A Randomized Controlled Trial of Chair Interventions on Back and Hip Pain Among Sewing Machine Operators: The Los Angeles Garment Study

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Objective: *Determine whether an adjustable chair with a curved or a flat seat pan improved monthly back and hip pain scores in sewing machine operators.* ***Methods:*** *This 4-month intervention study randomized 293 sewing machine operators with back and hip pain. The participants in the control group received a placebo intervention, and participants in the intervention groups received the placebo intervention and one of the two intervention chairs.* ***Results:*** *Compared with the control group, mean pain improvement for the flat chair intervention was 0.43 points (95% CI = 0.34, 0.51) per month, and mean pain improvement for the curved chair intervention was 0.25 points (95% CI = 0.16, 0.34) per month.* ***Conclusions:*** *A height-adjustable task chair with a swivel function can reduce back and hip pain in sewing machine operators. The findings may be relevant to workers who perform visual- and hand-intensive manufacturing jobs.* (J Occup Environ Med. *2008;50:255–262*)

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In 2000, the garment industry employed 11 million workers worldwide, with approximately 350,000 workers in the United States.[1] Most of the work is done by minimum wage, nonunion, immigrant women in shops that employ fewer than 20 persons.[2] The epidemiologic data linking garment work to an increased prevalence of neck and shoulder pain is relatively strong[3,4]; while the data linking garment work to back and hip pain is mixed. A study using the data from National Health and Nutrition Examination Survey (NHANES) found that approximately 15% of all sewing machine operators reported lower back pain, but there was no statistically discernable difference when compared with other NHANES respondents.[5] Conversely, a cohort study of Danish workers hospitalized during a 10-year period for prolapsed lumbar intervertebral discs found that sewing machine operators were at elevated risk.[6] A different Danish prospective study of 327 sewing machine operators found that at baseline 38% experienced low back pain for more than 30 days in the past 12 months and 23% reported lower back pain during the past 7 days.[4] Comparable figures after 6 years of follow-up were 47% and 25%, respectively.

Sewing machine operators perform precision tasks while seated at a relatively fast pace with work cycles of 30 to 60 seconds. This repetitive, stereotyped work is typically performed on nonadjustable worksta-

Fig. 1. Typical posture and chair of sewing operator. Note flexed lumbar and thoracic spine and the operator used extra cushion for hip support and to elevate torso height.

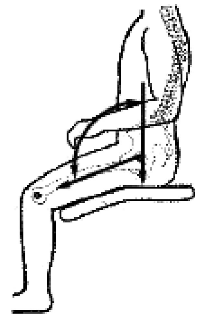

Fig. 2. Design of the curved task chair seat pan allowing for a more open thigh-torso angle and preservation of lumbar lordosis.

tions and chairs (Fig. 1). A typical sewing workstation has a flat work surface (51 × 122 cm) that can be adjusted by a mechanic to heights of 76 to 86 cm; but the height is usually fixed at 76 cm. The chairs are usually of fixed height, and made of metal or wood, with flat, sometimes padded seat pans. The task is visually demanding, and lighting quality varies widely between shops. The task demands and the lack of adjustability of the workstations often lead to sustained awkward postures, such as lumber spine flexion and repetitive torso twisting to move material from the left side to the machine. These motions may contribute to elevated rates of back and hip pain.[2,7–9]

A pilot study by our group carried out in sewing shops in Oakland, California, evaluated a variety of workstation interventions with the goal of reducing lumbar, thoracic, and cervical spine flexion and shoulder abduction during garment work. Ultimately, the intervention that appeared most likely to reduce risk factors for back and shoulder musculoskeletal pain was a new task chair with a curved, two-part seat pan (Fig. 2) based on principles proposed for industrial work.[10,11] Theoretically, the curved seat pan supports the forward leaning posture by allowing a more open thigh-torso angle, thereby preserving the lumbar curvature. The pelvis is supported on the more horizontal rear part of the seat to prevent forward sliding caused by the forward sloping seat pan. The seat was also adjustable in height and slope to accommodate different task demands and employees of different stature.

The objective of this randomized controlled trial was to evaluate the effects of height-adjustable, curved- and flat-seat-pan chairs on change in back and hip pain among sewing machine operators. In a prior publication of the subset of garment workers in this study with neck and shoulder pain, we reported that the curved-seat-pan chair reduced the severity of neck and shoulder pain in comparison with the flat-pan chair and the control group.[12] This article presents the findings of the effects of the chairs on change in back and hip pain among the garment workers with back or hip pain. We hypothesized that during a 4-month period, the reduction in back and hip pain among workers who used the curved-seat-pan chair would be greater than the pain change in those who received either the conventional chair or the control group using their regular work chair.

