The Influence of a Dynamic Elastic Garment on Musculoskeletal and Respiratory Wellness in Computer Users

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ABSTRACT

BACKGROUND

Computer use in the business setting is ubiquitous. Evidence is growing that computers 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; Santa Ana, CA) on musculoskeletal wellness and health in the computer workplace.

METHODS

Ninety-six computer users employed at a municipal utility provider volunteered to be prospectively evaluated in the work place. Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was given. A functional assessment of posture, lung function, and grip strength was performed after wearing the Posture Shirt® dynamic elastic shirt for four weeks. A training log was kept to track usage of the garment, as well as weekly sensations of fatigue, productivity, and energy level using a visual analogue scale (VAS).

RESULTS

After 4-weeks, there was a significant difference in forward shoulder posture, forward head posture, thoracic kyphosis, and grip strength. After adjusting for total reported hours of usage, all changes were statistically significant (all p's < .001). Improvements in spirometry measures did not meet statistical significance. VAS for postural fatigue and muscular fatigue decreased by 21% and 29%, respectively, and energy level and productivity increased by 20% and 13%, respectively.

DISCUSSION

This prospective study demonstrated positive short-term impact of the Posture Shirt® on objective measures of head and shoulder posture, thoracic kyphosis, lung function, and grip strength; subjective improvements in fatigue, posture, energy, and productivity were demonstrated as well.

INTRODUCTION

Computer use today is all but ubiquitous and spans virtually all age groups. Department of Education data notes that 97% of high school students, 91% of elementary students, and 80% of kindergarten students were computer users.[1] In the workplace, 49% of working adults used a computer at work in 1997; by 2003, this number had grown to 56%, and 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] Early studies identified keyboard use as a particular risk factor for musculoskeletal disease, and much work has been done in the field of workplace ergonomics to help prevent work-related musculoskeletal disorders such as back, neck, shoulder, and wrist pain related to keyboard use.

Nonetheless, work-related musculoskeletal disorders continue to be a substantial economic burden with significant impact on workplace productivity. According to the US Bureau of Labor Statistics, for example, musculoskeletal disorders accounted for 32 percent of the injuries and illnesses requiring days away from work in 2004. [6] Median 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 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. [10] Starr et. al found that back discomfort was reported statistically significantly more frequently in computer uses who had a downward monitor viewing angle. [11] Sauter et. al noted less frequent arm discomfort in patients with lower keyboard height relative to the elbows. [12] Faucett et. al found head rotation and keyboard height above elbow height to be significantly associated with upper torso pain and stiffness severity. [13] Marcus et. al found a similar link between keyboard height and greater risk of neck and shoulder outcomes. [14]

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 a potential solution. The *Posture Shirt*® (AlignMed Inc., Santa Ana, CA) is a commercially available dynamic elastic upper extremity ergonomic garment designed to harness biofeedback 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 musculoskeletal wellness and health, including head and shoulder posture, respiratory function, manual strength, as well as subjective perception of fatigue, energy level, and productivity in the workplace.

METHODS

Recruitment of volunteers

Our pool of study participants consisted of computer users at a large municipal utility provider. Prior to enrolling participants, a brief synopsis of the study and expectations were provided in an open staff meeting with city officials. Subsequently, extensive discussion was had with city administrators and city attorneys regarding the nature of the study, the safety of the dynamic elastic garment, and the potential impact of study participation on the ability of employees to complete their normal duties their allocated work hours without incurring overtime. Once safety and administrative concerns were appropriately vetted and addressed, study enrollment began.

The primary work duty of each study participant involved computer usage at a desk-based sedentary job. Participants were excluded if they had pre-existing major respiratory illness. One hundred participants expressed interest and were screened by questionnaires for major health problems such as significant respiratory dysfunction which could confound testing variables. Ninety six volunteer computer users were ultimately prospectively evaluated. 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 consists of a 30-item disability/symptom scale, which is scored from 0 (no disability) to 100 (severe disability).

