises was imperative in managing WRMSDs before, during and after the postural transition period. Work- and home-based exercise regimes addressed lower limb stiffness and atrophy. Exercise regimes were demonstrated to operators, and hard-copy hand-outs had pictorial and textual explanations. The work-based regime included four easy-to-do lower limb exercises for 30 s, to be repeated every 2 h. Work-based exercises could only be done in standing, therefore home-based exercises were added for goal-orientated strengthening and stretching in other positions. For example, stretching hip flexors, were done in prone. Performing home-based exercise regimes were not compulsory, but highly recommended by management and the physiotherapist as part of the participatory ergonomics programme.

The physiotherapist gave advice on the importance of matching individual anthropometric dimensions with furniture adjustability features; the job rotation rationale; benefits of alteration in weight bearing while using the pedals in the stand-up work posture.

2.5 Employee selection

When adjustability range could not accommodate the seated employee's individual anthropometric requirements, employee selection was done matching physical and workstation dimensions; while accommodating job description and employee skill.

2.6 Data management

Data on personal risk factors were included in the analysis, but not addressed as part of the PEIP. Data included information on age, gender, medical history (rheumatoid arthritis, hypertension, diabetes mellitus (DM)), musculoskeletal history, and body mass index (BMI).

The first ergonomic risk factor, posture, was addressed by the intervention and was categorized into either sitting (pre-intervention) or standing (post-intervention).

The second ergonomic risk factor, force, was categorised as either working with material type (cloth/vinyl or cloth/leather), or method of stitching (straight stitching or forceful precision stitching).

The third ergonomic risk factor, duration, comprised two elements: working overtime and performing job rotation. While working overtime (yes or no to the company producing more than 10 000 units per month), musculoskeletal exposure was more during months with higher production volumes; similar to performing job rotation between the two methods of stitching (either straight stitching or forceful precision stitching), where the level of musculoskeletal strain was higher with the latter. Job rotation was implemented between June 2004 and October 2005.(25)

Capturing of demographic data, medical-related data and data on risk factors was done by the first author, at three locations during the data collection period (2011 to 2012). First, demographic data were captured at the company's human resource department, and included name and surname, date of birth and employment period of all participants in order to compile a baseline data spreadsheet on Microsoft Excel (version 7). Thereafter, data regarding participant exposure to ergonomic risk factors on a timeline, were determined during a consensus building meeting between the physiotherapist and three coordinators of team leaders. Risk of error in this method of data collection was low, as allocation of participants to; and combination of ergonomic risk factors related to a specific production line, were consistent over the study period. Data on the number of units produced per month were provided by the finance department of the company via e-mail, and all information was added onto the spreadsheet.

Second, medical-related data on personal risk factors was captured from the on-site occupational health care company's medical surveillance forms and included base line information on hypertension, arthritis, DM, and BMI; and were added onto the spreadsheet.

Last, data of one personal risk factor, that is, musculoskeletal history, and data on the WRMSDs of each participant who received physiotherapy treatment, was added onto the spreadsheet. As for musculoskeletal history, the question was asked if this disorder had received physiotherapy treatment since June 2004, and the type of disorder was categorised as a spinal, upper limb or lower limb disorder. Names and surnames of participants were removed from the spreadsheet before statistical analysis commenced.

2.7 Ethical considerations

The Ethics Committee of the Faculty of Health Sciences at the University of Pretoria approved the ethical aspects of the study (S157/2011). Injured operators gave written permission that the nature of their WRMSDs was communicated to the company. The on-site occupational health care company gave written permission to access data. The company gave written permission for the study to be conducted, to access information as well as the publication of its name.

2.8 Statistical analysis

Monthly counts of self-reported and confirmed disorders (as proxy for incidence) were used in the analysis. Only the first date of physiotherapy sessions was captured. When course sessions overlapped between two consecutive months, the denominator for calculating the incidence rate ratio was decreased accordingly for the second of the 2 months. The denominator for incidence varied, depending upon the total number of participants in each specific month. Only new disorders in a specific month were counted. This happened only in a few cases, and had a negligible influence on results. Participants were followed for a maximum period of 56 months. Data for the participants was summarised using frequencies, percentages and cross-tabulations.

The incidences of disorders were determined in three anatomical areas: the spinal area; upper limbs; and lower limbs. The primary exposure variable of interest was work posture, that is, seated or stand-up. The disorders were analyzed individually as well as multiple (more than one of the disorders were present in the same month).

Incidence rate ratios for risk factors were determined using random effects Poisson regression considering risk factors individually; and in bivariate analyses both for individual and collective outcomes. Risk factors were modelled as fixed effects and participant was included as the random component. Along with including co-variates and ergonomic risk factors with P less than 0.2, purposeful factors were included in the multivariable analysis (as deemed by the physiotherapist). A co-variate was labelled a confounder only if the inclusion of the co-variate brought about a difference of more than 15% to the co-efficient of the exposure variable (change in work posture). This is standard procedure in model building.(35) For the duration of the study period, the monthly counts of disorders were displayed graphically using local polynomial smooth.

Testing was done at the 0.05 level of significance both for the scenario where all 56 months were considered ('full period'); and the scenario where the first three months and the 'initial stand-up month and the consecutive month' were omitted ('reduced period'). These data were omitted to accommodate the two transitional periods during the study period, and hence also impact the implementation of the PEIP and the change in work posture on the incidence of WRMSDs. The first transitional period accommodated the initial adaptation of the participant group to PEIP implementation (June to August 2004) ('program adaptation period'); and the second transitional period accommodated the individual adaptation of participants when his/her work posture changed ('postural adaptation period'). At onset of the data analysis of the reduced period, all participants employed, except one, at that stage (n=103) were injury free.

