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Impact of a Multi-component Participatory Ergonomic Intervention on Work Posture, Psychosocial and Physical Risk Factors Associated with Mobile Tablet Computer Workstations: A Controlled Study

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Abstract

This study examines the effects of a multi-component participatory ergonomic intervention on psychosocial (PS) and physical (PH) risk factors (RFs) associated with mobile tablet computer workstations. 46 pharmaceutical operators using tablet computers for at least 4 hours daily participated in a mixed methods design study. Rapid Upper Limb Assessment (RULA) was used to assess postural risk pre and post the redesign of the workstations. Data were collected at baseline and 2 months post intervention. PHRFs were measured using the Nordic Musculoskeletal Questionnaire (NMQ) and PSRFs using the Short Form 36 Health Survey (SF-36V_2). Workers' experience of the participatory process, was captured by semi-structured interviews. Two months post-intervention, postural risk scores dropped from 7 to 3 in both the Intervention and Control group (both $p<0.001$), indicating lower postural risk due to workstation re-design. Self-reports of musculoskeletal symptoms decreased significantly in both groups for the neck, shoulders and wrists/hands with no significant difference between the groups (all $p\geq0.346$). The Vitality, Role Emotional and Mental Health domains scores changed significantly in the Intervention (all $p<0.05$) but were not significantly different in the Control group (all $p>0.05$). A good macro-ergonomic design of the programme such as management commitment and support, appropriate team members, adequate training and an agreed budget were significant contributing factors for the success of the participatory ergonomic programme. A workstation redesign with the use of external accessories is effective in improving posture and reducing PHRFs in tablet computer users. The participatory nature of the multi-component ergonomic intervention program, which was of short duration,

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can have a rapid effect in reducing exposure to work related PSRFs.

Keywords: ergonomic hazards, computer risks, working with ICT

1 Introduction

Sensations of pins and needles in the fingers, stiff neck, sore shoulders or aching wrists are common symptoms for office workers. Until recently, such ailments have not been traditionally considered as common symptoms for pharmaceutical operators. However, with the recent advances in computer technology, pharmaceutical companies are moving towards a ‘Paperless Organization’ and tablet computers as a means of saving and maintaining evidence. A major difference between tablets and desktop computers is that tablet users interact with the display via a touch-screen and the tablets are smaller in size and highly portable. Thus, tablets offer a high level of mobility and flexibility. They can save the pharmaceutical industry money, time and effort by reducing cost of using paper documents and associated incidentals [1].

However, the consequences of new computer technology such as tablet devices needs to be considered, as often the ergonomic principles are not taken into account in their design [2]. Thus, the design advantages (size, virtual keyboard) of tablet computers that make them attractive can inadvertently predispose users towards musculoskeletal disorders [3]. Musculoskeletal disorders (MSDs) are a general term used to describe a wide range of symptoms and disorders of the neck, back, shoulders, elbows, forearms, wrists and hands [4].

The aetiology of MSDs in computer users has been described as multifaceted and controversial. However, multiple studies have established a relationship between MSDs and postural risk factors [5,6]. These factors include awkward or static postures, repetitiveness, improper equipment and design of monitors, keyboards, input devices and computer location [5,7]. According to Display Screen Equipment regulations (HSE, 1992), adjustable workstations where the keyboard and monitor can be adjusted independently are generally recommended for computer use to minimize discomfort.

Unfortunately, the tablet computer inherently violates this recommendation as due to its integrated touch screen display with a virtual keyboard, it is impossible to separate the screen and keyboard. This design could lead to a user assuming constrained wrist posture [3]. Awkward hand/wrist positions have been shown to be critical factors in the development of upper extremity MSDs [8,9]. A study by [10] Young *et al* (2013) reported that the “mean wrist extension for touch screen users, were at the high end of the spectrum of values observed in previous studies of desktop keyboard and mouse users”.

