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The influence of a dynamic elastic garment on musculoskeletal and respiratory wellness in computer users

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Background. Evidence is growing that computer users are at increased risk of developing musculoskeletal disorders, particularly those involving the upper extremity, with significant financial cost and lost productivity. *Objective*. The purpose of this study was to determine the short-term effects of wearing a dynamic elastic garment (Posture Shirt®; AlignMed, USA) on musculoskeletal wellness and health in the computer workplace. *Methods*. Ninety-six computer users were evaluated. The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was completed. A functional assessment of posture, lung function, and grip strength was performed after wearing the Posture Shirt® for 4 weeks. A training log was kept to track usage of the garment, as well as weekly sensations of fatigue, productivity, and energy level. *Results*. After 4 weeks, there was statistically significant improvement in forward shoulder and head posture, thoracic kyphosis, and grip strength. Improvements in spirometry measures did not meet statistical significance. Postural fatigue and muscular fatigue decreased by 21% and 29%, respectively, and energy level and productivity increased by 20% and 13%, respectively. *Conclusion*. This prospective study demonstrated positive short-term impact of the Posture Shirt® on both subjective and objective measures of posture, lung function, grip strength, fatigue, and productivity.

Keywords: feedback; posture; workplace ergonomics

1. Introduction

Computer use today is all but ubiquitous and spans virtually all age groups. Department of Education data [1] note that 97% of high school students, 91% of elementary students, and 80% of kindergarten students are computer users. In the workplace, 49% of working adults used a computer at work in 1997; by 2003, this number had grown to 56%, and it is even higher today.[2]

Because computer use is so prevalent, even relatively small risks associated with computer use can have important public health and financial implications. Evidence is growing that computer users are at increased risk of developing musculoskeletal disorders (MSDs), particularly those involving the upper extremity,[2–5] which continue to be a substantial economic burden with significant impact on workplace productivity. According to the US Bureau of Labor Statistics,[6] e.g., MSDs accounted for 32% of the injuries and illnesses requiring days away from work in 2004. The median number of days away from work was 7 days for all cases in this study. In addition, more than one-quarter of the working population is affected by low back pain each year, with a lifetime prevalence of 60–80%, and a significant impact on productivity.[7,8]

The role of posture in reducing the burden of work-related musculoskeletal disease has also been a topic of much research. In particular, improper posture can produce low energy levels and exert significant stress on the spine over time. The ensuing postural kyphosis can impact physical and respiratory function, neurologic problems, and back pain.[9] Several observational epidemiologic studies have linked postural variables to musculoskeletal outcomes. Hünting et al. [10] found greater reporting of neck, shoulder, and arm discomfort in patients with greater head rotation angle and inclination, and also noted that the ability to work with hands and forearms supported was associated with decreased discomfort. Starr et al. [11] found that back discomfort was reported statistically significantly more frequently in computer users who had a downward monitor viewing angle. Sauter et al. [12] noted less frequent arm discomfort in patients with lower keyboard height relative to the elbows. Faucett and Rempel [13] found head rotation and keyboard height above elbow height to be significantly associated with upper torso pain and stiffness severity. Marcus et al. [14] found a similar link between keyboard height and greater risk of neck and shoulder outcomes.

Accordingly, stretching, strengthening, postural education, and ergonomic office equipment have all been employed to help reduce posture-related complications of prolonged computer use in the office setting. However, these efforts may fall short in promoting optimal working posture. Biofeedback, a method which uses sensory cues to help train the mind to control bodily functions, has been proposed as a potential solution. The Posture

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Shirt® (AlignMed Inc., USA) is a commercially available, dynamic, elastic upper-extremity ergonomic garment designed to harness biofeedback to improve workplace function to stimulate muscles and induce joint alignment.

The purpose of this study was to determine the short-term effects of wearing the Posture Shirt®: on objective functional assessments of head and shoulder posture, respiratory function, and manual strength; and as subjective perception of fatigue, energy level, and productivity in the workplace.