Functional assessments.

A functional assessment of posture, lung function, and grip strength was performed before and after a four week period of wearing the Posture Shirt dynamic elastic garment while at work. These metrics are described below:

A. Forward shoulder posture

Forward shoulder posture was measured with a double square measurement device which consists of a 16-inch 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 acromioclavicular joint. Measurement between the wall and the participant's right shoulder was recorded with a relaxed normal posture.

B. 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 the spinous process of the seventh cervical vertebra, 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.

C. *Lung Volume Measurements*

Forced expiratory volume in 1 second (FEV1) was measured with a spirometer [19] while sitting with the 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 seconds. Three trials were performed with 1 minute of rest in between each forced expiratory maneuver. The largest value was recorded and analyzed.

D. *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 a hand with the wrist in neutral. The participant then squeezed as hard as possible for three separate three-second trials interspersed with 5 second inter-trial rest intervals. The largest value was recorded and analyzed.

Training Log

Participants were given a training 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 postural fatigue; neck, shoulder and arm fatigue; productivity; and energy level.

Statistical analysis

Participant characteristics were described as mean and standard deviation (SD) for continuous outcomes and as a percentage (%) for categorical variables. The distribution of continuous outcomes were examined for normality. Intent-to-treat analyses were performed using paired ttest to determine the immediate effect of wearing the shirt at pre-test, as well as the change after 4-weeks of shirt usage. Then linear regression models were 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 examined. Alpha level of 0.05 was used for all analyses.

RESULTS

Demographics

Ninety-six participants were included in this study. Ages ranged from 21-61 years (M = 44.7±8.4 years). Of these, 62 were females (64.6%) and the remainder were male. Three participants reported being asthmatic; one with medication, two without. One participant (#30) dropped out of the study, and there was some minor missing data on one other subject due to vacation during the study period. Study subjects at the beginning of the study period demonstrated a DASH activity score of 9.9 ± 11.6, consistent with no baseline upper extremity dysfunction. DASH subscore breakdown is noted below in Table 1.

Effects of the Posture Shirt®

Table 2 below shows the outcomes for participants at each measurement point. At baseline, there was a statistically significant improvement in FEV1 ($p = 0.04$), forward shoulder ($P < .001$), strength ($p < .001$), and forward head ($P = .03$) between measurements taken with and without the shirt.

After 4-weeks, there was a significant difference in all outcomes except spirometry measures FVC and FEV1, as reflected below in Figures 1-6. Percent change was highest for grip strength (12%). After adjusting for total reported hours of usage, all changes were statistically significant (all p's < .001). Though not statistically significant, the 3.8% improvement in FEV1 after 4 weeks did yield a magnitude of 5 L/min improvement, and may be functionally significant.

Participant compliance

The number of hours per week participants wore the posture shirt is reported in Table 3. Compliance data was available for 80 participants at week 1 and 79 participants for weeks 2-4.

Hours worn increased from weeks 1 to 2, with most people reporting wearing the Posture Shirt® for 20 hours during the first week and 40 hours during the second week. The hours of average usage was similar from weeks 2 – 4. While this pattern was observed in several individuals, it was not observed in all (see Figure 6).

VAS scores

Table 4 reports the VAS measures across 4 weeks. There was a significant linear decline in postural fatigue ($b = -0.025$; $P = 0.01$) and muscular fatigue ($b = -0.035$, $p < .001$). There were statistically significant increases in energy level ($b = 0.037$, $p < .001$) and improvement in productivity ($b = 0.024$, $p = .006$).