In addition, the virtual keyboard has been associated with higher levels of wrist discomfort than physical keyboard users due to a lack of haptic feedback. An evaluation by [11] Gwanseob & Xinhui (2011) on touch screen users attributed this increased discomfort to the fact that prolonged typing on screen can be cumbersome and fingertips may get painful from repetitively tapping against glass as opposed to a keyboard with energy absorbing keys. [12] Shin & Zhu (2011) contributes the increased wrist discomfort to the fact that touch screen users tend to hold their fingers in a ‘floating position’ to avoid an accidental activation of the touch screen. Such unsupported forearm positions can lead to MSDs because muscle tension is maintained, resulting in the wrists having no effective recovery time. Equally, this posture can also contribute to the increase in workers' shoulder pain by increasing the loading on their trapezium muscles [13].

The tablet in this study was positioned on a fixed stand (Fig. 1) and therefore subject to the problems of standard computer monitors. According to a report by [14] Boss (2001) on computers in general, 65% of monitors are placed at the incorrect height. Low computer display placement has been associated with a flexed neck and elevated and flexed shoulder [15]. In a cross sectional study [16], back discomfort was reported to occur more frequently with a downward monitor viewing angle. A simple change in the screen position was found to significantly reduce this problem [17].

However, such physical risk factors as described above do not represent the full spectrum of possible risks potentially associated with MSDs. Recent studies have shown that such disorders have a multi factorial aetiology which also includes psychosocial factors [18]. Psychosocial work factors have been aptly described by Hagberg *et al* (1995) [19], as "perceived" characteristics of the work place that can have emotional implications for workers and that can result in stress and strain. They can be categorised into specific workplace risk factors for example, job satisfaction, low autonomy, low job control and low social support and individual psychosocial characteristics such as anxiety, depression and mental stress [20].

Most theoretical models such as the bio-psychosocial model of job stress [21] describing the association between occupational factors and musculoskeletal problems argue that psychosocial stressors at work lead to MSD development by increasing muscle tension, therefore predisposing soft tissues to the effects of biomechanical stressors. Despite the fact that some employers often tend to view the psychosocial factors as somewhat irrelevant [22], research has shown that these factors are as significant as the physical and ergonomic requirements. In fact, several investigators have consistently shown that both biomechanical and psychosocial stressors can independently increase muscle tension and that the combined effect of both stressor types result in the highest tension levels [23].

Ergonomic training and improvements e.g. job rotation and rest breaks have been postulated as solutions to reduce psychosocial and physical risk factors for MSDs. Several studies [7, 24] have examined the effects of such ergonomic measures and reported that such interventions alone were not effective in preventing such risk factors. It has been hypothesized that this lack of effect might be due to dissatisfaction of the end user. Studies which have shown a positive improvement in both physical and psychosocial symptoms introduced a multi-component ergonomic intervention (ergonomic training and workstation re-design) which involved worker participation from the onset [18, 25]. This method is described as participatory ergonomics (P.E.) and is defined by [26] Wilson (1991) as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals". Reported outcomes from P.E. interventions include increased worker motivation [27], increased worker ability in problem solving [28], increased job satisfaction [29] and greater commitment for changes [30].

However, while these previous studies attempted to address physical and psychosocial issues, the outcomes concerning programme "effectiveness" is not well documented. In addition, few of these studies have provided consistent statistical evidence to support their claims. Hence, it is difficult to prove that participation has bought about a better process or that a more autocratic method would have been more effective. Naturally, management is unlikely to support measures to improve psychosocial well being if there is little evidence to support its effectiveness [26]. A systematic review by [31] Rivilis *et al* (2008) on the evaluation of ergonomic interventions, found that although experimental trials have been the "gold standard" in medical intervention studies, few have been conducted in ergonomic research. In their discussion, they strongly recommend that future quality trials with greater experimental rigor such as the use of a control should be considered, to isolate the effects of extraneous factors such as natural recovery and statistical regression.