2. Methods

2.1. Recruitment of volunteers

Our pool of study participants consisted of employees of a large municipal utility provider whose primary work duty involved computer usage at a desk-based sedentary job. Interested employees were screened by questionnaire for major health problems such as significant respiratory dysfunction which could confound testing variables. Of the 100 subjects who expressed interest in participation, four were excluded for having pre-existing major respiratory illness. Ninety-six volunteer computer users consented to participate and were evaluated prospectively. Participants were assigned a subject number which was used during the course of the study to protect their confidentiality and anonymity. Prior to beginning the study, the Disabilities of the Arm, Shoulder and Hand (DASH) outcome questionnaire [15] was administered to all study subjects to characterize any baseline upper-extremity dysfunction. The DASH questionnaire consists of a 30-item disability/symptom scale, which is scored from 0 = *no disability* to 100 = *severe disability*, and assesses the ability to perform activities of daily living as well as recreational activities. The DASH work module (which assesses a person's ability to use their usual work technique, any limitations due to upper-extremity pain, ability to do work as well as he/she wishes, and ability to spend usual amount of time doing work) and the DASH sports module (assessing these same characteristics as they pertain to sporting activities) were also assessed.

2.2. Functional assessments

A functional assessment of posture, lung function, and grip strength was performed on study subjects before and after a 4-week period of wearing the Posture Shirt®. During the study period, subjects performed their standard occupational duties (i.e., desk-based computer usage). The metrics assessed are described in the following.

2.2.1. Forward shoulder posture

Forward shoulder posture was measured with a double-square measurement device which consists of a 40.6-cm combination square with a second level added in an inverted position.[16,17] The participant stood next to a wall with their buttocks or back touching the wall. The double square was positioned over the shoulder with one square flush against the wall. The second square was adjusted until it touched the tip of the acromioclavicular joint. The measurement between the wall and the participant's right shoulder was recorded in a relaxed normal posture.

2.2.2. Forward head posture and thoracic kyphosis

Forward head and thoracic postural parameters were measured while the participant was sitting in a relaxed normal posture.[18] Reflective, anatomical markers were positioned on the spinous process of the seventh cervical vertebra, on the spinous process of the seventh thoracic vertebra, and on the acromioclavicular joint. A digital picture was taken of the participant and the angle of forward head posture was defined as the line drawn from the tragus of the ear to the seventh cervical vertebra subtended to the horizontal. Thoracic posture was calculated as the angle between this horizontal line and the line drawn from the seventh cervical spinous process to the seventh thoracic spinous process.

2.2.3. Lung volume measurements

Forced expiratory volume in 1 s (FEV_1) was measured with a spirometer [19] while sitting in a relaxed normal posture. The participant inhaled a full, deep breath and then placed the spirometer in his/her mouth and exhaled as forcefully as possible for 6 s. Three trials were performed with 1 min of rest in between each forced expiratory maneuver. The largest value was recorded and analyzed.

2.2.4. Hand grip strength measurements

Hand grip strength was measured with a hand-held dynamometer.[20] Participants were tested in the seated position with the elbow at a right angle and the dynamometer held in the hand with the wrist in a neutral position. The participant then squeezed as hard as possible for three separate 3-s trials interspersed with 5-s inter-trial rest intervals. The largest value was recorded and analyzed.

2.3. Garment usage log

Participants were given a log to track the daily amount of time they spent wearing the dynamic elastic garment at work. Visual analog scales (VAS) were also given as a part of the training log to track weekly sensations of subjective postural fatigue; neck, shoulder, and arm fatigue; productivity; and energy level.

2.4. Statistical analysis

Participant characteristics were described as the mean and standard deviation for continuous outcomes and as a percentage for categorical variables. The distribution of continuous outcomes was examined for normality. Intent-to-treat analyses were performed using a paired t test to determine the immediate effect of wearing the shirt at pretest, as well as the change after 4 weeks of shirt usage. Linear regression models were then performed to adjust for the effect of total hours reported across 4 weeks to determine the effect of adherence on change. VAS scores were reported for all 4 weeks and linear trends across time were examined. For all statistical analysis, an α level of 0.05 was used.

3. Results

3.1. Demographics

Ninety-six participants were included in this study. Ages ranged from 21 to 61 years ($M = 44.7 \pm 8.4$ years). Of these, 62 were females (64.6%) and the remainder was male. Three participants reported a history of mild asthma; one patient had been prescribed medication, and the remaining two patients had no prescribed medications. One participant dropped out of the study, and there was some minor missing data on one other subject due to vacation during the study period.

At the beginning of the study period, participants had a mean DASH activity score of 9.9 ± 11.6, consistent with no baseline upper-extremity dysfunction. The DASH subscore breakdown is presented in Table 1.

3.2. Effects of the Posture Shirt®

Table 2 presents the outcomes for participants at each measurement point. At baseline, there was a statistically significant improvement in FEV_1 ($p = 0.040$), forward shoulder posture ($p < 0.001$), strength ($p < 0.001$), and forward head posture ($p = 0.030$) between measurements taken with and without the shirt.

