4. Results

4.1 Introduction

After the data were collected at the company, medical clinic and physiotherapy practice, it was analysed according to the conceptual framework (Figure 1.1). The first objective was to describe the population of sewing-machine operators in terms of personal and ergonomic risk factors. The second objective was to describe the incidence of WRMSDs for the period of the study. The third objective was to determine the association between individual risk factors (personal and ergonomic) and WRMSDs longitudinal, and the last objective was to determine the association between work posture and WRMSDs, adjusted for influential risk factors. The results for the four objectives will be discussed descriptively and thereafter analytically.

4.2 Description of the population (objective 1)

Objective 1 was to describe the population of sewing-machine operators in terms of personal and ergonomic risk factors

4.2.1 Description of the population in terms of personal risk factors

Data on personal risk factors were collected at the company and the medical clinic at baseline.

Table 4.1 Personal risk factors of the sewing-machine operators at baseline (n=123)

Personal risk factors		Frequency (%)
Gender (=123)		
Male		3 (2.4%)
Female		120 (97.6%)
Age in years (n=123)*		
≤35 years		25 (20.3%)
35<age≤50		78 (63.4%)
>50 years		20 (16.3%)
Medical history (n=114)		
Hypertension	No	92 (74.8%)
	Yes	22 (17.9%)
	Missing	9 (7.3%)
Arthritis:	No	110 (89.4%)
	Yes	4 (3.3%)
	Missing	9 (7.3%)
Diabetes	No	106 (86.2%)
	Yes	8 (6.5%)
	Missing	9 (3.3%)
Musculoskeletal history		
Yes/No		No data available at baseline
BMI in kg/m² (n=113)**		
Normal		27 (22.0%)
Overweight		34 (27.6%)
Obese		36 (29.3%)
Morbidly obese		16 (13.0%)
Missing		10 (8.1%)

* Mean age was 42.3 years; Standard deviation (SD)=8.0 years; 95% Confidence Interval (CI) (40.8 ; 43.7) years.

** Mean BMI was 29.7 ±6.1 kg/m², and 95% CI (28.6; 30.8 kg/m²)

The population of sewing-machine operators comprised 97.6% females, of which the largest proportion was between 36 and 50 years of age (63.4%); 16.3% were older than 50 years; and the rest 35 years and younger (20.3%). Mean age was 42.3 years at baseline. As for medical history, 17.9% had hypertension, 3.3% reported as having arthritis and 6.5% had diabetes at baseline. For only 22% of the sewing-machine operators, BMI was normal at baseline. Of the remaining 69.9%, 13% were morbidly obese, and the mean BMI was 29.7 km/m^2 at baseline.

4.2.2 Description of the population in terms of ergonomic risk factors

Of the three ergonomic risk factors, only the change in work posture was part of the intervention. Force and duration were part of the programme as background to the intervention. Data on ergonomic risk factors were collected at baseline.

Table 4.2 (a) summarises the profile of all three risk factors at baseline and Table 4.2 (b) gives the dates at which the change in work posture was implemented as part of the intervention during the period of the study.

Table 4.2 (a) Ergonomic risk factors of the sewing-machine operators at baseline (n=123)

Ergonomic risk factors		**Frequency (%)**
Work posture		
Sit		123 (100%)
Stand		0 (0 %)
Force		
Material	Cloth & vinyl	13 (10.6%)
	Cloth and leather	110 (89.4%)
Stitching	Straight stitching	98 (79.7%)
	Forceful precision stitching	25 (20.3%)
Duration		
No job rotation		78 (63.4%)
Job rotation		45 (36.6%)

The data shows that the largest proportion of sewing-machine operators were sewing cloth and leather (79.7%). Only a small proportion performed forceful precision stitching (20.3%), including the sewing of headrests and airbags, and performing top stitching. Job rotation between forceful precision stitching and straight stitching, was applied for 36.6% of the sewing-machine operators.

Table 4.2 (b) A summary of the distribution of sewing-machine operators between different production lines at baseline and the dates that each production line adjusted the seated work posture to the stand-up work posture during the period of the study (n=123)

Production line category	n (%)	Date of change of work posture from seated to stand-up
C 307	22 (17.9%)	2005 January
FORD J97	14 (11.4%)	2007 January
J97 FORD	23 (18.7%)	2007 January
Nissan X11C	18 (14.6%)	2008 January
Nissan QW	25 (20.3%)	2008 January
P 301	8 (6.5%)	2008 March
Nissan D22	13 (10.6%)	2008 July

Only 17.9% of the sewing-machine operators changed their work posture early in the study. Just over 30% (30.1%) of the sewing-machine operators stood up in January 2007, and 34.9% a year later in January 2008. Just over 17% (17.1%) of the sewing-machine operators remained seated till the last year of the study. From July 2008 onwards, 100% of the sewing-machine operators performed sewing in the stand-up work posture.

4.2.3 Incidence of WRMSDs (Objective 2)

Objective 2 was to describe the incidence of WRMSDs for the period of the study (Figures 4.1 and 4.2 and Table 4.3).

In Figure 4.1 local polynomial smoothing was used to display the trend of monthly incidence of WRMSDs, by disorder group and for the multiple disorders group, over the 'full period'; i.e. all 56 months. In Figure 4.2, the initial three months of the study were removed (hereafter referred to as 'programme adaptation period'), and also the month when each sewing-machine operator adjusted his/her work posture along with the consecutive month (hereafter referred to as 'postural adaptation period'). The remaining months now constitutes the 'reduced period'.

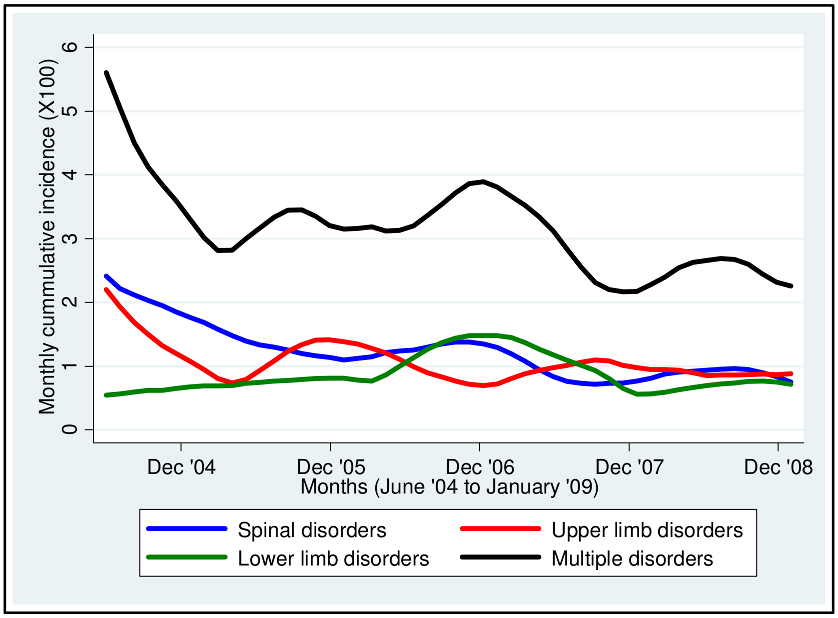

Figure 4.1 Monthly cumulative incidence (x100) for spinal, upper limb, lower limb and also multiple disorders for the full period of the study (n=123)