Materials and Methods

Subjects and Shops

This is a randomized controlled trial with two treatment arms and one control arm with repeated outcome assessments during a 4-month follow-up period. Details of the work tasks, shops, subject characteristics, subject selection, and randomization were previously presented.[12,13] Between October 2003 and March 2005, 13 of 29 garment shops contacted in Los Angeles, CA, agreed to participate. Employees were eligible to participate if they performed sewing machine work for more than 20 hours per week, were not in a probationary period, had worked for at least 3 months, and did not have an active workers' compensation claim. A total of 560 garment workers provided informed consent and entered the screening process, of which 520 met all inclusion criteria and completed the baseline questionnaire.[13] Before randomization, 40 dropped out, leaving 480 subjects for participation and randomization. This article reports findings on the subset of randomized subjects who reported back and hip pain during the month before completing the baseline questionnaire ($N = 293$). The Office for the Protection of Research Subjects at the University of California, Los Angeles, and the University of California, San Francisco approved the study, and all participants provided written informed consent.

Interventions

Subjects were randomized (simple) to three groups: 1) a control group that only received miscellaneous items, 2) an intervention group that received a curved-seat-pan (curved) chair and the miscellaneous items, and 3) an intervention group that received a flat-seat-pan (flat) chair and the miscellaneous items. Both chairs were adjustable in height and swiveled (Fig. 3). The leading edge of the curved chair sloped down approximately 15 degrees. The miscellaneous items provided to all subjects were a footrest, a small table-top storage box for items such as scissors, a side table, a task lamp, and reading glasses. Other details of the chairs and miscellaneous items were described previously.[12]

Participants received instructions on how to adjust the chairs and how to use the miscellaneous items. Those receiving an intervention chair were instructed to adjust the height and slope so that the feet were com-

Fig. 3. The two intervention chairs. The left chair has a flat seat pan and the right chair has the curved seat pan. The front half of the curved pan slopes forward at approximately 15 degrees. Both task chairs are adjustable in height and swivel. The chairs have no castors so that they do not move during sewing.

fortably supported on the footrest and machine pedal; the table was slightly below elbow height, and the pressure was evenly distributed under the thighs. The sewing machine operators were instructed to adjust the backrest until there was good support in their low back. The use of the interventions was confirmed at a visit to the worksite 1 month after the intervention.

Data Collection

Participants completed a baseline questionnaire 1 to 2 months before the interventions were installed, which elicited information on 1) symptoms, 2) demographic factors, 3) work-organizational factors, and 4) work-related psychosocial factors using the Job Content Questionnaire. They also completed four follow-up questionnaires at 1-month intervals after the intervention took place to assess musculoskeletal symptom intensity and frequency in six body regions, including the “back and hip” area. For each body region, they were asked whether they had experienced any pain that bothered them for one or more days in the past month. If yes, they rated the frequency of the pain as 1 or 2 days in the last month, 1 day per week, several days per week, and everyday. They also rated the intensity of the pain on a 5-point numerical scale with 1 being “a little painful” to 5 being “very painful.” All information was collected in face-to-face interviews at the workplace conducted in the language of the participant (Spanish, Cantonese, Mandarin Chinese, or English). Other details on the baseline questionnaire and the monthly questionnaire were described previously.[12,13]

Data Analysis

Data analysis followed an intention-to-treat approach and included only the subset of participants who reported back and hip pain in the past month at baseline. The primary outcome of the data analysis was the change in pain intensity score over follow-up from month 1 to month 4 after baseline. The difference in pain score change over time between the two treatment arms and the control arm was also analyzed using a repeat-measure linear regression model with a first-order autoregressive covariance structure. Specifically, the slope of pain score change in the control group was set to zero, and the estimates for two intervention groups are presented as the difference in the slope of pain score change between the two intervention groups and the control group. Missing data for the monthly symptom questionnaire was imputed by replacement with the mean pain value in the same treatment group at the corresponding point in time. Potential effect modification by baseline pain, age, gender, days worked per week was assessed in post hoc stratified analyses to assess the uniformity or nonuniformity of the estimated intervention effects over categories of other factors. A cross-sectional analysis guided our choice of these predictors and their particular cutoff values.[13] All statistical analyses were performed using statistical software SAS version 9.1 (SAS, Inc, Cary, NC).[14]