After 4 weeks, there was a significant difference in all outcomes except for the spirometry measures of forced vital capacity (FVC) and FEV_1, as reflected in Figures 1–5. Percent change was highest for grip strength (12%). After adjusting for total reported hours of usage, all changes were statistically significant ($p < 0.001$). Although not statistically significant, the 3.8% improvement in FEV_1 after 4 weeks did yield a magnitude of 5 L/min improvement, and may be functionally significant.

Table 1. DASH questionnaire items.

DASH subscore	N	M	SD
Activities	86	9.90	11.59
Work module	85	5.59	12.01
Sports module	37	12.50	18.22

Note: DASH = Disabilities of the Arm, Shoulder and Hand.

Table 2. Outcomes for participants at each measurement point.

Metric	No shirt			Shirt			Immediate effect			No shirt			4-week change				% change (weeks 1–4)	
	N	Mdn	SD	N	Mdn	SD	t	df	p	N	Mdn	SD	t	df	p	p_{adj}	Mdn	95% CI
Forward shoulder	96	267.2	20.8	96	275.9	19.7	−8.92	81	< 0.001	93	277.3	14.7	−9.16	81	< 0.001	< 0.001	5	[3, 5]
Forward head	96	43.8	6.0	96	44.5	6.0	−2.18	90	0.030	93	46.1	5.2	−5.24	79	< 0.001	< 0.001	6	[3, 9]
Thoracic kyphosis	96	245.4	5.8	96	245.0	5.3	0.95	90	0.351	93	247.4	5.4	−3.83	79	< 0.001	< 0.001	1	[0.4, 1]
Grip strength	96	73.6	22.5	96	76.4	23.5	−4.92	92	< 0.001	93	79.0	24.2	−3.36	79	0.001	< 0.001	12	[5, 18]
FVC	96	459.5	128.2	96	467.4	119.3	−1.41	92	0.162	93	462.5	126.0	0.91	88	0.371	< 0.001	4	[−2, 6]
FEV_1	96	3.01	0.72	96	3.07	0.69	−2.08	92	0.040	93	3.05	0.71	−1.40	88	0.172	< 0.001	2	[−1, 5]

Note: p_{adj} include total hours as a covariate. CI = confidence interval; FEV_1 = forced expiratory volume in 1 s; FVC = forced vital capacity.

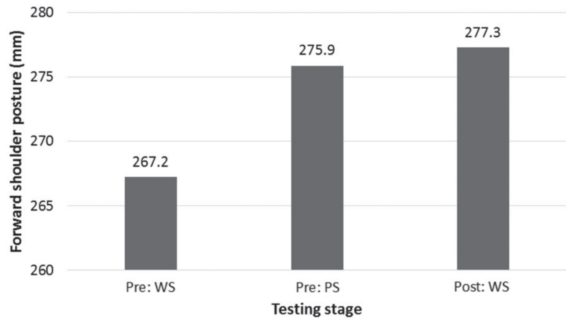

Figure 1. Forward shoulder posture.
Note: Post: WS = post-test without Posture Shirt®; Pre: PS = pre-test with Posture Shirt®; Pre: WS = pre-test without Posture Shirt®.

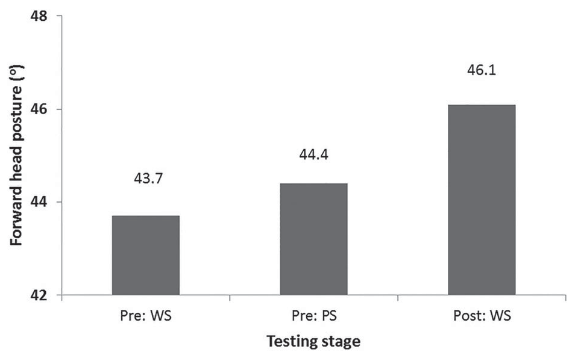

Figure 2. Forward head posture.
Note: Post: WS = post-test without Posture Shirt®; Pre: PS = pre-test with Posture Shirt®; Pre: WS = pre-test without Posture Shirt®.