3. RESULTS

3.1 Description of the population in terms of risk factors

The population (n=123) consisted of 120 (97.6%) females, of which the largest proportion was between 36 and 50 years of age (63.4%); 20.3% was 35 years and younger, and 16.3% was older than 50 years at baseline. The mean age was 42.3±8 years, 95% Confidence Interval (CI) (40.8; 43.7) years. As for medical history, 17.9% had hypertension, 3.3% reported having arthritis and 6.5% had DM (missing data accounted for 7.3% for hypertension and 3.3% for arthritis and DM). Furthermore, normal BMI accounted for 22% of the participants, 27.6% were overweight, 29.3% obese and 13% were morbidly obese (missing data accounted for 8.1%). The mean BMI was 29.7 ±6.1 kg/m², and 95% CI (28.6; 30.8 kg/m²). Musculoskeletal history data were compiled throughout the duration of the study period.

All participants were working in the seated work posture till December 2004, where after 17.9% transitioned to the stand-up work posture in January 2005, 30.1% in January 2007, 34.9% in January 2008, 6.5% in March 2008, and the last 10.6% in July 2008. From August 2008 onwards, all participants performed sewing in the stand-up work posture.

As for material type, cloth and leather were sewn by 89.4% of the participants; while the rest sew cloth and vinyl. As for method of stitching, 79.7% of participants performed relatively easy straight stitching; while the rest did forceful precision stitching (sewing of headrests and airbags, and perform top stitching). Job rotation between straight stitching and forceful precision stitching was applied for 36.6% of participants.

3.2 Incidence of WRMSDs

In Figure 2 local polynomial smoothing displays the trend of monthly incidence of WRMSDs, by disorder group, over the full period. In Figure 3, the program- and postural adaptation periods were removed from the full period. The effect of the removal of the data of the two adaptation periods demonstrates the impact of the implementation of the program and the change in work posture on specific disorders.

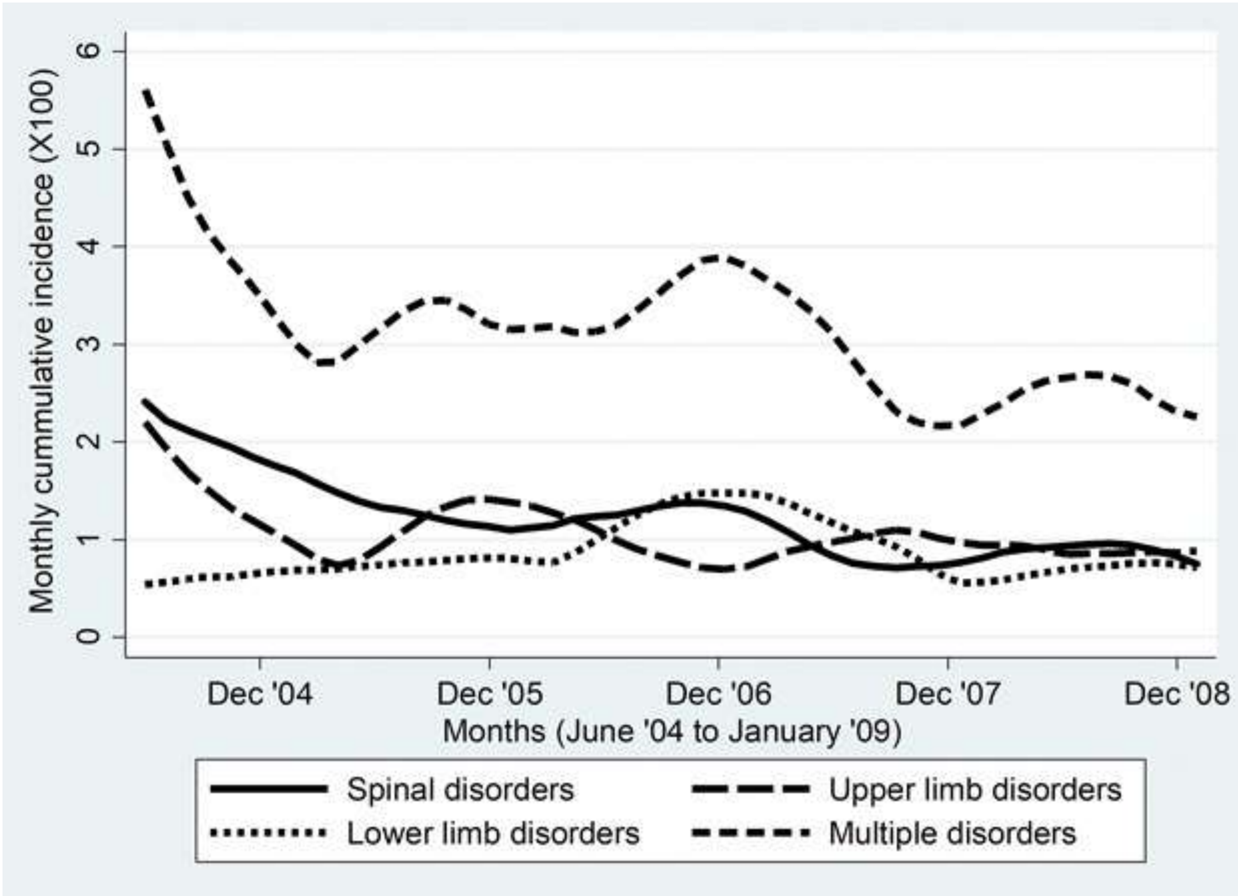

Figure 2 Monthly cumulative incidence (x100) for spinal, upper limb, lower limb and also multiple disorders for the full period of the study (n=123)