Results

Baseline Demographic Characteristics

Of the 480 participants randomized to three intervention arms, 293 (61%) reported back and hip pain during the month before completing the baseline questionnaire. The mean pain score at baseline was 2.58 (±1.1). All participants were immigrant workers, with a mean age of 38 years (range 18 to 68); most were female (61.1%) and Hispanic (77.8%). Other notable characteristics were that 63% of the participants were overweight (BMI >25), only 5% were current smokers, 45% had less than high school education, 86% had no health insurance, 78% had lived in the United States for more than 5 years, but 93% could speak only a few words or less of English. Demographic characteristics of the 293 participants by intervention group were generally similar (Table 1); nevertheless, some factors seemed to be unevenly distributed between groups, such as gender, age, ethnicity, BMI, education level, and years living in United States.

Missing Data

Between the time of randomization and completion of the interventions, 32 (10.9%) of the 293 participants with back and hip pain were lost to follow-up, leaving 261 subjects. The number of participants who withdrew from the study at each of the four monthly follow-up visits were 0 (0%), 9 (3.4%), 6 (2.2%), and 13 (5.0%), resulting in a cumulative loss of 10.7% for the whole follow-up. During the 4-month follow-up, monthly questionnaires were missing 19 times (2.4%). These pain intensity scores were imputed using the mean in the corresponding intervention group at the same point in time. Numbers of withdrawal and missing data during the follow-up period are shown in Fig. 4.

Severity Score Changes for Back and Hip Pain

The unadjusted and adjusted change in back and hip pain severity scores over time and by treatment group are presented in Fig. 5. The raw data indicate that pain scores in the control group worsened during the follow-up period, whereas the pain scores did not change much for the curved chair group. Nevertheless, there was an improvement in pain scores in the flat chair group (Fig. 5A). After adjusting for pain changes in the control group, both intervention groups showed a consistent decrease in pain score over the follow-up period (Fig. 5B).

In the repeat-measures linear regression model, the pain improvement was 0.43 (95% CI = 0.34, 0.51) points (on a 0 to 5 scale) per month in the flat chair group compared with the control group while the pain improvement was 0.25 points (95% CI = 0.16, 0.34) per month in the curved chair group compared with the control group (Table 2). Adjustment for seven possible confounders, either one at a time or all seven factors together, did not alter these estimates.

Stratum-Specific Estimates for Severity Score

The results from the post hoc stratum-specific analyses using the repeat-measures linear regression model are shown in Table 3. Subjects with greater baseline pain (pain score >2) reported more pain improvement with the flat chair compared with the curved chair. Men also reported more pain improvement with the flat chair compared with the curved chair, while women reported more pain improvement with the curved chair. Those with a BMI more than 25 reported a greater reduction in pain with the flat chair, whereas those with a normal BMI reported greater improvement with the curved chair. Subjects with a history of systemic illness had less pain improvement in both intervention groups than those without a history of systemic illness. Subjects who perceived high job strain and low physical isometric load had more pain improvement with the flat chair, and the improvements were greater when compared with curved chair. No differences were observed in the estimates for the intervention effects on pain improvement when stratifying on the following factors: age, medical history of MSD, workdays per week, perceived physical workload, number of rests in a day, pay method, job stress, job dissatisfaction, job security, and perceived physical workload (data not shown).

Discussion

In this randomized controlled trial, participants who reported back and hip pain at baseline and received one of two intervention chairs experienced less back and hip pain during a 4-month period when compared with a control group that did not receive either of the intervention chairs. The control group used their regular work chairs provided by their employers which were typically fixed in height, did not swivel, and had a flat, hard surface seat pan that many workers cushioned with extra pads. It is surprising that the flat chair provided a greater reduction in back and hip pain than the curved chair, a finding that was counter to our hypothesis. This finding, of a greater benefit derived from the use of the flat seat pan, was particularly evident among men and among those with a high BMI, whereas women had a slightly better outcome when using the curved chair. These findings suggest that the curved seat is not as effective in physically larger garment workers. One possible reason for this may be that the size of seat pans differed between the two chairs. The curved seat pan was 43 cm deep and 46 cm wide, and the flat pan was 46 cm deep and 48 cm wide. The curved chair may require further refinements to accommodate the physical needs of larger garment workers or the concept may not be effective for all larger workers. Further studies evaluating the effectiveness of curved chairs with several seat pan and backrest sizes applied to workers of different anthropometric types are warranted.