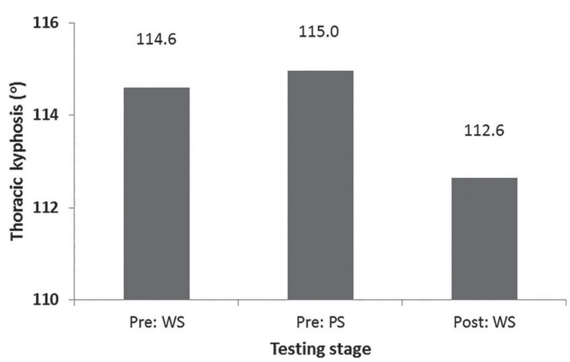

Figure 3. Thoracic kyphosis.
Note: Post: WS = post-test without Posture Shirt®; Pre: PS = pre-test with Posture Shirt®; Pre: WS = pre-test without Posture Shirt®.

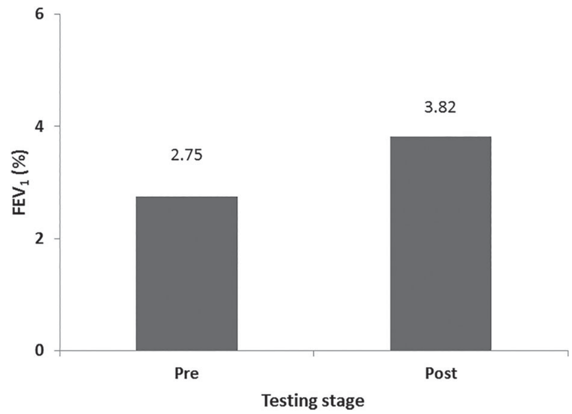

Figure 4. Forced expiratory volume in 1 s (%).
Note: FEV_1 = forced expiratory volume in 1 s; Post = post-test; Pre = pre-test.

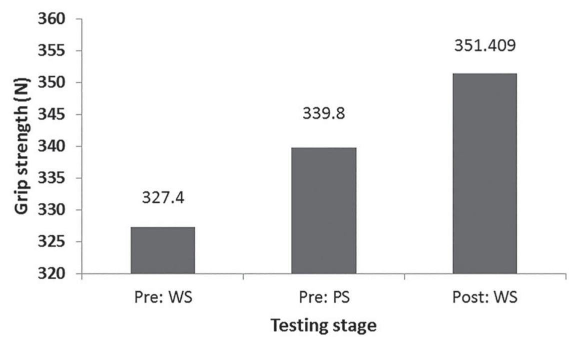

Figure 5. Grip strength.
Note: Post: WS = post-test without Posture Shirt®; Pre: PS = pre-test with Posture Shirt®; Pre: WS = pre-test without Posture Shirt®.

Table 3. Hours of wearing the Posture Shirt®.

Week	*N*	*Mdn*	*SD*	*M*	25th percentile	75th percentile
1	80	21.1	8.1	20	18	22
2	79	38.1	10.6	40	32	48.5
3	79	36.6	12.6	40	32	46
4	79	37.5	12.5	40	32	50
Total (weeks 1–4)	80	131.9	35.3	136.0	117.5	156
M per week	80	33.1	8.4	34.0	29.4	39

3.3. Participant compliance

The number of hours per week participants wore the Posture Shirt® is reported in Table 3. Compliance data were available for 80 participants in week 1 and for 79 participants in weeks 2–4. Hours worn increased from weeks 1 to 2, with most people reporting wearing the Posture Shirt® for 20 h during week 1 and for 40 h during week 2. The hours of average usage were similar for weeks 2–4.

3.4. VAS scores

Table 4 presents the VAS measures across 4 weeks. There was a significant linear decline in subjective measures of postural fatigue ($p = 0.011$) and muscular fatigue ($p < 0.001$). There were statistically significant increases in energy level ($p < 0.001$) and improvement in productivity ($p = 0.006$).

Table 4. VAS and DASH questionnaire scores across 4 weeks.

	Week 1			Week 2			Week 3			Week 4		
Metric (VAS)	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Postural fatigue	78	0.33	0.22	77	0.33	0.19	77	0.28	0.18	77	0.26	0.20
Muscular fatigue	78	0.34	0.22	77	0.33	0.19	77	0.28	0.17	77	0.24	0.18
Energy level	78	0.53	0.18	77	0.57	0.18	77	0.62	0.18	77	0.64	0.19
Productivity	78	0.59	0.16	77	0.62	0.16	77	0.63	0.17	77	0.66	0.18

Note: DASH = Disabilities of the Arm, Shoulder and Hand; VAS = visual analog scale.