The present study was intended to address this limitation in the literature by designing a controlled pre and post workplace study that targeted the physical and psychosocial risk factors potentially associated with tablet users within an Irish pharmaceutical plant. The following hypotheses were proposed:

Hypothesis 1: By addressing both ergonomic and psychosocial aspects of the job via a participatory process, a P.E. intervention can positively impact a worker's physical health and consequently reduce musculoskeletal symptoms.

Hypothesis 2: A participatory ergonomic approach where workers are given the opportunity and power to use their knowledge to address ergonomic problems in relation to their own working activities decreases psychosocial risk factors.

1.1 Study Background

The introduction of the tablet computers in 2012 was followed by increased reporting of MSDs. This prompted the current study. The operators were required to use the tablets for document preparation and numeric data entry at various terminals throughout the plant. The tablets were supported in an upright stand with no opportunity to change the height or tilt the angle (Fig. 1). The low height of the stand required users to look sharply downwards to read the screen, which resulted in reported pain in the neck, wrists and shoulders.

Figure 1: Workstation Pre Study

2 Methods

2.1 Study Design

The study was a mixed methods design using pre-post assessments and follow up interviews. It involved an evaluation of the self-reported feedback of the effectiveness of the independent variable (participatory ergonomic approach) on the dependent variables (physical and psychosocial symptoms) pre and post-intervention. Participants in the Intervention group participated in the decision making process regarding the ergonomic workstation redesign and received training on ergonomic principles in relation to posture risk analysis and correct workstation set up. The Control group received ergonomic training on correct workstation set up for the new design but was not involved in the re-design decision making process. The study was approved by the Psychology Research Ethics Committee of Derby University. Informed consent was obtained and confidentiality was guaranteed. Each questionnaire was filled out anonymously and a code was included to enable matching each participant to his/her assigned research group.

2.2 Participants

The study consisted of a sample of 48 operators who used mobile tablets for greater than 4 hours daily. The exclusion criteria included a cumulative sick leave period longer than 4 weeks due to musculoskeletal pain in the last 6 months. Of the 48 participants eligible for the study, 2 individuals were excluded before the intervention due to changing roles and participation refusal. All analyses are restricted to the 46 participants who completed the study. Half of respondents were assigned to the Intervention group and half to the Control group (Table 1). All participants were male, aged between 25 and 54 (76.1% were aged 35-44) and working between 3 and 24 years at the company (39.1% were working 10 years or more). The average duration of tablet computer use was 2 years. The respondents spent between 15 and 29 hours on average per week working on the mobile tablet workstation with 63.0% working on it between 20 and 24 hours per week. There was no significant difference between the Intervention and Control groups with respect to gender, age, handedness, years with the company or average hours per week spent working on the mobile tablet workstation (Table 1).

Table 1: Demographics of Survey Respondents

		Intervention		Control		All	
Variable	***Level***	***n***	***%***	***n***	***%***	***n***	***%***
Sex	Male	23	100.0%	23	100.0%	46	100.0%
Age Group	25-34	2	8.7%	3	13.0%	5	10.9%
	35-44	18	78.3%	17	73.9%	35	76.1%
	45-54	3	13.0%	3	13.0%	6	13.0%
Right or Left Handed	Right	21	91.3%	21	91.3%	42	91.3%
	Left	2	8.7%	2	8.7%	4	8.7%
Years with Company	0-4	3	13.0%	4	17.4%	7	15.2%
	5-9	11	47.8%	10	43.5%	21	45.7%
	10-14	6	26.1%	5	21.7%	11	23.9%
	15+ years	3	13.0%	4	17.4%	7	15.2%
Average hours per week spent working on mobile tablet workstation	15-19	2	8.7%	1	4.3%	3	6.5%
	20-24	14	60.9%	15	65.2%	29	63.0%
	25-29	7	30.4%	7	30.4%	14	30.4%

2.3 Sampling Method

The department consists of 4 teams (A, B, C, D). All teams work independently, however, communication occurs at the handover stage of the shift between team A and B and also between team C and D. To avoid potential confounding variables and cross contamination, A and B were considered team 1 and C and D were considered team 2. Teams were randomly assigned to the Intervention group (A & B) and the Control group (C & D).