The benefit of the intervention chairs on back and hip pain may be related to the height adjustability or swivel action of the chair. Sewing work requires feeding cloth located to the left of the employee into the sewing machine directly in front of the employee. The new chairs allow for rotating the seat pan and the whole torso, whereas the old chairs require the motion to be performed by twisting the upper torso, ie, a twisting of the spine which poses a risk for low back pain.[15]

The only other published study reporting on the use of a curved seat pan in manufacturing work was a short-term (4-day) study of 50 gar-

TABLE 1

Demographic Characteristics of Subjects by Intervention Group Reporting Back and Hip Pain at Baseline (N = 293)

Variables	Control (N = 111)		Curved Chair (N = 84)		Flat Chair (N = 98)	
	n	%	*n*	%	*n*	%
Gender						
Female	71	64.0	54	64.3	54	55.1
Male	40	36.0	30	35.7	44	44.9
Age group						
Mean (SD)	36.9 (9.0)		37.5 (10.5)		34.9 (9.5)	
<30	26	23.4	21	25.0	34	34.7
30–39	42	37.8	29	34.5	32	32.7
40–49	34	30.6	21	25.0	24	24.5
≥50	9	8.1	13	15.5	8	8.2
Ethnicity						
Asian/Pacific Islander	0	0.0	30	35.7	28	28.6
Hispanic	109	98.2	51	60.7	68	69.4
White	2	1.8	3	3.6	2	2.0
Marital status						
Live alone	29	26.9	17	23.3	23	31.1
Cohabitating but not married	37	34.3	15	20.5	18	24.3
Married but separated	23	21.3	13	17.8	14	18.9
Married and live with spouse	19	17.6	28	38.4	19	25.7
Children at home						
None	22	19.8	20	23.8	21	21.4
≤5 yr	41	36.9	28	33.3	35	35.7
>5 yr old	48	43.2	36	42.9	42	42.9
Body mass index						
Mean (SD)	27.4 (3.8)		25.1 (3.6)		26.5 (4.1)	
Underweight (<18.5 kg/m^2)	0	0.0	9	10.7	0	0.0
Normal (18.6–24.9 kg/m^2)	28	25.2	39	46.4	32	32.7
Overweight (25–29.9 kg/m^2)	57	51.4	29	34.5	49	50.0
Obese (>29.9 kg/m^2)	26	23.4	7	8.3	17	17.3
Physical activity (not work related)						
None	45	40.5	29	34.5	31	31.6
Less than once per week	5	4.5	7	8.3	8	8.2
Once or twice per week	36	32.4	29	34.5	41	41.8
Three or more times per week	25	22.5	19	22.6	18	18.4
Smoking						
None	92	82.9	75	89.3	75	76.5
Past smoker	13	11.7	6	7.1	18	18.4
Current smoker	6	5.4	3	3.6	5	5.1
Medical history of systemic illness*						
No	91	82.0	66	78.6	85	86.7
Yes	20	18.0	18	21.4	13	13.3
Medical history of musculoskeletal disorders						
No	101	91.0	73	86.9	86	87.8
Yes	10	9.0	11	13.1	12	12.2
Health insurance						
No	97	87.4	72	85.7	83	84.7
Yes	14	12.6	12	14.3	15	15.3
Education						
Primary	58	52.3	33	39.3	40	40.8
High school	49	44.1	46	54.8	52	53.1
University or above	4	3.6	5	6.0	6	6.1
Years in the United States						
Mean (SD)	14.9	(7.4)	11.2	(6.8)	8.7	(5.0)
<5 yr	12	10.8	20	23.8	33	33.7
5–10 yr	16	14.4	13	15.5	25	25.5
10–20 yr	24	21.6	31	36.9	29	29.6
>20 yr	59	53.2	20	23.8	11	11.2
English ability						
None at all	12	10.8	15	17.9	22	22.4
Only a few words	91	82.0	61	72.6	70	71.4
Enough to get by	6	5.4	8	9.5	6	6.1
Very well	2	1.8	0	0.0	0	0.0
Work (hr/wk); mean (SD)	42.2 (5.2)		43.9 (7.3)		44.8 (8.2)	

*The list of systemic illnesses or diseases included medical diabetes (excluding pregnancy-related diabetes), rheumatoid arthritis, lupus erythematodes, degenerative arthritis (osteoarthritis), hyper- or hypothyroidism, chronic renal failure, and gout.