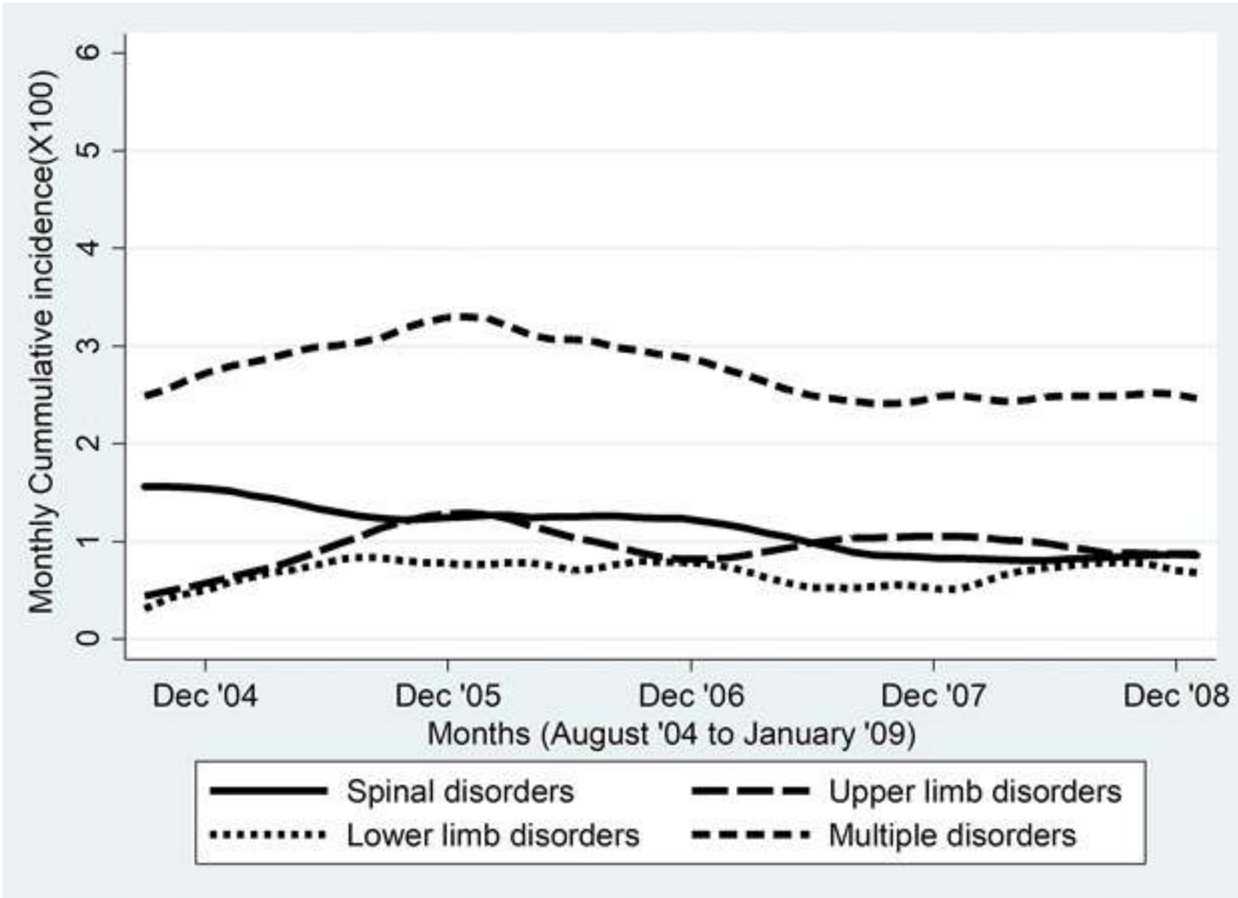

Figure 3 Monthly cumulative incidence (x100) for spinal, upper limb, lower limb and also multiple disorders for the reduced period of the study (n=123)

Figure 2 demonstrates an initial high incidence in spinal and upper limb disorders, levelling off over time. There is one noticeable peak of lower limb disorders during January 2007. In Figure 3, the initial high incidences are absent, and the former peaks are now less marked. Subsequently, the incidence in upper limb disorders did not change much over time.

The noticeable peak of lower limb disorders in Figure 2 during the first 2 months of 2007 when 30.1% of the participants changed their work posture from seated to stand-up, did not recur as expected during 2008 when the last 52% of the participants changed their work posture. Figure

3 demonstrated that the initial high incidence of disorders after implementation of a PEIP lasted 3 months; and the increase in lower limb disorders during the change of work posture for the study period, lasted 2 months. The multiple disorder sequence reflected that of the 3 groups of disorders.

The overall incidence per disorder was determined for the reduced period: the incidence of spinal disorders decreased by 5.7% (from 12.2 to 11.5 disorders per 1 000 person-months); for upper limb disorders by 9.3% (from 10.8 to 9.8 disorders per 1 000 person-months); for lower limb disorders by 22.7% (from 8.8 to 6.8 disorders per 1 000 person-months); and for multiple disorders by 11.6% (from 31.8 to 28.1 disorders per 1 000 person-months).

3.3 Associations

For outcomes spinal, upper limb, lower limb and multiple disorders**, over full and reduced periods***, the incidence rate ratio (IRR) of risk factors were determined from bivariate and subsequently multivariable random effects Poisson regression with risk factors as fixed effects and participant was included as the random component.

IRRs, 95% CI and P values (significance when $P<0.05$)* from the bivariate analysis of risk factors for spinal, upper limb, lower limb and multiple disorders over full and reduced time periods are summarized in Tables 1 and 2.

Risk factors, significant at the 0.2 level of significance in Tables 1 and 2, entered the multivariable random-effects Poisson regression and are summarized in Tables 3 and 4.