3 Measures and Outcomes

Four separate data collection methods as described below were used to create multiple sources of evidence to evaluate the impact of the P.E. process on work posture, psychosocial and physical risk factors.

3.1 Work Postures (RULA)

To assess work postures before and after the workstation redesign, the Rapid Upper Limb Assessment was selected as it was specifically designed to evaluate sedentary tasks [32]. In order to avoid inter-observer variation, all assessments were performed by the same person pre and post-intervention. The observation was made in the longest posture during two 15 minute cycles and the mean scores of the two observations were used for the analysis.

3.2 Physical Symptoms (NMQ)

The Nordic Musculoskeletal questionnaire [33] was used to screen for self-reported musculoskeletal symptoms. This questionnaire was completed by the participants at baseline and two months after the intervention. It covered nine anatomical sites - neck, shoulders, elbows, wrists/hands, upper back, lower back, hips/thighs/buttocks, knees and ankles/feet.

3.3 Psychological Symptoms (SF-36V_2)

The SF-36V_2 Health Survey, a self-administered questionnaire was used to assess the workers' Health Related Quality of Life (HRQOL) pre and post intervention. The questionnaire consisted of 36 closed ended questions, 14 of which represented mental health and 22 of which represented physical health. It has been reliably used for individuals with MSDs and was selected for this study based on its well established, validity, reliability and population norms [34].

3.4 Evaluation of the P.E. Process

In order to capture the workers' experience of the P.E. process, semi-structured interviews with each P.E. participant was conducted by the researcher. Four of the six questions were based on the most commonly reported facilitators/barriers of P.E. interventions proposed in a recent systematic review by [35] van Eerd (2010). These include management commitment (Q.2), appropriate representation (Q.3), control of decision making process (Q.4) and organisational and ergonomic learning (Q.5). The remaining two questions were based on the personal (Q.1) and team benefits (Q.6) of a P.E. process reported in a review by [36] Hignett & Morris (2005). The questions were open ended to give participants latitude to express themselves in their own terms and to fully elucidate their experiences and beliefs (Table 2). Probes were added to the main interview questions in order to encourage workers to expand on issues. Interview data was fully transcribed during the interview process.

Table 2: Interview Questions

1. How did participation in the P.E. Process benefit you personally?
2. What are your thoughts on management`s commitment to the programme with regard to participation, commitment, time and financial resources?
3. Do you there feel there was appropriate representation form other departments at the meetings?
4. How much control do you feel that you personally had in the decision making process?
5. Has your participation in the participatory process contributed to your level of understanding and knowledge and how?
6. After the P.E. Programme, were there any changes in your workgroup?

4 Description of the Participatory Ergonomic Process

To guide the intervention process, the researcher used the common facilitators proposed in a recent systematic review by [35]van Eerd *et al* (2010) to promote a successful P.E. process. These will be discussed in brief below:

4.1 Support of the P.E. Intervention

The pharmaceutical plant was unionized with a somewhat contentious labour relationship between management and the workers. The decision making process was perceived by union members to be driven by management with little opportunity for worker participation. Hence, prior to initiating the P.E. process, commitment from the union and management was sought and obtained.

4.2 Team Formation

Based on the representative participation model of P.E. by [37] Haines *et al* (2002), the team consisted of 23 operators (team 1), the plant health and safety representative, two team supervisors, a production manager and representatives from the Maintenance, Information Technology and Human Resources departments. The researcher acted as the ergonomic facilitator.