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 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, however still represent a complex interplay of muscular physiology. Sitting-related load on the cervical spine is affected by posture, for example, 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 toward a more upright posture tends to decrease cervical extensor activity and increase activation of deep flexor muscles. [26,27] In addition, 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 to upper extremity MSDs. Data for such devices is sparse in the literature, however. Wong et. al developed a garment consisting of three sensor modules, a digital data acquisition and feedback system, and the actual garment itself. [34] Five study subjects (mean age 25.2 years) were evaluated in the garment after 4-day trials of wearing the garment for 2 hours during daily activities. Statistically significant improvement in lumbar curve in the sagittal plane was noted. Similarly, Lou et. al designed a smart garment consisting of a harness and two data-sensor loggers and evaluated this in 4 subjects who wore the garment for 3 hours per day for 4 consecutive days. [9,35] A statistically significant improvement in kyphotic angle was noted. However, both these studies have much smaller numbers of participants and present much more short-term data as compared to the present study of 96 users with 4-week follow-up.

Moreover, the Posture Shirt® is different from the previously described garments, in that it has no built-in electronic mechanism. Rather, the form-fitting fabric and non-stretch neuro-bands within the garment are designed to retract the shoulders to help restore alignment of the spine, scapula, shoulder, and arm and improve forward head and shoulder posture. 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; subjective improvements in fatigue, posture, energy, and productivity were demonstrated as well.

The main limitations of this pilot study are the lack of a control group and the short period of follow-up and garment usage; long-term improvements in the measured parameters cannot be inferred from the present study. Nonetheless, even short-term reductions in workplace fatigue can be clinically and economically relevant. 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 IRB process. One year of time 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 above 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 this data without a formal IRB.

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 fatigue, posture, physiologic lung function, and subjective employee productivity.

LEGEND

Table 1. DASH items

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

Table 2. Outcomes for participants at each measurement point

	No shirt			Shirt			Immediate effect			No Shirt			4 week change				% change wks1-4	
	N	M	SD	N	M	SD	t	DF	p	N	M	SD	t	DF	p	padj	M	95%CI
Forward Shoulder	96	267.2	20.8	96	275.9	19.7	-8.92	81	<.001	93	277.3	14.7	-9.16	81	<.001	<.001	5%	(3%,5%)
Forward Head	96	43.8	6.0	96	44.5	6.0	-2.18	90	0.03	93	46.1	5.2	-5.24	79	<.001	<.001	6%	(3%,9%)
Thoracic Kyphosis	96	245.4	5.8	96	245.0	5.3	0.95	90	0.35	93	247.4	5.4	-3.83	79	<.001	<.001	1%	(.4%,1%)
Grip Strength	96	73.6	22.5	96	76.4	23.5	-4.92	92	<.001	93	79.0	24.2	-3.36	79	0.001	<.001	12%	(5%, 18%)
FVC	96	459.5	128.2	96	467.4	119.3	-1.41	92	0.16	93	462.5	126.0	0.91	88	0.37	<.001	4%	(-2%, 6%)
FEV1	96	3.01	0.72	96	3.07	0.69	-2.08	92	0.04	93	3.05	0.71	-1.40	88	0.17	<.001	2%	(-1%, 5%)

Note. Padj include total hours as a covariate

Table 3. Hours of wearing Posture Shirt

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

Table 4. VAS and DASH across 4 weeks

	Week											
	1			2			3			4		
	N	M	SD	N	M	SD	N	M	SD	N	M	SD
VAS – postural fatigue	78	.33	.22	77	.33	.19	77	.28	.18	77	.26	.20
VAS – muscular fatigue	78	.34	.22	77	.33	.19	77	.28	.17	77	.24	.18
VAS – energy level	78	.53	.18	77	.57	.18	77	.62	.18	77	.64	.19
VAS – productivity	78	.59	.16	77	.62	.16	77	.63	.17	77	.66	.18

Figure 1. Forward shoulder posture.