TABLE 1 Incidence rate ratio (IRR) from bivariate random-effects Poisson regressions, 95% CI and *P* values* of personal risk factors by type of disorder for the full-and reduced time periods (n=123)***

Personal risk factors		Spinal disorders		Upper limb disorders		Lower limb disorders		Multipl disorders **	
		Full period	**Reduced period *** **	**Full period**	**Reduced period *** **	**Full period**	**Reduced period *** **	**Full period**	**Reduced period *** **
Age(years)									
	IRR	0.51	0.63	0.46	0.62	0.42	0.56	0.32	0.41
36 to 50	95% CI	(0.21; 1.24)	(0.25; 1.6)	(0.16; 1.34)	(0.17; 2.27)	(0.12; 1.43)	(0.11; 3.01)	(0.66; 0.64)	(0.18; 0.93)
	p value	0.14	0.33	0.15	0.47	0.16	0.5	0.001*	0.03*
	IRR	0.41	0.57	0.54	0.6	0.51	0.71	0.33	0.42
Older than 50	95% CI	(0.15; 1.18)	(0.2; 1.66)	(0.16; 1.85)	(0.14; 2.6)	(0.14; 1.88)	(0.12; 4.13)	(0.14; 0.74)	(0.17; 1.09)
	p value	0.1	0.3	0.33	0.49	0.31	0.71	0.007*	0.07
Hypertension									
	IRR	1.16	1.28	1.31	1.53	1.561	1.79	1.35	1.56
Yes	95% CI	(0.57; 2.34)	(0.64; 2.57)	(0.5; 3.41)	(0.52; 4.51)	(0.76; 3.2)	(0.78; 4.28)	(0.75; 2.44)	(0.81; 3.0)
	p value	0.68	0.49	0.58	0.44	0.22	0.19	0.32	0.18
Arthritis									
	IRR	0.63	0.72	1.43	1.66	Insufficient data	Insufficient data	0.72	0.87
Yes	95% CI	(0.07; 5.53)	(0.09; 5.94)	(0.15; 13.7)	(0.14; 20.19)			(0.15; 3.57)	(0.16; 4.7)
	p value	0.68	0.76	0.76	0.69			0.69	0.87
Diabetes mellitus	(DM)								
	IRR	0.83	1.0	1.0	1.19	1.19	0.84	0.95	1.0
Yes	95% CI	(0.26; 2.63)	(0.32; 3.03)	(0.23; 4.24)	(0.24; 5.97)	(0.37; 3.85)	(0.16; 4.34)	(0.39; 2.36)	(0.37; 2.73)
	p value	0.74	0.98	0.99	0.83	0.78	0.84	0.92	1.0
Musculoskeletal	**history**								
	IRR	1.82	1.91	0.85	0.94	0.74	0.64	1.1	1.16
Yes	95% CI	(1.12; 2.94)	(1.14; 3.21)	(0.51; 1.42)	(0.53; 1.65)	(0.41; 1.32)	(0.31; 1.33)	(0.82; 1.48)	(0.83; 1.61)
	p value	0.02	0.01	0.53	0.82	0.31	0.23	0.54	0.38
BMI									
	IRR	0.96	0.99	1.88	1.99	2.54	2.8	1.57	1.62
Overweight	95% CI	(0.47; 1.98)	(0.49; 1.99)	(0.67; 5.31)	(0.63; 6.32)	(0.88; 7.31)	(0.8; 9.76)	(0.82; 2.98)	(0.8; 3.27)
	p value	0.92	0.98	0.23	0.24	0.09	0.11	0.17	0.18
	IRR	0.66	0.5	1.04	0.84	2.4	1.97	1.04	0.81
Obese	95% CI	(0.31; 1.41)	(0.23; 1.11)	(0.35; 3.1)	(0.24; 2.96)	(0.84; 6.84)	(0.55; 7.04)	(0.54; 1.98)	(0.39; 1.69)
	p value	0.29	0.09	0.94	0.79	0.1	0.3	0.92	0.57
Morbidly	IRR	0.76	0.73	3.34	3.81	6.26	4.81	2.24	2.09
obese	95% CI	(0.3; 1.95)	(0.29; 1.87)	(1.04; 10.69)	(1.05; 13.81)	(2.2; 17.82)	(1.3; 17.79)	(1.07; 4.69)	(0.92; 4.72)
	p value	0.57	0.51	0.04*	0.04*	0.001*	0.02*	0.03*	0.08

* Significant at $P<0.05$

** ‘Multiple’ denotes that more than one of the disorders were present in the same month

*** Reduced time period excluded the first three months of the study for all the sewing-machine operators and the month that each sewing-machine operator changed his/her work posture, as well as the consecutive month

TABLE 2 Incidence rate ratio (IRR) from bivariate random-effects Poisson regressions, 95% CI and *P* values* of ergonomic risk factors by type of disorder for the full-and reduced time periods (n=123)***

Ergonomic risk Factors		Spinal disorders: Full period	Spinal disorders: Reduced period ***	Upper limb Disorders: Full period	Upper limb Disorders: Reduced period ***	Lower limb disorders: Full period	Lower limb disorders: Reduced period ***	Multiple disorders **: Full period	Multiple disorders **: Reduced period ***
Work posture									
Stand	IRR	0.37	0.48	0.72	1.24	1.51	1.32	0.63	0.77
	95% CI	(0.22; 0.64)	(0.28; 0.84)	(0.41; 1.28)	(0.64; 2.41)	(0.87; 2.78)	(0.64; 2.72)	(0.45; 0.89)	(0.52; 1.12)
	p value	<0.001*	0.01*	0.26	0.52	0.19	0.45	0.008*	0.17
Material types									
Cloth and Leather	IRR	1.36	1.5	1	1.6	1.63	1.1	1.24	1.35
	95% CI	(0.49; 3.87)	(0.49; 4.54)	(0.21; 4.89)	(0.21; 12.28)	(0.45; 5.85)	(0.27; 4.44)	(0.51; 3.01)	(0.49; 3.68)
	p value	0.56	0.48	1.0	0.65	0.45	0.89	0.63	0.56
Forceful precision	**Stitching**								
Forceful Precision Stitching	IRR	0.71	0.75	0.42	0.51	0.72	0.78	0.59	0.65
	95% CI	(0.35; 1.46)	(0.36; 1.55)	(0.15; 1.21)	(0.16; 1.62)	(0.32; 1.63)	(0.29; 2.08)	(0.33; 1.08)	(0.34; 1.26)
	p value	0.35	0.44	0.11	0.25	0.43	0.62	0.09	0.2
Overtime									
More than 10 000 units per month	IRR	0.81	0.9	1.03	1.24	0.58	0.82	0.81	1.0
	95% CI	(0.43; 1.55)	(0.48; 1.78)	(0.55; 1.94)	(0.64; 2.38)	(0.25; 1.37)	(0.34; 1.98)	(0.55; 1.21)	(0.66; 1.5)
	p value	0.53	0.82	0.93	0.52	0.22	0.66	0.31	0.98
Job rotation									
Performing Job Rotation	IRR	1.04	0.93	0.77	0.64	1.12	0.48	0.85	0.66
	95% CI	(0.6; 1.8)	(0.53; 1.63)	(0.37; 1.6)	(0.29; 1.43)	(0.6; 2.12)	(0.21; 1.09)	(0.55; 1.31)	(0.41; 1.05)
	p value	0.88	0.79	0.49	0.28	0.72	0.08	0.46	0.08