4.3 Ergonomic Training

To provide the participatory team (Intervention group) with the knowledge and skills to enable the re-design of the workstations, the team underwent a series of 5 ergonomic training sessions each lasting 4 hours (Table 3). In order to facilitate the acceptance of the changes made to the workstations, the Control group were informed and given basic 1 hr. training on workstation set up. This training included topics such as basic ergonomic principles, workstation risk factors and guidelines to follow for injury prevention e.g. positioning, rest breaks and environmental modifications.

Table 3: Ergonomic Training Sessions

P.E. Programme – Ergonomic Training Sessions	
Session 1	➢ General background information & reason for setting up the PE programme ➢ Team`s expectation & the role of members ➢ Sharing of the information collected at the pre-measurement stage (RULA, SF-36V$_2$ & NMQ)
Session 2	➢ Presentation on the impact and causes of musculoskeletal injuries, anatomy of the spine, postural alignment and workstation design
Session 3	➢ Practice using RULA with the aid of photographic images of current workstation. ➢ Group invited to give their opinion on the following 1. Difficulties encountered during operation of the current workstations. 2. Reported MSDs complaints from workstation equipment and associated tasks 3. General conditions that make working at the stations difficult
Session 4	This session focused on solution finding. In order to formalize this solution finding process, it was structured into four steps **Step 1**: Through a brainstorming exercise, the team members were invited to propose without holding back, ergonomic workstation interventions that could potentially reduce these factors. **Step 2**: This consisted of organizing the different ideas presented into solution scenarios. Through group discussion, advantages and disadvantages of each solution proposal was discussed to allow the most pertinent one to be retained. **Step 3**: Specifications for a proposed prototype to accommodate all the user population was defined. At this stage, any repercussions that a change to a workstation may have on the manufacturing process were considered. Cost and technical feasibility was also considered. **Step 4**: An action plan to devise and implement the proposed prototype was drawn up. This plan described the responsibilities of each working group member and a deadline of 3 weeks was agreed.
Session 5	Evaluation of the prototype via: ➢ RULA postural assessment ➢ Feedback from the user group At this stage, suggestion for improvement were explored

4.4 Description of the Workstation Changes

The agreed new design improvements (Fig. 2) were implemented to the existing workstations.

Figure 2: Re-designed Workstation Flexible monitor stand and standard keyboard and mouse

The tablet computer was mounted on an articulated flexible monitor arm. The position of the device was adjustable in height, tilt angle and distance from the participant. This allowed the worker to find his own optimum working settings with regard to comfort and productivity. A standard keyboard and a two button mouse were added.

5 Analysis

5.1 Statistical

Data was analysed using the Statistical Program for Social Sciences (SPSS, v21).

5.1.1 RULA

The RULA scores were not normally distributed (Kolmogorov-Smirnov test; all $p<0.05$); thus, all analyses of RULA scores were carried out using non-parametric tests. The RULA scores for the Intervention and Control groups were compared at baseline and again post-intervention using the Mann-Whitney U Test. Changes in the RULA scores between baseline and post-intervention were compared for the Intervention and Control groups separately using the Wilcoxon Signed-Rank Test.

5.1.2 NMQ

The responses to the Nordic Musculoskeletal Questionnaire (NMQ) for the anatomical sites that distinguished between trouble on either or both sides of the body (shoulders, elbows, wrists/hands) were collated into Yes/No to make the analyses easier. The NMQ responses at the two time points (baseline and post-intervention) were cross-tabulated separately with the study groups (Intervention and Control) for each of the nine anatomical sites. As the data did not meet the assumptions of Pearson’s Chi-Square test, Fisher’s Exact Test was used to determine if there was a statistically significant association between study group and NMQ responses. The 2-sided p-values are reported for Fishers Exact test at baseline and post-intervention as the author was interested in whether there was any association between the study group and NMQ responses. The responses to the NMQ questions at baseline and post-intervention were compared for the Intervention and Control groups separately using McNemar’s Test.