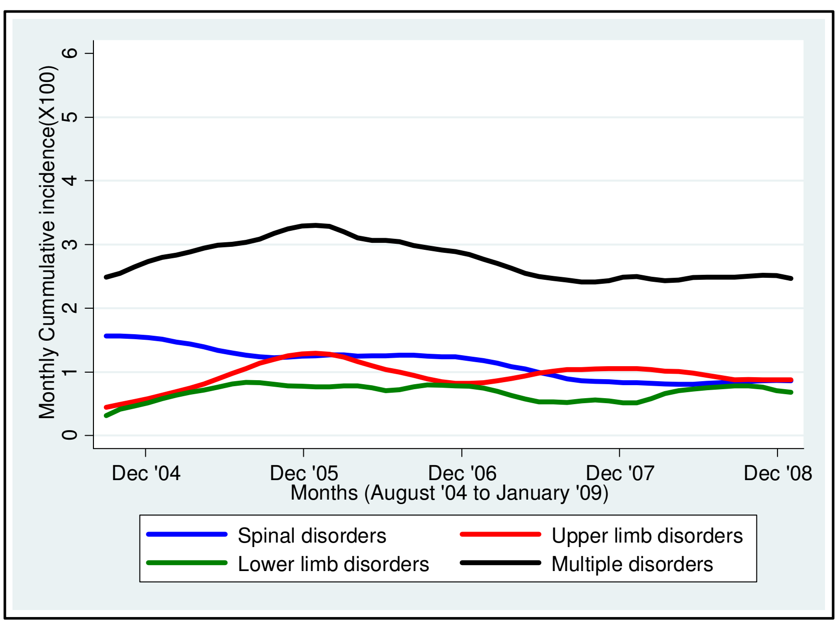

Figure 4.2 Monthly cumulative incidence (x100) for spinal, upper limb, lower limb and also multiple disorders for the reduced period of the study (n=123)

The effect of the removal of the data of the programme adaptation period and the postural adaptation period demonstrates the impact of the implementation of the programme and the change in work posture on the disorder groups in Figures 4.1 and 4.2. Figure 4.1 demonstrates a high incidence of WRMSDs at the beginning of the programme, especially for the spinal and upper limb disorders. Thereafter, spinal disorders gradually levelled off over time, with noticeable peaks during the postural-adaptation periods. Figure 4.2 displays the situation after removing the programme- and postural-adaptation periods – June to August 2004 (for the programme) and the individual 'stand-up months' and the consecutive month (for postural adaptation). Here the initial high incidences are absent and, furthermore, the former peaks are now less marked. (For most sewing-machine operators, their postural adaptation period was either early in 2007 or early in 2008.) Subsequently, the incidence in upper limb disorders did not change much over time.

The incidence of lower limb disorders spiked during the first two months of 2007 when 30.1% of the sewing-machine operators changed their work posture (as demonstrated in Figure 4.1). This did not recur to the same extent in 2008 when the last 52% of the sewing-machine operators changed their work posture (Figure 4.2). Figure 4.2 demonstrates that the increase of lower limb disorders during the change of work posture was temporary. The multiple disorder ("multiple" denotes that more than one of the disorders was present in the same month) sequence reflected that of the three groups of disorders.

The overall incidence per disorder was also determined and is displayed in Table 4.3.

Table 4.3 The overall incidence per 1 000 person months per disorder (n=123)

Disorders	Spinal disorders		Upper limb disorders		Lower limb disorders		Multiple disorders	
Periods	Full period	Reduced period	Full period	Reduced period	Full period	Reduced period	Full period	Reduced period
Overall incidence rates	12.2	11.5	10.8	9.8	8.8	6.8	31.8	28.1

Table 4.3 indicates the incidence of spinal, upper limb, lower limb and multiple disorders for the full period and the reduced period. The incidence of spinal disorders decreased by 5.7% (from 12.2 to 11.5 disorders per 1 000 person-months) when the programme- and postural-adaptation periods were removed from the incidence of the full period (reflected as the reduced period).

Furthermore, the incidence of upper limb disorders decreased by 9.3% (from 10.8 to 9.8 disorders per 1 000 person-months) and the incidence of lower limb disorders decreased by 22.7% (from 8.8 to 6.8 disorders per 1 000 person-months) when both adaptation periods were removed from the incidence of the full period (reflected as the reduced period).

The incidence of multiple disorders decreased by 11.6% (from 31.8 to 28.1 disorders per 1 000 person-months) after removal of the adaptation periods (reflected as the reduced period).

4.3 Analytical findings (objectives 3 and 4)

Objective 3 was to determine the association between individual risk factors (personal and ergonomic) and WRMSDs longitudinally, and objective 4 was to determine the association between work posture and WRMSDs – adjusted for influential risk factors. Results of analytical findings related to objectives 3 and 4 were derived from univariable- and multivariable analysis. Tables 4.4 to 4.6 report on the univariable analysis and Tables 4.7 to 4.10 on the multivariable analysis. Note the significant influence of the intervention (changing the work posture) on the incidence of disorders.

4.3.1 Univariable analysis

Tables 4.4 to 4.6 show the univariable analysis for spinal disorders, upper limb disorders, lower limb disorders and multiple disorders.

Table 4.4 Incidence rate ratio (IRR) from univariable random-effects Poisson regressions, 95% confidence intervals (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		Multiple disorders **	
		Full period	Reduced period ***	Full period	Reduced period ***	Full period	Reduced period ***	Full period	Reduced period ***
Age(years)									
36 to 50	IRR	0.51	0.63	0.46	0.62	0.42	0.56	0.32	0.41
	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*
Older than 50	IRR	0.41	0.57	0.54	0.6	0.51	0.71	0.33	0.42
	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									
Yes	IRR	1.16	1.28	1.31	1.53	1.561	1.79	1.35	1.56
	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									
Yes	IRR	0.63	0.72	1.43	1.66	Insufficient data	Insufficient data	0.72	0.87
	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
Diabetic									
Yes	IRR	0.83	1.0	1.0	1.19	1.19	0.84	0.95	1.0
	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**								
Yes	IRR	1.82	1.91	0.85	0.94	0.74	0.64	1.1	1.16
	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									
Overweight	IRR	0.96	0.99	1.88	1.99	2.54	2.8	1.57	1.62
	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
Obese	IRR	0.66	0.5	1.04	0.84	2.4	1.97	1.04	0.81
	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 obese	IRR	0.76	0.73	3.34	3.81	6.26	4.81	2.24	2.09
	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*	.001*	0.02*	0.03*	0.08

* Significant at p<0.05

** Refer to Table 4.1 for reference categories

*** "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 4.5 Incidence rate ratio (IRR) from univariable random-effects Poisson regressions, 95% confidence intervals (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									
	IRR	0.37	0.48	0.72	1.24	1.51	1.32	0.63	0.77
Stand	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	<001*	0.01*	0.26	0.52	0.19	0.45	0.008*	0.17
Force/Material									
Cloth and	IRR	1.36	1.5	1	1.6	1.63	1.1	1.24	1.35
leather	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	IRR	0.71	0.75	0.42	0.51	0.72	0.78	0.59	0.65
precision	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)
stitching	*P value*	0.35	0.44	0.11	0.25	0.43	0.62	0.09	0.2
Overtime									
More than	IRR	0.81	0.9	1.03	1.24	0.58	0.82	0.81	1.0
10 000	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)
units per month	*P value*	0.53	0.82	0.93	0.52	0.22	0.66	0.31	0.98
Rotate									
Performing	IRR	1.04	0.93	0.77	0.64	1.12	0.48	0.85	0.66
job	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)
rotation	*P value*	0.88	0.79	0.49	0.28	0.72	0.08	0.46	0.08

* Significant at p<0.05
** Refer to Table 4.1 for reference categories
*** "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 4.6 Risk factors that were associated with WRMSDs at the 0.2-level of significance, to be included in the multivariable analysis

Risk factor	Spinal disorders		Upper limb disorders		Lower limb disorders		Multiple disorders***	
	Full period	Reduced period****	Full period	Reduced period****	Full period	Reduced period****	Full period	Reduced period****
Age	√		√				√	√
Hypertension								√
Musculoskeletal history	√	√						
BMI			√	√	√	√	√	√
Work posture	√	√	√	√	√	√	√	√
Forceful precision stitching			√				√	
Overtime					√			

*** “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

4.3.2 Multivariable analysis

Objective 3 was to determine the association between work posture and WRMSDs adjusted for influential risk factors. Tables 4.7, 4.8, 4.9, and 4.10 show the multivariable analysis for spinal, upper limb, lower limb and multiple disorders.