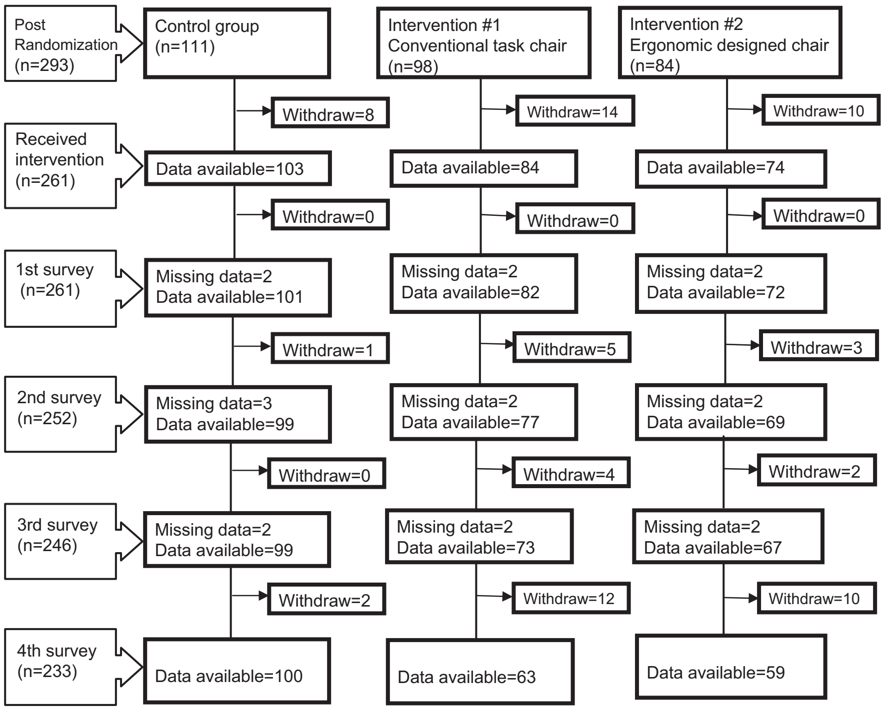

Fig. 4. Flow chart tracking subjects from recruitment to study completion.

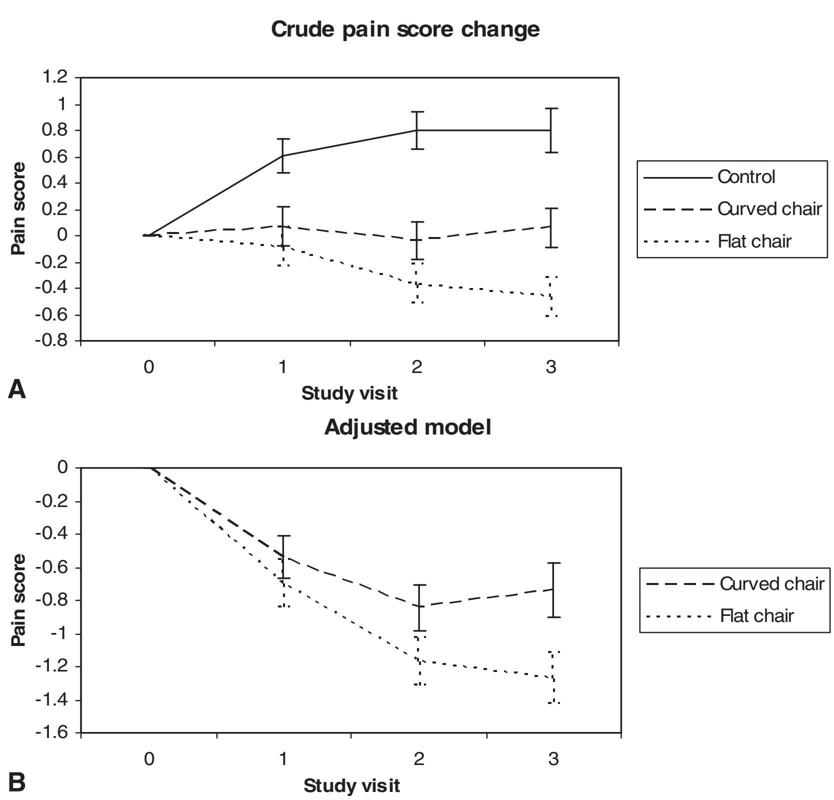

Fig. 5. Pain score changes between month 1 and 4 after randomization. Crude score changes (A) and score changes of two interventions compared with control group (B).