* Significant at $P<0.05$

** ‘Multiple’ denotes that more than one of the disorders were present in the same month

*** Reduced time period excluded the first three months of the study for all the sewing-machine operators and the month that each sewing-machine operator changed his/her work posture, as well as the consecutive month

TABLE 3 Incidence rate ratio (IRR) from multivariable random effects Poisson regressions, with 95% CI and *P* values* of personal risk factors for spinal, upper limb, lower limb and multiple disorders for full-and reduced time periods*** (n=123)**

Personal risk factors		Spinal disorders Full period	Spinal disorders Reduced period***	Upper limb disorders Full period	Upper limb disorders Reduced period***	Lower limb disorders Full period	Lower limb disorders Reduced period***	Multiple disorders** Full period	Multiple disorders** Reduced period***
Age (years)									
36 to 50	IRR			0.37				0.36	0.44
	95% CI			(0.14; 1.01)				(0.18 ; 0.7)	(0.2 ; 0.96)
	P value			0.05				0.003*	0.04*
Older than 50	IRR			0.52				0.4	0.53
	95% CI			(0.16; 1.68)				(0.18 ; 0.9)	(0.21 ; 1.35)
	P value			0.28				0.03*	0.18
Musculoskeletal history									
Yes	IRR	1.4	1.49						
	95% CI	(0.86; 2.3)	(0.87; 2.55)						
	P value	0.18	0.144						
BMI									
Overweight	IRR			1.52	2.05	2.58	2.82	1.48	1.59
	95% CI			(0.54: 4.30)	(0.64; 6.51)	(0.9; 7.43)	(0.81 ; 9.79)	(0.75 ; 2.91)	(0.76 ; 3.31)
	P value			0.43	0.23	0.08	0.1	0.26	0.22
Obese	IRR			0.89	0.88	2.45	2.02	1.03	0.78
	95% CI			(0.28; 2.82)	(0.25; 3.08)	(0.86 ; 6.99)	(0.57 ; 7.20)	(0.5 ; 2.11)	(0.35 ; 1.74)
	P value			0.85	0.84	0.09	0.28	0.94	0.54
Morbidly obese	IRR			3.35	3.91	6.24	4.87	2.43	2.21
	95% CI			(1.06; 10.64)	(1.08; 14.13)	(2.2 ; 17.72)	(1.32 ; 17.89)	(1.12 ; 5.28)	(0.94 ; 5.16)
	P value			0.04*	0.04*	0.001*	0.02*	0.03*	0.07

* Significant at *P*<0.05
** 'Multiple' denotes that more than one of the disorders were present in the same month
*** Reduced time period excluded the first three months of the study for all the sewing-machine operators and the month that each sewing-machine operator changed his/her work posture, as well as the consecutive month

TABLE 4 Incidence rate ratio (IRR) from multivariable random effects Poisson regressions, with 95% CI and *P* values* of ergonomic risk factors for spinal, upper limb, lower limb and multiple disorders for full-and reduced time periods*** (n=123)**

Ergonomic risk factors		Spinal disorders Full period	Spinal disorders Reduced period***	Upper limb disorders Full period	Upper limb disorders Reduced period***	Lower limb disorders Full period	Lower limb disorders Reduced period***	Multiple disorders** Full period	Multiple disorders** Reduced period***
Work posture									
Stand	IRR	0.29	0.4	0.78	1.21	1.49	1.42	0.68	0.81
	95% CI	(0.17; 0.48)	(0.23; 0.68)	(0.44; 1.39)	(0.63; 2.34)	(0.8 ; 2.8)	(0.68 ; 2.96)	(0.48 ; 0.95)	(0.55 ; 1.2)
	P value	<0.001*	0.001*	0.4	0.57	0.21	0.34	0.03*	0.29
Forceful precision stitching									
Forceful precision stitching	IRR			0.42					
	95% CI			(0.15; 1.20)					
	P value			0.11					
Overtime									
More than 10 000 units per month	IRR					0.67			
	95% CI					(0.28 ; 1.6)			
	P value					0.37			

* Significant at *P*<0.05
** 'Multiple' denotes that more than one of the disorders were present in the same month
*** Reduced time period excluded the first three months of the study for all the sewing-machine operators and the month that each sewing-machine operator changed his/her work posture, as well as the consecutive month

4. DISCUSSION

In this study the impact of a change from sitting to stand-up work posture on operator-WRMSDs was investigated, and the stand-up work posture was found to be significantly protective towards spinal disorders.(12,21,29) The increased risk of lower limb disorders due to standing, did not reach statistical significance in this small sample. Unfortunately, the high BMI was simultaneously significantly associated with lower limb disorders (15) in the stand-up work posture, requesting an effort from the PEIP role players to manage the negative impact of WRMSDs on productivity.