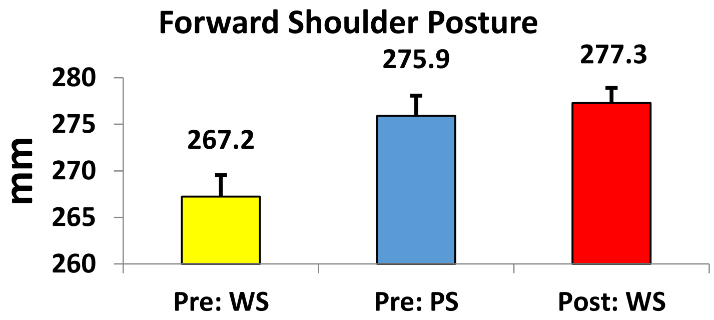


Figure 2. Forward head posture

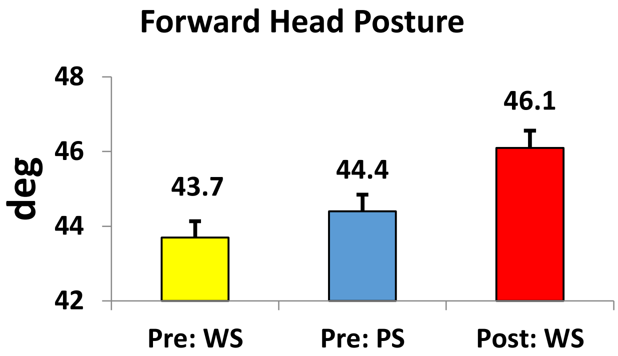


Figure 3. Thoracic kyphosis

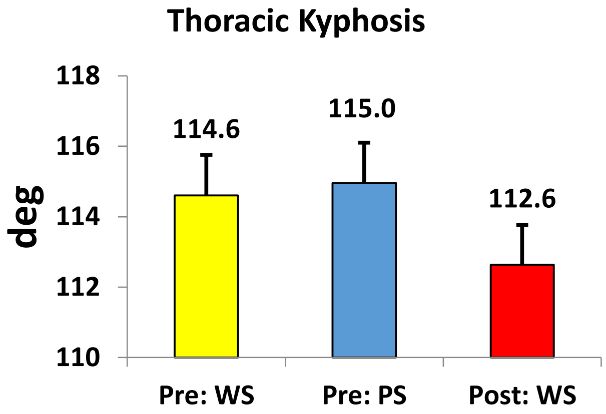