ment workers that compared a task chair with a curved seat pan to a traditional flat-seat-pan chair.[11] These subjects reported less back discomfort when using the curved seat pan chair. Only 23 of the subjects completed the study and only six of the participants had a history of low back disorders, and therefore, the authors were unable to evaluate the influence of BMI or gender.

We found that seven factors, possibly related to back pain, including age, gender, ethnicity, education, years lived in the United States, BMI, and shop size, were not equally distributed between our three treatment groups. Nevertheless, adjusting for these variables in the regression model, either one at a time or all together, did not alter our findings. There was a similar lack of confounding for other demographic and work-related factors. This suggests little or no bias for the intervention effect estimated in our model.

A limitation of our study is that we did not measure seat height changes or the hip and spine postures after the intervention. Other limitations are the small number of shops and the lack of ability to blind subjects during the intervention follow-up. The garment shops included in this study represented a convenient sample, but the size of the shops and the ethnicity of their employees are representative of the garment shops in the Los Angeles area.[13] A strength of the study was the high participation rate of subjects within shops that reduced the possibility of selection bias.

The study demonstrates that garment workers may experience a decline in back and hip pain if they are provided height-adjustable task chairs that can swivel. Overall, there was a greater reduction in back and hip pain with the flat-seat-pan chair compared with the curved seat pan for men and garment workers who are overweight or obese. The findings may be generalizable to other seated jobs that are visually demanding and involve the repetitive manipulation of tools or material. Health

TABLE 2
Unadjusted and Adjusted Estimates (95% CI) of Pain Improvement Over Time Using the Repeat-Measures Linear Regression Models Adjusted for the Changes in Control Groups (ie, Slope of Control Group Was Set to 0)

	Flat Chair*		Curved Chair†	
	Estimate	95% CI	Estimate	95% CI
Unadjusted model	0.43	(0.34, 0.51)	0.25	(0.16, 0.34)
Model adjusted by				
Age	0.43	(0.34, 0.52)	0.25	(0.15, 0.35)
Gender	0.42	(0.33, 0.52)	0.25	(0.15, 0.35)
Ethnicity	0.42	(0.33, 0.52)	0.25	(0.15, 0.35)
Education	0.43	(0.33, 0.52)	0.25	(0.15, 0.35)
Years in the United States	0.42	(0.33, 0.52)	0.25	(0.15, 0.35)
BMI	0.42	(0.33, 0.52)	0.25	(0.15, 0.35)
Shop	0.42	(0.33, 0.52)	0.25	(0.16, 0.35)
Final model‡	0.43	(0.33, 0.52)	0.25	(0.15, 0.35)

*The estimates of difference between the flat chair group and the control group.
†The estimates of difference between the curved chair group and the control group.
‡The model adjusted for all the seven potential confounders in the table.

care providers may consider recommending a height-adjustable task chair for patients with back or hip pain who are garment workers or those who perform forward sitting tasks for more than 20 hours per week. Owners of sewing companies should consider providing height-adjustable task chairs for their employees as a way of reducing back and hip pain. In addition to being adjustable, the dimensions of the chairs seem to be important factors to consider when designing or selecting a task chair for sewing machine operators to reduce pain.

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TABLE 3
Estimates (95% CI) of Pain Improvement Over Time Based on the Post Hoc Stratified Analyses Using the Repeat-Measures Linear Regression Models Adjusted for the Changes in Control Groups Over Time (ie, Slope of Control Group Was Set to 0)