Table 4.7 Incidence rate ratio (IRR) from multivariable random effects Poisson regressions, 95% CI and *P* values * of risk factors for spinal disorders for full - and reduced time periods** (n=123)**

Risk factors		**Spinal disorders**	
		Full period	**Reduced period******
Musculoskeletal history			
Yes	IRR	1.4	1.49
	95% CI	(0.86; 2.3)	(0.87; 2.55)
	P value	0.18	0.144
Work posture			
Stand	IRR	0.29	0.4
	95% CI	(0.17; 0.48)	(0.23; 0.68)
	P value	<0.001*	0.001*

* Significant at p<0.05

**** 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

Spinal disorders (full period included)

Age category did not contribute in any way while "musculoskeletal history" was a confounder for work posture and the stand-up work posture reduced the incidence for spinal disorders to 0.29 fold the incidence for the seated work posture ($p < 0.001$).

Spinal disorders (reduced period)

Similar to the above, the incidence for spinal disorders in the stand-up work posture was reduced to 0.4 times the incidence for the seated work posture ($p=0.001$).

Table 4.8 Incidence rate ratio (IRR) from multivariable random effects Poisson regressions, 95% CI and *P* values * of risk factors for upper limb disorders for full - and reduced time periods** (n=123)**

Risk factors		**Upper limb disorders**	
		Full period	**Reduced period******
Stand			
	IRR	0.78	1.21
	95% CI	(0.44; 1.39)	(0.63; 2.34)
	P value	0.4	0.57
Age (years)			
36 to 50	IRR	0.37	
	95% CI	(0.14; 1.01)	
	P value	0.05	
Older than 50	IRR	0.52	
	95% CI	(0.16; 1.68)	
	P value	0.28	
BMI			
Overweight	IRR	1.52	2.05
	95% CI	(0.54: 4.30)	(0.64; 6.51)
	P value	0.43	0.23
Obese	IRR	0.89	0.88
	95% CI	(0.28; 2.82)	(0.25; 3.08)
	P value	0.85	0.84
Morbidly obese	IRR	3.35	3.91
	95% CI	(1.06; 10.64)	(1.08; 14.13)
	P value	0.04*	0.04*
Forceful precision stitching			
Forceful precision stitching	IRR	0.42	
	95% CI	(0.15; 1.20)	
	P value	0.011	

* Significant at p<0.05

**** 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

Upper limb (full period included)

Age was a confounder for forceful precision stitching and, although not statistically significant (p=0.11), the incidence for forceful precision stitching was reduced to 0.42 times of that for straight stitching. Morbid obesity had significantly increased (p=0.04) incidence of upper limb disorders, 3.35 times that of normal BMI.

Upper limb (reduced period)

Morbid obesity was the only risk factor for upper limb disorders with an increased (p=0.04) incidence of 3.91 times that of normal BMI.

Table 4.9 Incidence rate ratio (IRR)) from multivariable random effects Poisson regressions, 95% CI and *P* values * of risk factors for lower limb disorders for full - and reduced time periods** (n=123)**

Risk factors		**Lower limb disorders** Full period	Reduced period****
BMI			
Overweight	IRR	2.58	2.82
	95% CI	(0.9; 7.43)	(0.81 ; 9.79)
	P value	0.08	0.1
Obese	IRR	2.45	2.02
	95% CI	(0.86 ; 6.99)	(0.57 ; 7.20)
	P value	0.09	0.28
Morbidly obese	IRR	6.24	4.87
	95% CI	(2.2 ; 17.72)	(1.32 ; 17.89)
	P value	0.001*	0.02*
Work posture			
Stand	IRR	1.49	1.42
	95% CI	(0.8 ; 2.8)	(0.68 ; 2.96)
	P value	0.21	0.34
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

**** 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

Lower limb (full period included)

Overtime (more than 10 000 units per month) was a confounder for work posture and the incidence for stand-up work posture increased to 1.49 times of the incidence for the seated work posture (p=0.21). Although not statistically significant (p=0.21), standing was associated with an increase IRR (1.49) for lower limb disorders. For BMI, overweight (IRR 2.58; p=0.08) and obese (IRR=2.45; p=0.09) categories were associated with an increased IRR in lower limb disorders, though only marginally significant. However, the morbidly obese group had a significantly increased association with lower limb disorders (IRR=6.24; p=0.001).

Lower limb (reduced period)

Although not statistically significant, overweight (IRR=2.82; p=0.1) and obese (IRR=2.02; p=0.28) categories were associated with an elevated IRR for lower limb disorders. However, the morbidly obese group had a significantly increased association with lower limb disorders (IRR=4.87; p=0.02). Therefore, on removing the adaptation time periods, the IRR was also significantly increased for the morbidly obese sewing-machine operators.

Table 4.10 Incidence rate ratio (IRR) from multivariable random effects Poisson regressions, 95% CI and *P* values * of risk factors for multiple disorders for full - and reduced time periods** (n=123)**

Risk factors		**Multiple disorders*** Full period**	**Reduced period********
Age (years)			
36 to 50	IRR	0.36	0.44
	95% CI	(0.18 ; 0.7)	(0.2 ; 0.96)
	P value	0.003*	0.04*
Older than 50	IRR	0.4	0.53
	95% CI	(0.18 ; 0.9)	(0.21 ; 1.35)
	P value	0.03*	0.18
BMI			
Overweight	IRR	1.48	1.59
	95% CI	(0.75 ; 2.91)	(0.76 ; 3.31)
	P value	0.26	0.22
Obese	IRR	1.03	0.78
	95% CI	(0.5 ; 2.11)	(0.35 ; 1.74)
	P value	0.94	0.54
Morbidly obese	IRR	2.43	2.21
	95% CI	(1.12 ; 5.28)	(0.94 ; 5.16)
	P value	0.03*	0.07
Work posture			
Stand	IRR	0.68	0.81
	995% CI	(0.48 ; 0.95)	(0.55 ; 1.2)
	P value	0.03*	0.29

* 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

Multiple disorders (full period)

Age was a confounder for work posture and in work posture the incidence of multiple disorders for standing was reduced (p=0.03) to 0.68 times that for sitting down. Morbid obesity had a significantly increased (p=0.03) incidence of multiple disorders, 2.43 times that of normal BMI.

Multiple disorders (reduced period)

Age was a confounder for work posture and incidence for standing was now no longer significantly reduced (p=0.29); i.e. incidence was 0.81 times that for sitting down. Morbid obesity had a marginally significantly increased (p=0.07) incidence of multiple disorders, 2.21 times that of normal BMI.

4.4 Concise overview of the data analysis

This chapter reported on the results of the study – the incidence of disorders to the spinal area, upper and lower limbs. The disorders were analysed both individually as well as collectively (multiple disorders). The primary exposure variable of interest was work posture, i.e. sitting and standing.

For the duration of the period of programme implementation, the incidence of disorders by month was displayed graphically and described in reference to the change in work posture.

5. Discussion and recommendations

In order to address the first objective of the study, the population of sewing-machine operators was described in terms of personal- and ergonomic risk factors. The second objective was to describe incidence of WRMSDs for the period of the study. The third objective was to determine the association between individual risk factors (personal and ergonomic) and WRMSDs longitudinally, and fourthly, to determine the association between work posture and WRMSDs adjusted for influential risk factors. The correspondence between personal and ergonomic risk factors of the population of sewing-machine operators in the current study will be compared with the populations in the mentioned studies.

5.1 Personal risk factors (objective 1)

Descriptive data regarding sample size, gender, age, medical history, musculoskeletal history and BMI of sewing-machine operators and the association of personal risk factors and WRMSDs in the current study (objective 3), are discussed in relation to findings in literature.

Sample size

This sample consisted of all 123 sewing-machine operators employed by the company. Although population-based samples are large (2,685 participants in the study of Roquelaure, Ha *et al.* (2006: 765-778), and 34,868 participants in the study of McDonald, DiBonaventura *et al.* (2011: 767-769)), some studies on sewing-machine operators have included smaller cohorts of participants – n=120 (Westgaard, Jansen 1992: 154-162); n=89 (Andersen, Gaardboe 1993: 677-687); n=178 (Kaergaard, Andersen 2000: 528-534); n=253 (Roquelaure, Mariel *et al.* 2002: 452-458); n=520 (Wang, Rempel *et al.* 2007: 806-813); n=157 (Sealetsa, Thatcher 2011: 279-289), and n=38 (Mostert-Wentzel, Grobler *et al.* 2010: 6-18). The sample size of the current study was large enough for statistical comparison of sub-groups.