Figure 4. FEV1%

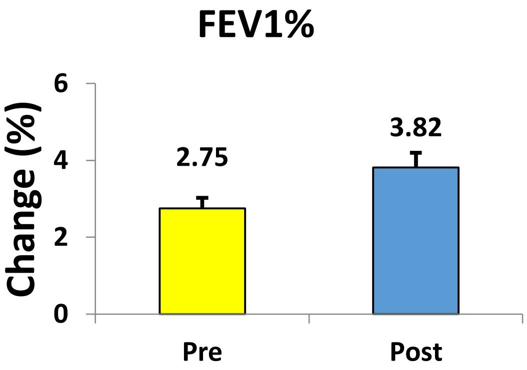


Figure 5. Grip strength

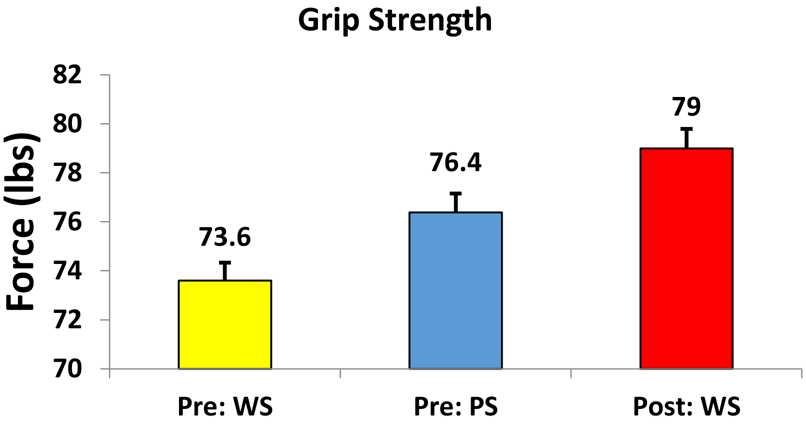
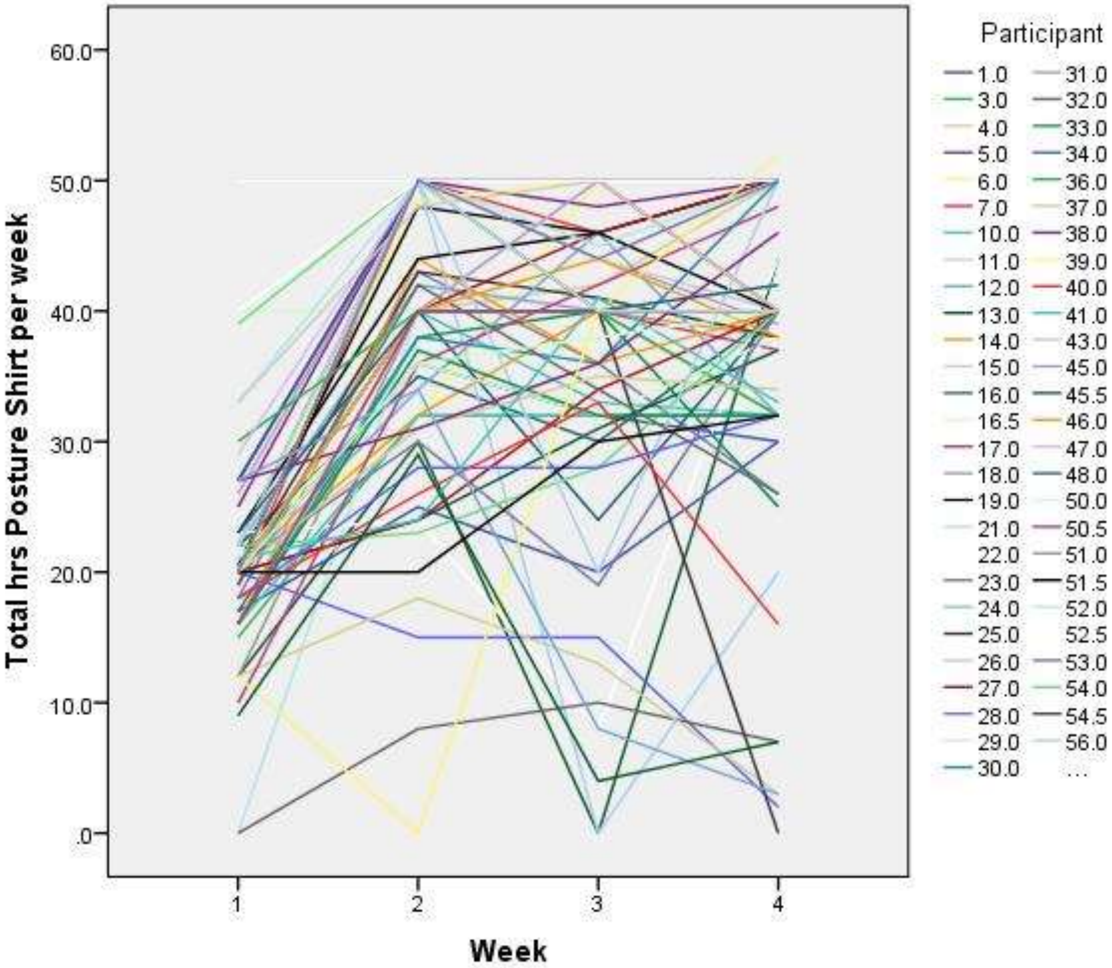