	Flat Chair			Curved Chair		
Covariates	*N*	Estimate	95% CI	*N*	Estimate	95% CI
Baseline pain						
Score ≤2	46	0.3	(0.2, 0.41)	46	0.27	(0.17, 0.37)
Score >2	52	0.53	(0.38, 0.68)	38	0.23	(0.06, 0.4)
Age group						
<30	34	0.51	(0.37, 0.64)	21	0.27	(0.13, 0.4)
30–39	32	0.34	(0.2, 0.48)	29	0.07	(0.08, 0.22)
40–49	24	0.78	(0.49, 1.07)	21	0.27	(0.04, 0.49)
≥50	8	0.42	(0.3, 0.54)	13	0.53	(0.37, 0.68)
Gender						
Female	54	0.36	(0.22, 0.5)	54	0.42	(0.27, 0.58)
Male	44	0.48	(0.36, 0.6)	30	0.15	(0.03, 0.28)
Ethnicity						
Asian/Pacific Islander	28	0.41	(0.04, 0.87)	30	0.65	(0.28, 1.02)
Hispanic	68	0.47	(0.38, 0.56)	51	0.35	(0.24, 0.45)
White	2	0.44	(0.3, 0.58)	3	0.14	(0, 0.27)
Medical history of systemic illness						
No	85	0.65	(0.44, 0.86)	66	0.5	(0.28, 0.72)
Yes	13	0.4	(0.31, 0.49)	18	0.22	(0.12, 0.31)
Job strain						
Low	44	0.38	(0.27, 0.49)	36	0.27	(0.16, 0.38)
High	54	0.52	(0.41, 0.64)	48	0.27	(0.14, 0.4)
Physical exertion						
Low	39	0.46	(0.35, 0.57)	34	0.23	(0.11, 0.35)
High	59	0.41	(0.3, 0.52)	50	0.33	(0.21, 0.45)
Physical isometric loads						
Low	46	0.53	(0.42, 0.64)	38	0.27	(0.15, 0.38)
High	52	0.35	(0.23, 0.46)	45	0.28	(0.16, 0.41)
Body mass index						
Normal (18.6–24.9 kg/m^2)	32	0.36	(0.22, 0.5)	39	0.34	(0.21, 0.47)
Overweight/obese (>25 kg/m^2)	66	0.49	(0.59, 0.38)	36	0.22	(0.36, 0.09)

References

1. International Labour Office Geneva. *Labour Practices in the Footwear, Leather, Textiles, and Clothing Industries. October 16, 2000*. Geneva: International Labour Organization (ILO); 2004. TMLFI/2000.
2. Chan J, Janowitz I, Lashuay N, Stern A, Fong K, Harrison R. Preventing musculoskeletal disorders in garment workers: preliminary results regarding ergonomics risk factors and proposed interventions among sewing machine operators in the San Francisco Bay Area. *Appl Occup Environ Hyg*. 2002;17:247–253.
3. Brisson C, Vinet A, Vezina M. Disability among female garment workers: a comparison with a national sample. *Scand J Work Environ Health*. 1989;15:323–328.
4. Schibye B, Skov T, Ekner D, et al. Musculoskeletal symptoms among sewing machine operators. *Scand J Work Environ Health*. 1995;21:427–434.
5. Sokas RK, Spiegelman D, Wegman DH. Self-reported musculoskeletal complaints among garment workers. *Am J Ind Med*. 1989;15:197–206.
6. Jensen MV, Tuchsen F. [Occupation and lumbar disk prolapse.] *Ugeskr Laeger*. 1995;157:1519–1523.
7. Serratos-Perez JN, Mendiola-Anda C. Musculoskeletal disorders among male sewing machine operators in shoemaking. *Ergonomics*. 1993;36:793–800.
8. Cole DC, Hudak PL. Prognosis of nonspecific work-related musculoskeletal disorders of the neck and upper extremity. *Am J Ind Med*. 1996;29:657–668.
9. 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;49:154–162.
10. Li G, Haslegrave CM, Corlett EN. Factors affecting posture for machine sewing tasks: the need for changes in sewing machine design. *Appl Ergon*. 1995;26:35–46.
11. Yu CY, Keyserling WM. Evaluation of a new work seat for industrial sewing operations: results of three field studies. *Appl Ergon*. 1989;20:17–25.
12. 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;32:931–938.
13. Wang PC, Rempel D, Harrison R, Chan J, Ritz B. Work-organizational and personal factors associated with upper body musculoskeletal disorders among sewing machine operators. *Occup Environ Med*. 2007;64:806–813.
14. SAS Institute Inc. STAT Software: Changes and Enhancements through Release 9.1. (9.01). Cary, NC: SAS Institute; 2002.
15. Marras WS, Lavender SA, Leurgans SE, et al. The role of dynamic three-dimensional trunk motion in occupationally-related low back disorders. The effects of workplace factors, trunk position, and trunk motion characteristics on risk of injury. *Spine*. 1993;18:617–628.