Gender

Of the 123 sewing-machine operators in the current study, only three were male. This over-representation of females among sewing-machine operators is also found in the literature. While some studies have been female-only studies (Westgaard, Jansen 1992: 154-162; Andersen, Gaardboe 1993: 677-687; Kaergaard, Andersen 2000: 528-534; Sealetsa, Thatcher 2011: 279-289), in other studies females represented the majority of the study population (62% (Roquelaure, Mariel *et al.* 2002: 452-458), 62.4% (Wang, Rempel *et al.* 2007: 806-813) or only one male in a cohort of 38 sewing-machine operators (Mostert-Wentzel, Grobler *et al.* 2010: 12)). Only one study of sewing-machine operators was a male-only study (Serratos-Perez, Mendiola-Anda 1993: 793-800). As the current study sample consisted of females mainly, it correlated with the mentioned studies on gender representation, but no associations between gender as a personal risk factor and WRMSDs could be determined.

Age

The mean age of the sewing-machine operators in the current study at baseline was 42.3 ±8, with a 95% CI of 40.5 to 43.7 years. The age group '36 to 50 years' represented 63.4% of this cohort of sewing-machine operators at baseline. These sewing-machine operators were older than sewing-machine operators in four other studies, and slightly younger than the population in one study.

In the first study, that of Kaergaard and Andersen (2000: 528-534), the mean age was 5.4 years younger (38.3 ±10.4) than the study population of the current study. In the second study of Roquelaure, Mariel *et al.* (2002: 452-458), the mean age was 40.2 years, two years younger than the study population of the current study. In the third study, the mean age was 4.3 years younger (38 years, ranging from 18 to 65 years) than the study population of the current study (Wang, Rempel *et al.* 2007: 806-813). In the fourth study of Sealetsa and Thatcher (2011: 279-289), the mean age was ten years younger than the population of the current study, i.e. 32.25 ±7.

On the other hand, the mean age of the population in the current study was 2.3 years older (44 ±1) than the population of the study of Mostert-Wentzel, Grobler *et al.* (2010: 12) at baseline (June 2004 in both studies). Both studies were conducted on the same population, with the difference that the study of (Mostert-Wentzel, Grobler *et al.* 2010: 12) was conducted on sewing-machine operators with WRUEMSDs only (n=38), and the current study included spinal, and lower limb disorders (n=123) as well. This corresponded with the results of the current study, with age (being 36 to 50 years) being a confounder for forceful precision stitching (although not statistically significant (p=0.11)) among upper limb disorders. (Refer to Section 4.3.2.)

These differences are important, as age, as well as 'length of employment' (a function of age) is mentioned as a risk factor for WRMSD in the literature.

Age category did not contribute to spinal disorders or lower limb disorders. Being older than 36 years of age was also a confounder for the stand-up work posture among multiple disorders for the full - and reduced periods. (Refer to Section 4.3.2.)

According to the literature, a higher prevalence of upper body pain could be expected among sewing-machine operators younger than 30 years (Wang, Rempel *et al.* 2007: 806-813), and of neck and shoulder pain among sewing-machine operators older than 40 years (Andersen, Gaardboe 1993: 677-678). These findings correspond with the results that age older than 36 was a confounder for upper limb disorders and can be expected.

Medical history

At baseline, 17.9% of sewing-machine operators in the current study were hypertensive. Cardiovascular diseases were mentioned among other diseases as reasons for disability among the study population of sewing-machine operators who had left employment (Brisson, Vinet *et al.* 1989: 323-328). The difference between the current and this study populations, was that blood pressure was measured pre-employed in the population in the current study and in the study described in the literature (Brisson, Vinet *et al.* 1989: 323-328), it was mentioned as a reason for disability. Therefore, a higher incidence of hypertension is not necessarily associated with being a sewing-machine operator. No hypertensive values were mentioned in one of the studies. According to the Demographic and Health Survey of 1998 (performed on 13 802 randomly selected South Africans 15 years and older, who were visited in their homes), using the cut-off point of 160/95 mmHg, the prevalence of hypertension in South Africa was 11% for men and 14% for women (Steyn, Gaziano *et al.* 2001: 1717-1725). Blood pressure of the sewing-machine operators in the current study was measured when they were appointed at the company to screen for hypertension, but the exact values were not captured.

The fact that only 3.3% of sewing-machine operators complained of arthritis at baseline in the current study corresponds well with populations described in the literature. In an epidemiological study conducted among healthy French workers representing all sectors of the workforce (Roquelaure, Ha *et al.* 2006: 770), only 2% of workers reported having inflammatory rheumatism or arthritis of the upper limbs or back. Although arthritis was not associated with WRMSDs in this population of sewing-machine operators, one should bear in mind that the healthy-worker effect might have played a role here, as this occupation required forceful actions with the upper limbs. (The healthy-worker effect can be described as sewing-machine operators with arthritis leaving employment because of pain. Therefore, only sewing-machine operators without pain stayed employed as sewing-machine operators).

For the third condition, the incidence of diabetic mellitus among the study population of sewing-machine operators was three times higher (6.5%) at baseline than the incidence of diabetic mellitus of 2% in the French study (Roquelaure, Ha *et al.* 2006: 770). Although the World Health Organization (WHO), reported that the prevalence of diabetes in France compared to the prevalence in South Africa in 2000 was 1:2, these two populations cannot be compared meaningfully. Levitt, Steyn *et al.* (2001: 946) investigated the prevalence of type-2 diabetes in a similar community (a working class peri-urban community, 55 km from the centre of Cape Town) as the sewing-machine operators in the current study. The crude prevalence of diabetes mellitus type-2 was 7.1% in the Cape Town study. The prevalence of diabetic mellitus in these two South-African populations was in agreement, and diabetes mellitus did not influence the incidence of WRMSDs in the current study.

Although the prevalence of hypertension and diabetes of this study group of sedentary sewing-machine operators was in agreement with the prevalence in the general local population, it contradicted the findings of Wilmot, Edwardson *et al.* (2012: 2989) They concluded that higher levels of sedentary behavior are associated with a 112% increase in the effect estimate of diabetes, 147% increase in the risk of cardiovascular disease, 90% increase in the risk of cardiovascular mortality and 49% increase in the risk of all-cause mortality in a systematic review and meta-analysis conducted on eighteen studies including 794,577 participants in the United Kingdom.

Musculoskeletal history

No data on pre-employment musculoskeletal history were available in the current study at baseline - data were collected during the period of the study. Musculoskeletal history was a confounder for work posture; the stand-up work posture reduced the incidence for spinal disorders to 0.29 times the incidence for the seated work posture (P<0.001) during the full period, and 0.4 times (P=0.001) during the reduced period. Having had a 'pre-employment musculoskeletal disorder' is a known risk factor for the development of WRMSDs during employment (Westgaard, Jansen 1992: 158; Wilson 2002: 39-63; Kaergaard, Andersen 2000: 528-534; Wang, Rempel *et al.* 2007: 806-813). The conclusion is that a sewing-machine operator who had previously contracted a spinal disorder might experience future incidents, regardless of work posture in sewing.

Body mass index

The mean BMI of this population of sewing-machine operators (29.7 kg/m², ±6.1, 95% CI 28.6; 30.8 kg/m²) was higher than the mean BMI for woman the general population in South Africa (27.3 kg/m²) in 2003.

Of the 69% with a BMI higher than 25 kg/m², 27.6% were overweight, 29.3% obese and 13.0% morbidly obese (BMI ≥ 35 kg/m²). Missing data accounted for 8.1% and only 22% of the sewing-machine-operator population's BMI was normal at baseline. This is similar to the BMI of a group of 80 (mostly female) clothing and textile manufacturing employees in Cape Town, South Africa, that participated in the study of Edries, Jelsma *et al*. (2013: 7). The mean BMI of the experimental group of 39 participants was 28.9 kg/m², and for the control group of 41 participants, the mean BMI was 29.80 kg/m².