The over-representation of females in this study, was matched in international sewing industry studies.(13,14,16,18,25) The mean age in this study was higher than the average age of most studies conducted(13-15,18), possibly due to the low participant turn-over during the production years of the company. In addition, the current study was longitudinal, with participants aging over the study period, compared to cross-sectional design of similar studies. This relative older age could explain the finding that participants older than 36 years experienced temporary difficulty adapting to the stand-up work posture; performing forceful precision stitching; and had more upper limb and lower limb disorders than younger participants.(15,16) In terms of medical conditions, that is, hypertension, arthritis and DM, this was a relatively healthy population,(7,36) and these conditions did not contribute towards WRMSD-incidence during the postural transition.

The significantly decreased incidence in spinal disorders after the work posture change may be attributed to the protective effect of the stand-up work posture per sè (12,21,29); along with implementation of the self-use height-adjustability feature of sewing tables in standing workstations and health education within the PEIP.(2,22-25,32) Within the PEIP, spinal musculoskeletal discomfort was managed by the physiotherapist with manual therapy (9), while exercises (18,23,25,29-32) addressed stiffness and muscular atrophy. The positive results may be explained by spinal biomechanics (10); and vertebral disc nutrition.(11)

The relationship between musculoskeletal history and spinal disorders is mentioned in literature.(10,14,17) During the study period, musculoskeletal history was defined as a specific disorder 'being treated by the physiotherapist since June 2004'. Therefore increased incidence of spinal disorders during the first 3 months of the study period can be explained as unrehabilitated spinal disorders sustained before June 2004. Musculoskeletal rehabilitation of these historical disorders might have been neglected prior to the study period due to personal financial constraints and work-related time pressure of participants in the absence of an on-site physiotherapist. Another possible contributor to the increase in the incidence of spinal disorders may have been an increase in awareness of symptoms and the positive environment to report disorders. Similar results on increased incidence of disorders shortly after the implementation of a workplace health program were found.(21)

International studies among operators showed that 'being an operator' does not imply a higher BMI (15,37); but a high BMI might be associated with WRMSDs.(14,15) The participants in the current study matched a similar local population of sewing-machine operators,(31) and both studies equalled the elevated average BMI of the African urban women category in South Africa.(36) The authors speculate about possible contributing factors towards the obesity level of these participants, that is, ergonomic factors (posture and force) (26,37); psychosocial factors (38,39), and food environment at work.(39)

Sedentary behaviour is most commonly defined as “seated or reclining postures that require low levels of energy expenditure, typically 1–1.5 METs.”(40) Furthermore, sewing “classed as ‘light work’ requires an enormous amount of exertion in a constrained position”.(37) Although sewing in the current study was initially performed in the seated posture, the authors agree that sewing cannot be categorised as part of a sedentary life style, nor was it performed in a static posture (sitting or standing).(26)

Although psychosocial risk factors *per se* were not measured in the current study, some of the ‘obesogenic’ psychosocial risk factors mentioned in literature were recognized amongst participants, that is, high demands, low control (decision latitude), time pressure, psychological job demands, and injuries at work.(38,39)

As far as the food environment at work was concerned, the participants in this study had predictable meal times. The adequate canteen facility was equipped with refrigerators and microwaves for participants to store and reheat food brought from home, and prepared meals were sold. No information on the caloric value of the meals was available.(39)

Sibella, Galli *et al.*(41) observed that obese individuals have significantly less trunk flexion during the sit-to-stand action; and Godde and Taylor (8) concluded that larger individuals rely more on their upper limbs during this action than non-obese individuals. This could explain why obesity was causative to upper limb disorders, regardless of work posture.

As far as the association between obesity and lower limb disorders are concerned, the authors speculate that development of muscular atrophy during the years of sewing in the seated posture; and increase in interstitial and vascular volume, and biomechanical heel impact in the stand-up work posture might have been causative to lower limb disorders.(9)

The incidence of lower limb disorders spiked for a period of 2 months during the first 2 months of 2007, and may be due to participants being older (15) and physically unprepared for musculoskeletal challenges associated with prolonged standing.(9) Standing in this study was prolonged, but not static(26). The fact that the spike did not recur as expected during 2008, may be explained by the protective effect of the physiotherapist giving advice on acquisition of supportive footwear,(9) silicone innersoles,(33) compression stockings,(34) and regular exercises.(30,31) Ergonomic changes were made to the seated workstations of all participants within the programme adaptation period. This data were excluded from the analysis of the reduced period and therefore did not influence the findings. As expected, working overtime had a temporary negative effect on the monthly count of lower limb disorders, and should not be done during the implementation phase of a change in work posture.

The change in work posture, did not influence the incidence of upper limb disorders; but as mentioned in other studies (7,15) the participants' high mean BMI was significantly associated with an increase in upper limb disorders. Similar to the spinal disorders, the incidence of upper limb disorders was high during the first 3 months of the study period - specifically due to carpal tunnel syndrome.(25) Upper limb disorders did not change much over time and may be attributed to the relatively older population (15) performing regular life-time sit-to-stand transitions.(8) The relationship between obesity and upper limb disorders can be explained by a study done to compare musculoskeletal markers of "arm muscles during the sit-to-stand transition of normal, obese and active cadavers."(8) Contrary to expectations in the company, no association was found between sewing different types of materials; in hindsight, stitching with vinyl and leather both posed similar musculoskeletal demands. Although not statistically significant, a trend was observed of a possible 'work hardening' effect of conducting forceful precision stitching, compared to easier straight stitching, that is, protective against upper limb disorders.