Figure 6. Hours of wearing Posture Shirt Weeks 1- 4



REFERENCES

1. DeBell M. Rates of Computer and Internet use by Children in Nursery School and Students in Kindergarten Through Twelfth Grade, 2003. *US Department of Education: National Center for Education Statistics*. <http://nces.ed.gov/pubs2005/2005111rev.pdf>. Accessed January 3, 2014.
2. Newburger EC. Computer Use in the United States, 1997. *United States Census Bureau*.<https://www.census.gov/prod/99pubs/p20-522.pdf>. Accessed January 3, 2014.
3. Gerr F, Marcus M, Monteilh C. Epidemiology of musculoskeletal disorders among computer users: Lessons learned from the role of posture and keyboard use. *J Electromyogr Kinesiol*. 2004;14:25–31.
4. Gerr F, Monteilh CP, Marcus M. Keyboard use and musculoskeletal outcomes among computer users.*J Occup Rehabil*. 2006 Sep;16(3):265-77.
5. Tittiranonda P, Burastero S, Rempel D. Risk factors for musculoskeletal disorders among computer users. *Occup Med*. 1999;14:17–38.
6. Lost-work time injuries and illnesses: characteristics and resulting days away from work, 2004. *United States Department of Labor, Bureau of Labor Statistics*. <http://www.bls.gov/news.release/archives/osh2_12132005.pdf>. Accessed January 5, 2014.
7. Lee P, Helewa A, Goldsmith CH,et. al. Low back pain: prevalence and risk factors in an industrial setting. *J Rheumatol*. 2001;28(2):346–351.
8. Lis AM, Black KM, Korn H, et. al. Association between sitting and occupational LBP. *Eur Spine J*.2007 Feb;16(2):283-98.
9. Lou E, Lam GC, Hill DL, et. al. Development of a smart garment to reduce kyphosis during daily living. *Med Biol Eng Comput*. 2012 Nov;50(11):1147-54.
10. Hünting W, Läubli T, Grandjean E.Postural and visual loads at VDT workplaces. I. Constrained postures. *Ergonomics*. 1981 Dec;24(12):917-31
11. Starr SJ, Shute S, Thompson CR. Relating posture to discomfort in VDT use. *J Occup Med.* 1985;27:269–271.
12. Sauter SL, Schleifer LM, Knutson SJ. Work posture, workstation design, and musculoskeletal discomfort in a VDT data entry task. *Hum Factors*. 1991;33:151–167.
13. Faucett J, Rempel D. VDT-related musculoskeletal symptoms: interactions between work posture and psychosocial work factors. *Am J Ind Med*. 1994;26:597–612.
14. Marcus M, Gerr F, Monteilh C, et. al. A prospective study of computer users: II. Postural risk factors for musculoskeletal symptoms and disorders. *Am J Indust Med*. 2002;41:236–239.
15. De Smet L. The DASH questionnaire and score in the evaluation of hand and wrist disorders. *ActaOrthop Belg*. 2008 Oct;74(5):575-8
16. Kluemper M, Uhl TL, Hazelrigg H. Effect of Stretching and Strengthening Shoulder Muscles on Forward Shoulder Posture in Competitive Swimmers. *J Sport Rehabil*. 2006;15(1):58-70.
17. Peterson DE, Blankenship KR, Robb JB, et. al. Investigation of the validity and reliability of four objective techniques for measuring forward shoulder posture. *J Orthop Sports Phys Ther*. 1997 Jan;25(1):34-42.
18. Greenfield B, Catlin PA, Coats PW,et. al. Posture in patients with shoulder overuse injuries and healthy individuals. *J Orthop Sports Phys Ther*. 1995 May;21(5):287-95.
19. National Institute for Occupational Safety and Health (NIOSH)Spirometry Guidelines. *Center for Disease Control and Prevention*, 2005. <http://www.cdc.gov/niosh/docs/2004-154c/pdfs/2004-154c.pdf>. Accessed January 4, 2014.