According to the South African Department of Health, African urban women had the highest mean BMI (27.6 kg/m²) in 2003. Therefore, both local populations of sewing-machine operators had a higher BMI than the rest of the population in South Africa.

Being a sewing-machine operator does not necessarily imply a high BMI. The BMIs of sewing-machine operators in three international studies were compared to the BMIs of the general population in the specific countries where the studies were carried out. For the studies carried out in Denmark, and Botswana, the sewing-machine-operator BMI correlated well with the BMI of the general population in those countries. No correlation could be drawn for the study in the USA.

In the study conducted on sewing-machine operators in Denmark, the mean BMI of a group of 96 females was 24.7 km/m², ranging from 18.4 to 39.9 (Hansen, Kaergaard *et al.* 2003: 268). This prevalence was the same as the mean BMI (24.7 kg/m², 95%CI 24.6; 24.9) of 3 352 Danish woman in the general population (Bendixen, Holst *et al.* 2012: 1465).

Sealetsa and Thatcher reported on the situation among sewing-machine operators in Botswana (2011: 282). Their BMI averaged 24.2 kg/m². This corresponded well to the mean BMI of 24.4 kg/m² for the rest of the Botswana population (Letamo 2011: 75-84).

In the study conducted on sewing-machine operators in Los Angeles (USA), it was concluded that more than half (54%) of the study population of sewing-machine operators were overweight or obese, with a BMI of more than 24.9 kg/m² (39% were overweight and 16% obese) (Wang, Rempel *et al.* 2007: 808). This population cannot be compared to the general population in the USA, because probably all of these sewing-machine operators were immigrant workers (Hispanic or Asian).

In the current study, an increased BMI had no association with spinal disorders, only with upper limb, lower limb and multiple disorders. Although not statistically significant, overweight and obese categories were associated with an increased IRR for lower limb disorders. However, morbid obesity had significantly increased the IRR of upper limb, lower limb and multiple disorders among this South African population of sewing-machine operators. Only one study investigated the association of BMI with WRMSDs, and no association was found between a high BMI and upper body musculoskeletal disorders among sewing-machine operators in Los Angeles, USA (Wang, Rempel *et al.* 2007: 806-813). This finding can be explained on the basis that only 54% of the sewing-machine operators in their study population were overweight and obese, and none were morbidly obese as was the case in the South African study.

When the results from the literature are compared to the baseline results in this South African study, the local challenge is clear: The South African sewing-machine operators were much heavier than their peers in other studies.

In conclusion, the population of sewing-machine operators in the current study had a slightly increased prevalence of hypertension and arthritis, and a decreased prevalence of diabetes compared to the general population of South-Africa. In spite of the fact that and this population of sewing-machine operators had a high mean BMI and that sedentary time is associated with an increased risk of diabetes, cardiovascular disease and all-cause mortality (the strength of the association is most consistent for diabetes), the conclusion can be made that this was a relatively healthy working population (Wilmot, Edwardson *et al.* 2012: 2898). Neither hypertension, nor arthritis, nor diabetic mellitus influenced the incidence of WRMSDs, which lead to the conclusion that among personal risk factors, age, BMI, and musculoskeletal history had a stronger association with WRMSDs than medical history did.

5.2 Ergonomic risk factors (objective 1)

Descriptive data regarding force (including material used and method of stitching) and duration (working overtime and performing job rotation), and the association of ergonomic risk factors with WRMSDs in the current study (objective 3) are discussed in relation to findings in the literature. The association between work posture (objective 4) and WRMSDs, adjusted for influential factors, will be discussed as well.

5.2.1 Work posture

At baseline, all the sewing-machine operators in the current study worked in the seated work posture. Only 17.9% of the sewing-machine operators changed their work posture early in the study. Of the remaining group of sewing-machine operators, 30.1% changed their work posture in January 2007, and 34.9% a year later in January 2008. Seventeen per cent of the sewing-machine operators remained seated till the last year of the study (20.3% changed in January 2008, 6.5% changed in March 2008 and 10.6%

changed in July 2008). From July 2008 onwards, 100% of the sewing-machine operators performed sewing in the stand-up work posture.

The result was that the stand-up work posture reduced the incidence for spinal disorders to 0.29 times the incidence for the seated work posture (P<0.001) for the full period, and 0.4 times for the reduced period (P=0.001). The incidence of multiple disorders for the stand-up work posture was also reduced 0.68 times that of the seated work posture for the full period. Although the incidence of multiple disorders was not reduced significantly for the reduced period, it was still reduced 0.81 times that of the seated work posture.

With the exception of the studies of Halpern and Dawson (1997: 429-440) and Mostert-Wentzel, Grobler *et al.* (2010: 6-18), the current study is the only one that refers to the change work posture among sewing-machine operators. The study of Mostert-Wentzel, Grobler *et al.* (2010: 6-18) only mentioned postural change and did not investigate the influence of postural change on the incidence of WRMSDs. Furthermore, Halpern and Dawson (1997: 429-440) reported on the design, implementation and ultimately performance of a participatory programme in an automobile-accessories manufacturing plant. As part of the implementation of the participatory programme, the sewing operations were converted from seated to primarily stand-up operations, leading to an improved posture of the torso and back. The results of the programme were reflected in the 85% decrease in the number of musculoskeletal disorders. The results of this South African study confirmed the positive results of Halpern and Dawson (1997: 429-440) in the USA as far as the incidence of WRMSDs in sewing-machine operators – and specifically spinal disorders – is concerned.

Furthermore, the protective effect of the stand-up work posture on spinal disorders, is confirmed by Schierhout, Meyers *et al.*, who reported that “seated, rather than standing work was significantly associated with pain of the neck and shoulders” among 401 employees from seven different manufacturing industries in South Africa (1995: 49).

> Standing appears to be a good rest from sitting, given the change in lumbar spine posture and shift in loading of the posture dependant passive tissues.

> Therefore, standing, used alternatively as a rest from sitting, could form a basis for injury prevention when designing work. However, the constant loading with little dynamic movement present in both standing and sitting would provide little rest or change for muscular activation levels and the resultant low back loads. (Callaghan, McGill 2001: 292)

From the current study, it is clear than the stand-up work posture was protective towards WRMSDs in this population of sewing-machine operators, specifically for spinal disorders. The results confirm the outcomes of other authors internationally and locally.

5.2.2 Force

Material

These sewing-machine operators sewed car-seat covers for the automotive industry. The majority of sewing-machine operators (89.4%) sewed with cloth and leather, compared to a smaller group that sewed with cloth and vinyl (10.6%). Although both groups sewed the same product – a car-seat cover – the logical assumption was that sewing with cloth and vinyl was relatively 'easier' material to sew compared to the cloth and leather combination, as cloth and vinyl required less force from the upper limb.

The background to this assumption was searched for in the literature, as sewing can be done on many different types of materials, ranging from lightweight material used for making children's clothes, to canvas and leather as required by the automotive industry. The material sewed in the study conducted by Westgaard and Jansen (1992: 154-162) for making thermal clothing was similar to the light material sewn by sewing-machine operators in other studies (Andersen, Gaardboe 1993: 677-687; Sealetsa, Thatcher 2011: 279-289; Wang, Rempel *et al.* 2007: 806-813; Kaergaard, Andersen 2000: 528-534). Unlike these, other studies reported on sewing-machine operators working with canvas automobile products (Halpern, Dawson 1997: 429-440), car seat material (Mostert-Wentzel, Grobler *et al.* 2010: 6-18) and leather in a shoe factory (Roquelaure, Mariel *et al.* 2002: 452-458).

Although these differences were taken into account in the current study, no association was determined between this ergonomic risk factor and WRMSDs. The sewing-machine operators did not rotate between the two categories of material investigated in the current study. Therefore, the reason that no association was found between the type of material sewn and WRMSDs might be that the healthy-worker effect was present, or that the work-hardening effect was protective regarding WRMSDs.