4.1 Evaluation of the research

The longitudinal nature of the study made observation of 'actual place, actual thing' ('Genchi Genbutsu' in Japanese), managed within a participatory ergonomics model possible; and is a strength of this study.(42) This study also describes the comprehensive postural exposure of participants during workings hours - putting the impact of the postural change of work posture from sitting to stand-up on musculoskeletal disorders in perspective.(26) The sample size of the current study was large enough for statistical comparison of sub-groups. Other comparative studies had similar sample sizes.(8,13,14,16,25)

However, the sample size was not large enough to observe some small associations (e.g., IRR=1.3) as being statistically significant. Another study limitation was the absence of a control group and investigation of other possible risk factors (i.e. pregnancy in a predominantly female population). Although findings might be a slight under estimate of the true number of disorders, as they were self-reported, the effect might be negligent due to the reasons provided.

More information on psychosocial risk factors, caloric consumption, factors such as compliance to performing home-based exercise programmes and after-hours activities were not gathered and the authors cannot account for effects this could have had on the results.

As the researchers did not have control over the intervention timing, results must be interpreted with caution; as all participants were not exposed to similar circumstances before and after the intervention. For example, the participants who stood up in January 2007, were not prepared for the change in work posture, as the groups who stood up later.

4.2 Recommendations for further research

Monitoring of medical conditions, including a strategy of alternation between sitting and standing (43-44) and inclusion of psychosocial risk factors may identify additional risk factors that may guide the implementation of postural change interventions. For future studies, we suggest that caloric consumption logs are kept, along with objective activity level measurements over a 24 hour day.(26,40)

5. CONCLUSION

The change in work posture led to a temporary increased incidence of WRMSDs. The situation was aggravated by the fact that this population of sewing-machine operators was older, and had a higher mean BMI than operators in other international studies. The benefit of the stand-up work posture was statistically significant only for the incidence of spinal disorders. The increase in risk of lower limb disorders due to the intervention was temporary (especially for the morbidly obese operators); and obesity was a risk factor for upper limb disorders, regardless of the change in work posture.

The responsibilities of the employer as well as the employee for optimised musculoskeletal health in the workplace, can be described as two sides of the same coin. For the employer, the responsibility is to create and maintain a safe work environment, including sound ergonomic workplace design; as well as a workplace health program to prevent and manage work-related musculoskeletal disorders. For the employee, the responsibility to perform the work safely, as well as to identify and address potential risk factors to their health and safety.

Postural implementation guidelines for South African employers of sewing operators in the holistic management of work-related musculoskeletal disorders should not combine a change in work posture with working overtime; include management of lower leg disorders with the combination of supportive footwear, silicone innersoles, compression stockings, and exercise; and promote the reduction of high BMIs.

Acknowledgements: We thank the company, the participants, and Elsje Rudman, who acted as a critical reader.

Funding: The authors report that there was no funding source for the work that resulted in the article or the preparation of the article.

REFERENCES

(1) Sanders MJ. Management of cumulative trauma disorders. Boston, United States of America: Butterworth-Heinemann Medical; 1997.

(2) Chu C, Dwyer S. Employer role in integrative workplace health management. Dis Manag Health Outcomes. 2002;10(3):175-186.

(3) Patel AV, Bernstein L, Deka A, et al. Leisure time spent sitting in relation to total mortality in a prospective cohort of US adults. Am J Epidemiol. 2010;172(4):419-429.

(4) Van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. Arch Intern Med. 2012;172(6):494-500.

(5) Pulsford RM, Stamatakis E, Britton AR, Brunner EJ, Hillsdon M. Associations of sitting behaviours with all-cause mortality over a 16-year follow-up: the Whitehall II study. Int J Epidemiol. 2015;44(6):1909-1916.

(6) Chau JY, Van der Ploeg HP, Van Uffelen JGZ, Wong J, Riphagen I, Healy GN, Gilson ND, et al. Are workplace interventions to reduce sitting effective? A systematic review. Preventive medicine 2010;51(5):352-356

(7) Brisson C, Vinet A, Vézina M. Disability among female garment workers: a comparison with a national sample. Scand J Work Environ Health. 1989; 323-328.

(8) Godde K, Taylor RW. Musculoskeletal stress marker (MSM) differences in the modern American upper limb and pectoral girdle in relation to activity level and body mass index (BMI). Forensic Sci Int. 2011;210(1):237-242.

(9) Lin Y, Chen C, Cho M. Influence of shoe/floor conditions on lower leg circumference and subjective discomfort during prolonged standing. Appl Ergon. 2012;43(5):965-970.

(10) Wilson A. Effective management of musculoskeletal injury: a clinical ergonomics approach to prevention, treatment, and rehabilitation. Edinburg: Hartcourt; 2002.

(11) Nordin M, Pope MH, Andersson G. Musculoskeletal disorders in the workplace: principles and practice. New York, NY: Mosby; 2007.

(12) Blåder S, Barck-Holst U, Danielsson S, et al. Neck and shoulder complaints among sewing-machine operators: a study concerning frequency, symptomatology and dysfunction. Appl Ergon. 1991;22(4):251-257.

(13) Kaergaard A, Andersen JH. Musculoskeletal disorders of the neck and shoulders in female sewing machine operators: prevalence, incidence, and prognosis. Occup Environ Med. 2000;57(8):528-534.

(14) Rempel DM, Wang PC, Janowitz I, Harrison RJ, Yu F, Ritz BR. A randomized controlled trial evaluating the effects of new task chairs on shoulder and neck pain among sewing machine operators: the Los Angeles garment study. Spine. 2007;32(9):931-938.

(15) Dianat I, Kord M, Yahyazade P, Karimi MA, Stedmon AW. Association of individual and work-related risk factors with musculoskeletal symptoms among Iranian sewing machine operators. Appl Ergon. 2015;51:180-188.