20. Kelln BM, McKeon PO, Gontkof LM, et. al.. Hand-held dynamometry: reliability of lower extremity muscle testing in healthy, physically active, young adults. *J Sports Rehabil*. 2008 May;17(2):160-70
21. Mahmud N, Kenny DT, Md Zein R, Hassan SN. The Effects of Office Ergonomic Training on Musculoskeletal Complaints, Sickness Absence, and Psychological Well-Being: A Cluster Randomized Control Trial. Asia Pac J Public Health. 2011 Aug 30.
22. Choi H. Quantitative assessment of co-contraction in cervical musculature. *Med Eng Phys*. 2003 Mar;25(2):133-40.
23. Côté P, van der Velde G, Cassidy JD,et. al. for the Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders. The burden and determinants of neck pain in workers: results of the Bone and Joint Decade 200-2010 Task Force on Neck Pain and Its Associated Disorders. *Spine* (Phila Pa 1976). 2008 Feb 15;33(4 Suppl):S60-74.
24. Yip CH, Chiu TT, Poon AT. The relationship between head posture and severity and disability of patients with neck pain. *Man Ther*. 2008 May;13(2):148-54.
25. Straker L, Skoss R, Burnett A, et. al. Effect of visual display height on modelled upper and lower cervical gravitational moment, muscle capacity, and relative strain. *Ergonomics*. 2009 Feb;52(2):204-21.
26. Caneiro JP, O'Sullivan P, Burnett A,et. al. The influence of different sitting postures on head/neck posture and muscle activity. *Man Ther*. 2010 Feb;15(1):54-60.
27. Falla D, O'Leary S, Fagan A, et. al.Recruitment of the deep cervical flexor muscles during a postural-correction exercise performed in sitting. *Man Ther.* 2007 May;12(2):139-43.
28. Edmondston SJ, Sharp M, Symes A, et. al. Changes in mechanical load and extensor muscle activity in the cervico-thoracic spine induced by sitting posture modification. *Ergonomics*. 2011 Feb;54(2):179-86.
29. Harms-Ringdahl K, Ekholm J, Schüldt K,et. al.. Load moments and myoelectric activity when the cervical spine is held in full flexion and extension. *Ergonomics*. 1986 Dec;29(12):1539-52.
30. Kennedy CA, Amick BC 3rd, Dennerlein JT, Brewer S, Catli S, Williams R, Serra C, Gerr F, Irvin E, Mahood Q, Franzblau A, Van Eerd D, Evanoff B, Rempel D. Systematic review of the role of occupational health and safety interventions in the prevention of upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time. J Occup Rehabil. 2010 Jun;20(2):127-62.
31. Boocock MG, McNair PJ, Larmer PJ, Armstrong B, Collier J, Simmonds M, Garrett N. Interventions for the prevention and management of neck/upper extremity musculoskeletal conditions: a systematic review. Occup Environ Med. 2007 May;64(5):291-303.
32. Brewer S, Van Eerd D, Amick BC 3rd, Irvin E, Daum KM, Gerr F, Moore JS, Cullen K, Rempel D. Workplace interventions to prevent musculoskeletal and visual symptoms and disorders among computer users: a systematic review. J Occup Rehabil. 2006 Sep;16(3):325-58.
33. Hoe VC, Urquhart DM, Kelsall HL, Sim MR. Ergonomic design and training for preventing work-related musculoskeletal disorders of the upper limb and neck in adults. Cochrane Database Syst Rev. 2012 Aug 15;8:CD008570.
34. Wong WY, Wong MS. Smart garment for trunk posture monitoring: A preliminary study. *Scoliosis*. 2008 May 20;3:7.
35. Lou E, Moreau MJ, Hill DL, et. al. Smart garment to help children improve posture. *ConfProc IEEE Eng Med Biol Soc*. 2006;1:5374-7.