Forceful precision stitching

A fifth (20.3%) of the population of sewing-machine operators in the current study, performed forceful precision stitching. This kind of stitching included: 1) assembling headrests; 2) airbags, as well as; 3) performing top-stitch operations that required a combination of precision and force along with increased responsibilities regarding quality of work. The rest of the sewing-machine operators sewed bulkier parts together, mainly by straight stitching. Age was a confounder for forceful precision stitching and, although not statistically significant (p=0.11), the incidence for forceful precision stitching was reduced to 0.42 times that for straight stitching in upper limb disorders.

This ergonomic factor was taken into account in the current study, to fill a gap in the literature regarding the influence of method of stitching on the incidence of WRMSDs. Only one study mentioned this ergonomic risk factor among sewing-machine operators, but no association with WRUEMSDs was investigated (Mostert-Wentzel, Grobler *et al.* 2010: 6-18).

The fact that the incidence for forceful precision stitching was reduced 0.42 times than for straight stitching, in upper limb disorders for the full period, indicated that the handling of bulkier parts, compared to forceful precision stitching, influenced the incidence of upper limb disorders negatively.

Forceful precision stitching (method of stitching) was managed in the current study by the application of a job-rotation policy. The results regarding the association of method of stitching and the incidence of upper limb disorders confirmed the importance of the implementation of a job-rotation policy among sewing-machine operators, who were carefully planned to rotate between different types stitching-method.

5.2.3 Duration

Overtime

Overtime was captured according to the number of car-seat units produced by the company per month. No baseline information was available, as the number of units was captured by month. Working overtime was regarded as working longer hours (more than 10 000 units were produced by the company per month). Although working overtime in the current study was found to be a confounder for work posture and the incidence for stand-up work posture increased to 1.49 times of the incidence for the seated work posture (p=0.21) for the full period, this did not apply to the reduced period for lower limb disorders.

Although there is no consensus in the literature regarding the relationship between working overtime and the prevalence of musculoskeletal disorders (Blåder, Barck-Holst *et al.* 1991: 251-257; Wang, Rempel *et al.* 2007: 806-813), a previous conclusion was: "having less overtime should be considered when treating patients or planning workplace interventions for managing work-related disorders." (Wang, Harrison *et al.* 2010: 352-360).

Therefore, when working overtime – especially during the transition in work posture – accommodation for regular breaks (to sit) should be made in order to relieve spinal discomfort.

Job rotation

No association was found between job rotation and the incidence of WRMSDs in the current study. Rotation between forceful precision stitching and straight stitching operations accounted for 36.6% of this population of sewing-machine operators. The implementation of job rotation from the beginning of the study possibly had a positive outcome regarding upper limb disorders among these sewing-machine operators. In spite of the implemented job-rotation policy – aiming to prevent upper limb disorders, morbid obesity was proven to be a significant risk factor to upper limb disorders.

5.3 Incidence of WRMSDs (objective 2)

The incidence of WRMSDs during the study can be described and discussed for the period of the study. There was a high incidence of WRMSDs at the beginning of the programme, especially for the spinal and upper limb disorders. The initial high incidence of spinal disorders could be attributed to musculoskeletal history as a confounding factor for spinal disorders, as well as the fact that there was no programme implemented to facilitate physiotherapy treatment before June 2004 (as demonstrated by the removal of the programme adaptation period). Thereafter, spinal disorders gradually levelled off over time, with noticeable peaks during the postural adaptation periods when large percentages of the population changed their work posture. This decrease in incidence of spinal disorders during the study period could be attributed to the fact that poorly rehabilitated spinal disorders were addressed by the physiotherapist with manual therapy, education and exercises during the period, as well as the protective effect of the change in work posture.

Likewise, the high incidence of upper limb disorders at the beginning of the study period could be attributed to unattended upper limb WRMSDs, specifically carpal tunnel syndrome (Mostert-Wentzel, Grobler *et al.* 2010: 16). Although these disorders were also influenced by the physiotherapy treatment and the adjusted work posture, the incidence in upper limb disorders did not change much over time. This fact can be attributed to the negative influence of the high mean BMI of this population and the reasoning that the change in work posture does not influence the biomechanics of the upper limb as much as it does for the spinal and lower limb areas.

In contrast with the spinal and upper limb disorders, the incidence of lower limb disorders was low while the majority of the population worked in a seated work posture. As expected, the incidence of lower limb disorders spiked during the first two months of 2007 when 30.1% of the sewing-machine operators changed their work posture (Lin, Chen et al. 2012: 965-970). This increase resulted from the fact that the involved group was not physically prepared for the adaptation to the stand-up work posture. The increase in incidence of lower limb disorders did not recur to the same extent during 2008 when the last 52% of the sewing-machine operators stood up to work. When the postural adaptation period was removed from the statistical analysis, the increase of lower limb disorders during the change of work posture was shown to be temporary. This adaptation to the stand-up work posture can be attributed to the management of these disorders with advice on acquisition of proper footwear, silicon innersoles, and supportive stockings, and regular exercises from the physiotherapist.

The multiple- disorder ("multiple" denotes that more than one of the disorders was present in the same month) sequence reflected the incidence of injuries in a similar way to the three groups of disorders.

In summary, the incidence of spinal disorders decreased by 5.7% disorders per 1 000 person-months when the programme and postural adaptation periods were statistically removed, compared to the 9.3% disorders per 1 000 person-months decrease in incidence of upper limb disorders and the 22.7% disorders per 1 000 person-months decrease in incidence of lower limb disorders. Likewise, the incidence of multiple disorders decreased by 11.6% disorders per 1 000 person-months after removal of the adaptation periods. The largest contributor to these trends was the influence of the removal of the 'programme adaptation period' on the upper limb and spinal disorders and the removal of the 'postural adaptation period' on the lower limb disorders. It is clear that the stand-up work posture had a temporary negative impact in the incidence of lower limb disorders, and this can be attributed to the influence of the high mean BMI as an influential risk factor.

Similar results on an increase of disorders during adaptations periods had been documented. An initial increase in the incidence of WRMSDs following the implementation of a participatory ergonomics programme was reported by Halpern and Dawson (1997: 429-440), and the German study (Appendix 1) reported on a similar postural adaptation period following a change in work posture. Both studies reported that the increase in incidence was temporary, as was reflected by the current study.

Although these results can be summarised by the saying: "Sometimes one has to be cruel to be kind", it is important that lessons learnt during the implementation of a programme, as well as a change in work posture, be documented as part of a continuous process of improvement in order to prevent and manage WRMSDs.

5.4 Disorders (objectives 3 and 4)

The association between personal and ergonomic risk factors, work posture and WRMSDs, are discussed. These results cannot be compared to similar studies, as most of the studies determined the prevalence of disorders among sewing-machine operators. Some studies reported on the prevalence of WRMSDs applicable to the whole body, and others only to a specific body region.

Spinal disorders

The association of risk factors with spinal disorders during the period of implementing the change of work posture is concluded as such: For the full period, when considering spinal disorders, musculoskeletal history was a confounder for work posture and the incidence for stand-up work posture reduced to 0.29 times the incidence for the seated work posture ($P<0.001$). After period adaptations for the programme and postural change, musculoskeletal history was again a confounder and the incidence for spinal disorders in the stand-up work posture was reduced to 0.4 times the incidence of the seated work posture. Some of the pre-existing spinal disorders were treated after adjusting for programme and postural change; however, musculoskeletal history remained a confounder for spinal disorders throughout the study period. Note that the high BMI had no association with spinal disorders - only with disorders of the upper limbs and lower limbs.

Two possible explanations for the association of a decreased incidence of spinal disorders with working in the stand-up work posture lies with biomechanics and nutrition of vertebral discs. In the first place, figure 5.1 explains why most people find it difficult to maintain a 90^0 angle at the hip, and still maintain a reasonable lumbar lordosis. In most people, the pelvis starts to rotate posteriorly and the lumbar curve reverses when hip flexion reaches 60^0. In order to maintain a 90° angle between the trunk and thighs, there is 0° to 20°'s of lumbar flexion (Bendix, Bloch 1986: 127-135; Wilson 2002: 156).