(16) Andersen JH, Gaardboe O. Musculoskeletal disorders of the neck and upper limb among sewing machine operators: a clinical investigation. Am J Ind Med. 1993;24(6):689-700.

(17) Westgaard RH, Jansen T. Individual and work related factors associated with symptoms of musculoskeletal complaints. II. Different risk factors among sewing machine operators. Br J Ind Med 1992;49(3):154-162.

(18) Sealetsa O, Thatcher A. Ergonomics issues among sewing machine operators in the textile manufacturing industry in Botswana. Work. 2011;38(3):279-289.

(19) Zhang FR, He LH, Wu SS, Li JY, Ye KP, Wang S. Quantify work load and muscle functional activation patterns in neck-shoulder muscles of female sewing machine operators using surface electromyogram. Chin Med J (Engl). 2011;124(22):3731-3737.

(20) Wang P, Harrison RJ, Yu F, Rempel DM, Ritz BR. Follow- up of neck and shoulder pain among sewing machine operators: The Los Angeles garment study. Am J Ind Med. 2010;53(4):352-360.

(21) Halpern CA, Dawson KD. Design and implementation of a participatory ergonomics program for machine sewing tasks. Int J Ind Ergonomics. 1997;20(6):429-440.

(22) Loisel P, Abenhaim L, Durand P, et al. A population- based, randomized clinical trial on back pain management. Spine. 1997;22(24):2911-2918.

(23) Olson DL. An on-site ergonomic program: A model for industry. Work. 1999;13(3):229-238.

(24) Williams R, Westmorland M, Lin C, Schmuck G, Creen M. Effectiveness of workplace rehabilitation interventions in the treatment of work-related low back pain: a systematic review. Disabil Rehabil. 2007;29(8):607-624.

(25) Mostert-Wentzel K, Grobler SH, Moore R, Ferreira N, Lumley M, Burelli K. Effect of a work-based physiotherapy and ergonomics programme on work-related upper-extremity musculoskeletal disorders in car-seat seamstresses. Occup Health Southern Africa. 2010;(May/June):6-18.

(26) Messing K, Stock S, Côtè J, Tissot F. Is sitting worse than static standing? How a gender analysis can move us toward understanding determinants and effects of occupational standing and walking. J Occup Environ Hyg. 2015;12:D11-D17.

(27) Piligian G, Herbert R, Hearns M, Dropkin J, Landsbergis P, Cherniack M. Evaluation and management of chronic work-related musculoskeletal disorders of the distal upper extremity. Am J of Industrial Medicine. 2000;37(1):75-93.

(28) Wang PC, Ritz BR, Janowitz I, et al. A randomized controlled trial of chair interventions on back and hip pain among sewing machine operators: the Los Angeles garment study. J Occup Environ Med. 2008;50(3):255-262.

(29) Schierhout GH, Meyers JE, Bridger RS. Work related musculoskeletal disorders and ergonomic stressors in the South African workforce. Occup Environ Med. 1995;52(1):46-50.

(30) Maher CG. A systematic review of workplace interventions to prevent low back pain. Aust J Physiother. 2000;46(4):259-269.

(31) Edries N, Jelsma J, Maart S. The impact of an employee wellness programme in clothing/textile manufacturing companies: a randomised controlled trial. BMC Public Health. 2013;13(1):1. doi:10.1186/1471-2458-13-25

(32) Maduagwu S, Sokunbi G, Bwala M, et al. Work-Related musculoskeletal disorders among self employed sewing machine operators in Maiduguri, Nigeria. Occup Med Health Aff. 2015;2015:216. doi:10.4172/2329-6879.1000219

(33) Hansen L, Winkel J, Jørgensen K. Significance of mat and shoe softness during prolonged work in upright position: based on measurements of low back muscle EMG, foot volume changes, discomfort and ground force reactions. Appl Ergon. 1998;29(3):217-224.

(34) Kraemer WJ, Volek JS, Bush JA, et al. Influence of compression hosiery on physiological responses to standing fatigue in women. Med Sci Sports Exerc. 2000;32(11):1849-1858.

(35) Hosmer DW, Hosmer T, Le Cessie S, Lemeshow. S. A comparison of goodness-of-fit tests for the logistic regression model. Stat Med. 1997;16(9):965-980.

(36) Puoane T, Steyn K, Bradshaw D, et al. Obesity in South Africa: the South African demographic and health survey. Obes Res. 2002;10(10):1038-1048.

(37) Vèzina N, Tierney D, Messing K. When is light work heavy? Components of the physical workload of sewing machine operators at piecework rates. Applied Ergonomics. 1992;23(4):268-276.

(38) Solovieva S, Lallukka T, Virtanen M, Viikari-Juntura E. Psychosocial factors at work, long work hours, and obesity: a systematic review. Scand J Work Environ Health. 2013;39(3):241-258.

(39) Nobrega S, Champagne N, Abreu M, et al. Obesity/Overweight and the role of working conditions: A qualitative, participatory investigation. Soc Pub Health Edu. 2016;17(1):127-136

(40) Marhall SJ, Merchant G. Advancing the science of sedentary behaviour measurement. Am J Prev Med. 2013;44(2):190-191

(41) Sibella F, Galli M, Romei M, Montesano A, Crivellini M. Biomechanical analysis of sit-to-stand movement in normal and obese subjects. Clin Biomech. 2003;18(8):745-750.

(42) Marksberry P. The Toyota Way-a quantitative approach. International J Lean Six Sigma. 2011;2(2):132-150.

(43) Callaghan JP, McGill SM. Low back joint loading and kinematics during standing and unsupported sitting. Ergon. 2001;44(3):280-294.

(44) Thorp AA, Kingwell BA, Owen N, Dunstan DW. Breaking up workplace sitting time with intermittent standing bouts improves fatigue and musculoskeletal discomfort in overweight/obese office workers. Occup Environ Med. 2014;71(11):765-771.