4. Discussion

Postural dysfunction in the workplace is a major concern with the potential for significant morbidity and loss of work time and work productivity. This pilot study demonstrates statistically significant objective improvements in short-term head and shoulder posture, kyphosis, and grip strength, decreases in postural and muscle fatigue, and improvements in subjective energy level and productivity in municipal computer users. These results warrant longer-term follow up with a larger sample.

Upper-extremity MSDs result from many factors, including physical, psychosocial, and personal factors.[21] Of these, physical factors may be the most easily modifiable, but still represent a complex interplay of muscular physiology. Sitting-related load on the cervical spine is affected by posture, e.g., and may be an important contributor to neck pain in office workers performing computer-based tasks.[22,23] Flexed head and neck postures have been associated with increased gravitational load and cervical extensor muscle activity, which may contribute to the higher prevalence of neck pain in individuals with this postural alignment.[24,25] Conversely, correction towards a more upright posture tends to decrease cervical extensor activity and to increase activation of deep flexor muscles.[26,27] In addition, the overall sitting posture may influence this dynamic balance of muscle activation. More slumped sitting postures involving cervico-thoracic flexion are associated with greater cervical extensor muscle activity, while more upright sitting postures that reduce forward head translation and cervical flexion appear to reduce the level of cervical extensor activity. [26,28,29]

Current practices in occupational MSD management to address this multifactorial problem are varied, and include workplace interventions such as ergonomics training and workstation readjustment, clinical interventions such as physical therapy, and disability management programs. Several recent systematic reviews [30–33] have noted a mixed or insufficient level of evidence for the effect of occupational interventions on upper-extremity MSDs, and have failed to show any single-dimensional or multi-dimensional strategy that has been consistently effective across occupational settings.

'Smart garments' designed to help promote biofeedback to maintain proper posture have been proposed as a novel solution for upper-extremity MSDs. Data for such devices are sparse in the literature, however. Wong and Wong [34] developed a garment consisting of three sensor modules, a digital data acquisition and feedback system, and the actual garment itself. Five study subjects (*M* age 25.2 years) were evaluated in the garment after 4-day trials of wearing the garment for 2 h during daily activities. Statistically significant improvement in the lumbar curve in the sagittal plane was noted. Similarly, Lou et al. [9,35] designed a smart garment consisting of a harness and two data-sensor loggers and evaluated this in four subjects who wore the garment 3 h/day for 4 consecutive days. A statistically significant improvement in kyphotic angle was noted. However, both of these studies have much smaller numbers of participants and present much more short-term data compared with the present study of 96 users with 4-week follow-up.

The Posture Shirt® is different from the previously described garments, in that it has no built-in electronic mechanism. Rather, the garment is designed to envelop portions of the torso, iliac crests, and upper arms and utilize anatomically-placed elastomeric fabric panels (known as Neuro-Bands®) to stimulate biofeedback. Specifically, the varying tensions within the Neuro-Bands® provide conscious and unconscious postural cues to help restore alignment of the spine, neck, and shoulder girdle.

As such, the present prospective study demonstrated a positive short-term impact of the Posture Shirt® on objective measures of head and shoulder posture, thoracic kyphosis, lung function, and grip strength. In addition, subjective improvements in fatigue, posture, energy, and productivity were demonstrated.

One main limitation of this pilot study is the lack of a control group; there may be a component of a placebo effect and a selection bias of those wishing to participate in the study. In addition, the short period of follow-up and garment usage provide only pilot data for short-term outcomes among municipal computer users; long-term improvements in the measured parameters cannot be inferred from the present study. Nonetheless, even short-term reductions in workplace fatigue can be relevant clinically and economically. In addition, although improvements in lung function did not meet statistical significance by the end of the study period, these improvements may be relevant clinically and in the workplace.

Moreover, this study did not undergo the scrutiny of an Institutional Review Board (IRB) process. One year was spent holding numerous meetings with city administrators and attorneys regarding the safety of the dynamic elastic garment, the ability of study participants to conduct their normal duties without going over hours while fulfilling study testing, and other logistical concerns. Ultimately, the administrators and attorneys were satisfied with the non-invasive nature of the study garment, and the repeated-measures design without a control group as described was deemed to be most efficient within this structured work environment. As such, the decision was made to proceed within a tight window of employee use to uniquely collect these data without formal IRB approval of the study protocol.

5. Conclusion

This dynamic elastic garment had a statistically significant short-term improvement in both subjective and objective measures of workplace ergonomics among municipal computer users. Occupational application of the Posture Shirt® during prolonged sitting and computer work may improve posture, physiologic lung function, and subjective employee productivity and fatigue.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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