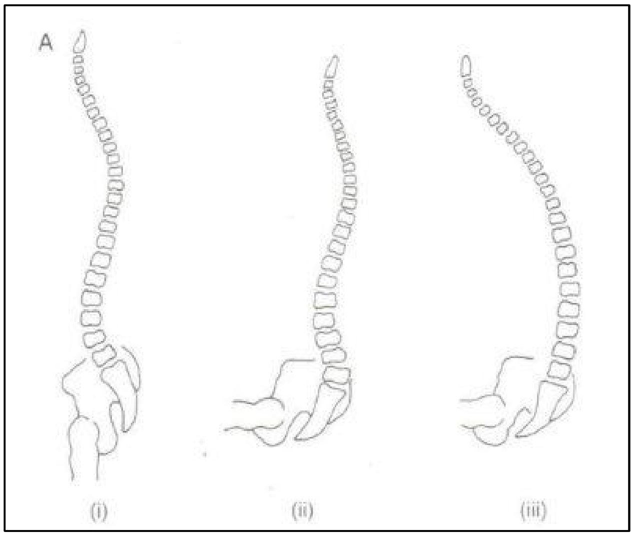

Figure 5.1 A (i) The normal standing posture, (ii) the idealised sitting posture, (iii) the actual sitting posture usually adopted with a reverse lumbar curve. Source: Wilson (2002: 157)

Secondly, intervertebral discs are avascular and viscoelastic, in that their nutrition depends entirely on diffusion. While an individual is sitting, the load on the intervertebral disc is 140% more than that imposed by standing. The static load of a seated posture progressively decreases the water content of a disc; and increased load accelerates this process. Loss of water from a disc makes the diffusion process more difficult and results in reduced oxygen tension and lack of nourishment, leading to disc degeneration. According to Kumar and Konz (in Nordin, Pope *et al)*, sedentary occupations involve prolonged exposure to static loads, hastening this process and making the disc more vulnerable to injuries. A constant static load also deforms the viscoelastic disc and causes compression creep. Because creep is time dependent, elimination of a load (by standing up) does not immediately restore either the pre-load disc configuration or the water content. The reduction in water and oxygen is therefore prolonged, interfering with disc metabolism by decreasing the amount of glycosaminoglycans (which have a strong affinity for water) and increasing the content of keratin sulphate (which is amorphous with far less capacity to imbibe water). In the short term, the viscoelastic deformation may lead also to laxity of the ligament and lack of coordination, potentiating injury through biomechanical perturbations. Over the long term, it leads to degenerative and permanent changes that are a hazard to the back (2007: 137). This susceptibility to injury might explain why musculoskeletal history was a confounder for work posture.

Recommendation: Russel (2012: 15) agrees with the view expressed by Callaghan, and McGill (2001: 292):

> The best way to reduce pressure in the back is to be in a standing position. However, there are times when you need to sit. (2012: 15)

Upper limb disorders

The association of risk factors and upper limb disorders during the period of implementing the change of work posture is concluded as such: For the full period, when considering upper limb disorders, age (36 to 50 years) was a confounder for forceful precision stitching and the incidence for forceful precision stitching. Although not statistically significant (P=0.11), adjusted for age, the incidence of upper limb disorders for forceful precision stitching was 0.42 times that for straight stitching. Furthermore, the incidence for morbid obesity was increased 3.35 times (P=0.04) relative to normal BMI. For the reduced period, the incidence for morbid obesity was only increased 3.91 times (P=0.04) relative to normal BMI. After the periods of adaptation for the programme and postural change were removed (reduced period), age (36 to 50 years) was no longer a confounder. With reference to figures 4.1 and 4.2, the reason for this result may be that the majority of upper limb disorders that were self-reported at the onset of the programme, were reported by sewing-machine operators in the age group 36 to 50 (44 ±10 years) (Mostert-Wentzel, Grobler *et al.* 2010: 12), who complained of carpal tunnel syndrome (2010: 8).

The high incidence of upper limb disorders among obese subjects (performing a sedentary job) can be explained on the basis of biomechanics. Roberts and McCollum (1996: 147-157) described the sit-to-stand change as involving two phases: before lift-off and after lift-off. In the before lift-off phase, propulsion is generated by trunk flexion and arm flexion. The after-lift-off phase is characterised by knee extension. An emphasis on arm use for propulsion during sit-to-stand change has been noted by Carr and Gentile (1994: 175-193). When examining these basic movements during sit-to-stand, differences have been detected between obese patients, and patients with a normal BMI. Sibella, Galli *et al.* (2003:1488-192) observed that obese individuals have significantly less trunk flexion in the first few position changes from sitting to standing.

> Average, obese, and athletic individuals all use their upper limb to help pull themselves from a sitting to upright position and to assist in lowering the body back to a sitting position. Larger individuals rely on the upper arm more in this action because it performs as a leverage system to pull weight and assist other muscles in transitioning to an upright position. (Godde, Taylor 2011: 238)

Therefore, for this overweight population of sewing-machine operators (working in a sedentary work posture for many years) the combination of frequent change between standing and sitting combined with sewing, probably contributed towards a high incidence of upper limb disorders. This biomechanical explanation of increased upper limb strain during the postural change between sitting and standing for obese individuals, might explain why the postural change in work posture did not influence the incidence of upper limb disorders during the study period.

Recommendation: Since morbid obesity is strongly associated with an elevated risk of upper limb disorders, reduction in BMI should be promoted as there was no association between the change in work posture and upper limb disorders.

Lower limb disorders

The association of risk factors with lower limb disorders during the period of implementing the change of work posture is concluded as such: For the full period, when considering lower limb disorders, overtime (more than 10 000 units per month) was a confounder for work posture and the incidence for stand-up work posture increased to 1.49 times the incidence for the seated work posture (P=0.21). BMI was an independent risk factor and for morbidly obese sewing-machine operators the incidence increased 6.24 times compared to normal (P < 0.001). After the periods of adaptation for the programme and postural change were removed *reduced period), lower limb disorders were associated with BMI only and for morbidly obese sewing-machine operators the incidence increased 4.87 times compared to normal BMI (P=0.02).

Parameters measuring discomfort in the lower limbs include total foot volume, vascular volume, interstitial volume, biomechanical heel impact and perceived discomfort in the legs and feet. Hansen, Winkel *et al.* (1998: 217-224) conducted a study to investigate the significance of mat and shoe softness during prolonged work in an upright position on these physiological, biomechanical and comfort measurements related to the lower extremities (and the low back) on eight healthy female Danish volunteers with a mean BMI of 21 kg/m², and a mean age of 24 years. The results indicated that for both standing/walking work, the largest oedema-preventing effect occurs with the combination of soft shoes and a hard floor (Hansen, Winkel *et al.* 1998: 223). These facts explain the preventative results of the current study by advising the purchasing of supportive shoes and silicone innersoles.

Furthermore, the implication of a high BMI is that there is more strain on muscles and ligaments in the body – during working - and during domestic hours of the day. This fact was particularly highlighted when the incidence of lower limb disorders increased when work posture for the first group changed during January to March in 2007. Although the incidence of lower limb disorders increased during this period, it was effectively managed by advising sewing-machine operators on purchasing supportive footwear, inserting silicone innersoles in shoes, wearing compressive stockings, and performing regular work-based exercises. Thereafter, the incidence decreased, confirming that this discomfort was only temporary. In fact, a recurrence of an increased incidence of lower limb disorders was possible to prevent, as was indicated by the fact that the incidence in lower limb disorders did not rise to the same extend during January to March 2008 when the second group, who had physically been prepared, changed their work posture.

Recommendation: Since morbid obesity was strongly associated with an elevated risk of lower limb disorders, reduction in BMI should be promoted. Although the combination of supportive footwear, silicone innersoles, compressive stockings, shock-absorbing mats and regular work-based exercises played an important role in the management and prevention of lower limb disorders, these components were not compared with each other to determine to what extent each component contributed.

Multiple disorders

The association of risk factors with multiple disorders during the period of implementing the change of work posture is concluded as such: For the full period, when considering multiple disorders, age (older than 35 years) was a confounder for work posture and the incidence for the stand-up work posture reduced to 0.68 times that of the seated work posture (P=0.03). Furthermore, the incidence for morbid obesity was increased 2.43 times (P=0.03) relative to normal BMI. For the reduced period, age (older than 35 years) was a confounder for work posture and, although not statistically significant (P=0.29), the incidence for the stand-up work posture reduced to 0.81 times that of the seated work posture. Furthermore, the incidence for morbid obesity was increased 2.21 times (P=0.07) relative to normal BMI.

Recommendation: Since morbid obesity was strongly associated with an elevated risk of multiple disorders, a reduction in BMI should be promoted.

5.5 Limitations and strengths of the study

Internal validity is the validity of inferences in scientific studies. External validity is the validity of generalised inferences in scientific studies, usually based on experiments as experimental validity (Internal and External Validity: 2012). Limitations and benefits of the study are discussed on the basis of internal and external validity.

5.5.1 Internal validity

Internal validity refers both to how well a study was run (i.e. research design, operational definitions used, how variables were measured, what was/was not measured) and how confidently one can conclude that the observed effect(s) was (were) produced solely by the independent variable and not extraneous ones.

5.5.1.1 Study design

The benefit of this longitudinal study compared to a randomised controlled study is that 'actual things, happening in actual places, were seen while they happened' ("Genba genbutsu" in Japanese [1]), as this intervention took place among many uncertainties. Complexity theory has been used in the fields of strategic management and organisational studies. Application areas include understanding how organisations or firms adapt to their environments and how they cope with conditions of uncertainty. This contribution to the body of knowledge is important, as no incident happens in isolation (Mitleton-Kelly 2003: 1).

Another benefit to the study was that because of the retrospective longitudinal study design, causal relationships could be determined in the absence of a control group. A strong point was that trends in the incidence of WRMSDs were determined for the period of implementation of the change in work posture and the programme.

A possible threat to internal validity in the current study was maturation. Maturation might have happened during the implementation of the intervention. The sewing-machine operators signed acknowledgement of the expected change of work posture when they were employed (some in 1998). Over the study period of 4.5 years, the sewing-machine operators aged and realised that the stand-up work posture was inevitable and permanent. This might have contributed towards the lower incidence of lower limb disorders during January to March 2008.

History was not a threat to internal validity, as no study had previously been conducted on this population of sewing-machine operators. No programme or change in work posture of this kind has ever been implemented in this area.

Experimental mortality was not a threat to internal validity either. All the employed sewing-machine operators were included in the implementation of the change in work posture, as well as the programme for the full duration of the study. No dropouts occurred. Unfortunately, there was 9% missing data regarding medical history. This fact has been reported and taken into account during the analysis (Internal and External Validity: 2012).

*[1] Quoted by Ken Baine at FORD Motor Company of South Africa.

5.5.1.2 Risk factors

A shortcoming of the study was the fact that no parenting-data or data on 'length of employment' were available. Traditionally in this community females take care of households and children after hours (often being single parents), and there might have been an association between female gender and parenting status. There might also have been an association between age, and 'length of employment' in this group of sewing-machine operators.

5.5.2 External validity

External validity represents the extent to which a study's results can be generalised or applied to other people or settings.

The benefit of this retrospective study is that the sewing-machine operators were not aware of the fact that they were participants in a study. Therefore the response, regarding incidence of WRMSDs, to the implementation of the change in work posture and the programme can be expected among other populations of sewing-machine operators with similar demo - and biographic profiles.

The majority of the study population sewed with leather and cloth, compared to the relatively smaller group that sewed with vinyl and cloth. Therefore, the outcome of the current study, specifically for WRMSDs of the upper limb, might not be applicable to other sewing industries that work with lighter materials.

5.6 Summary

In many ways, the implementation of a European policy regarding work posture among a South African population of sewing-machine operators was characterised by adaptation difficulties. Fortunately, the implementation of changing the work posture was managed within a programme. This service enabled the company to manage developed WRMSDs and prevent recurrence of WRMSDs to a certain extent.

5.7 Recommendations

Recommendations are based on lessons learnt in the current study and are made in relation to managing a change in work posture among the sewing-machine operators, within a programme. Further recommendations are also made for managers (and the union representing the sewing-machine operators), physiotherapists and for research.

5.7.1 Managers and the union (representing the sewing-machine operators)

Change of work posture

- Since sewing in the stand-up work posture was protective compared to sewing in the seated work posture, the change in work posture is recommended to reduce the risk of spinal disorders.
- Other strategies to prevent and manage lower limb disorders in the stand-up work posture could include supportive foot wear, silicone innersoles, compressive stockings and regular work-based exercises before sewing in the stand-up posture is commenced, and thereafter.
- Ergonomic design of stand-up work stations should include: height-adjustable work surfaces to enhance a good work posture; optimised layout and storage heights to prevent excessive reaching; shock absorbing mats, and pedal design to encourage alternative weight bearing.

The programme

- Personal risk factor: Since morbid obesity was a risk factor for upper limb disorders and had a significantly increased association with lower limb disorders, reduction in BMI should be promoted.

- Ergonomic risk factor: As forceful precision stitching was protective compared to straight stitching, job rotation is recommended to reduce the risk of upper limb disorders while carrying out straight stitching.

5.7.2 Physiotherapists

Change of work posture

- When physiotherapists manage WRMSDs in the clinical setting, it is important that advice to patients and their employers of the impact of changing work posture on the musculoskeletal system, is evidence-based.

The programme

- In order to promote similar programmes in industry, physiotherapists should be set on demonstrating the cost benefits of such programmes. Evidence-based healthcare in an occupational setting is needed in order to prove that the benefits obtained outweigh cost of providing occupational physiotherapy, due to decreased medical expenses, and improved productivity of workers.

5.7.3 Research

Areas that arise from the findings of the current study need to be explored further. The first is the characteristics of this population of sewing-machine operators compared to the populations in the literature, including the relatively higher age and the increased BMI of sewing-machine operators in South Africa. The second is the fact that the incidence of WRMSDs demonstrated that the programme succeeded in preventing and managing WRMSDs. The third is the better understanding of the association of the personal and ergonomic risk factors and WRMSDs. Therefore,

- Similar studies could be repeated on other working populations to determine the association between personal and ergonomic risk factors, work posture and WRMSDs, in order to develop strategies to prevent and manage WRMSDs.
- The change of work posture had a positive impact on WRMSDs – specifically spinal disorders – but may also impact other systems. Further recommendations are to investigate the impact of the stand-up work posture

on other systems – i.e. the cardiovascular, respiratory and digestive systems – as well as strategies to manage risk factors within a managed healthcare programme.

- Similar studies could include psychosocial risk factors in the multivariate analysis of the data as psychosocial risk factors might influence the incidence of WRMSDs.
- A retrospective qualitative study on the content and nature of the programme can be done.
- A randomised controlled study can be conducted to compare the value of supportive footwear, silicone innersoles, compressive stockings, shock-absorbing mats and regular work-based exercises with each other in order to decrease the incidence of lower limb disorders in a standing work population.

6. Conclusion

The change in work posture led to a temporarily increased incidence of WRMSDs. The situation was aggravated by the fact that this population of sewing-machine operators was relatively older and had a higher mean BMI than sewing-machine operators in most other studies. The benefit of the stand-up work posture was statistically relevant for the incidence of spinal disorders, and the negative impact on the lower limbs as a result of the change in work posture, was temporarily (especially for the overweight, obese and morbidly obese sewing-machine operators). Furthermore, being obese was a risk factor for upper limb disorders, regardless of the change in work posture.

In the management of WRMDS within a health-promoting workplace programme, a physiotherapy service should be included in the multidisciplinary team in order to deliver a clinical intervention in close association with clinical ergonomics.

The responsibilities, of the employer as well as the employee for optimised health in the work place, can be described as two sides of the same coin. As for the employer, the responsibility is to create and manage a safe work environment, including sound ergonomic workplace design and a stand-up work posture, as well as a programme to prevent and manage work-related musculoskeletal disorders. As for the employee, the responsibility is to maintain a healthy personal lifestyle, including regular exercise and a balanced diet.