5.1.3 SF-36V$_2$

Norm-based domain scores were calculated from the SF-36V$_2$ data using male UK norms from Jenkinson *et al* (1999) [34]. The author used UK norms because the only Irish norms available for the SF-36V$_2$ are based on a small sample size and the respondents involved in this research would more closely match the UK population than the US population. Most of the individual domain scores at baseline and post-intervention were not normally distributed (Kolmogorov-Smirnov test; all $p<0.05$ except the Role Physical and Vitality Norm-Based scores at baseline for both groups); thus, non-parametric tests were used for the analyses of the individual domain scores. The Mann-Whitney U Test was used to compare the SF-36V$_2$ domain scores for the Intervention and Control groups at baseline and again post-intervention. The baseline and post-intervention SF-36V$_2$ domain scores were compared for the Intervention and Control groups separately using the Wilcoxon Signed-Rank Test.

The Physical Component Summary Score (PCS) and Mental Component Summary Score (MCS) were calculated using the UK factor score coefficients reported by Jenkinson *et al* (1999) [34]. Both the norm-based PCS and MCS were normally distributed for both groups at the two time points (Kolmogorov-Smirnov test; all $p>0.05$); thus, the PCS and MCS between and within groups were compared using parametric tests. The Independent Samples T-Test was used to compare scores for the Intervention and Control groups at baseline and again post-intervention. The Paired Samples T-Test was used to compare the baseline and post-intervention scores for the Intervention and Control groups separately.

5.1.4 Qualitative

Interview data were analysed using template analysis as described by Brooks *et al* (2014) [38]. The main procedural steps carried out in the analysis were as follows:

1. The four key facilitators/barriers derived from the systematic review [35] and the personal and team benefits identified in a review[36] were used as *a priori* themes to formulate the template.
2. The interview transcripts were closely analysed to identify emerging subthemes within each *a priori* theme.
3. A coding template was defined to incorporate the relationship between each a priori theme and each subtheme.
4. The initial template was applied to the interview data and the template was modified in an iterative process until all members of the P.E. team were satisfied that the template provided a comprehensive representation of their experience.

6 Results

6.1 Effects of the Intervention on Postural Risk Scores (RULA)

At baseline, the median final postural score for both groups was 7, which is the highest level of risk quantified by RULA (Table 4). There was no difference in the baseline RULA scores for the Intervention and Control groups (Mann-Whitney U test; p-values range from 0.145 to 1.000, Table 5). The parts of the body that had the highest individual RULA scores at baseline for both the Intervention and Control groups were the wrist, the neck and the trunk; the median wrist score was 4 while the median score for the neck and trunk was 3.

Table 4: Median RULA Scores for Intervention and Control groups at baseline and post-intervention

	Baseline		Post-Intervention	
	Intervention	Control	Intervention	Control
Upper Arm/Shoulder	3	2	2	1
Lower Arm	2	2	1	1
Wrist	4	4	2	2
Neck	3	3	2	2
Trunk	3	3	1	1
Legs	1	1	1	1
Final Score	7	7	3	3

The median final postural score reduced from 7 at baseline to 3 post-intervention for both groups. There was no difference in any of the post-intervention RULA scores for the Intervention and Control groups (Mann-Whitney U test; p-values range from 0.279 to 1.000, Table 5).

There was a significant change between the baseline and post-intervention RULA scores for all areas of the body except the legs for both the Intervention and Control groups (Wilcoxon Signed-rank test; all $p<0.05$).

Table 5: P-values of statistical tests comparing RULA Scores for Intervention and Control groups at baseline and post-intervention

	Intervention versus Control Mann Witney U Test		Baseline versus Post-Intervention Wilcoxon Paired Samples Test	
	Baseline	Post-Intervention	Intervention	Control
Upper Arm/Shoulder	0.145	0.279	0.003 *	0.002 *
Lower Arm	0.770	0.732	<0.001 *	<0.001 *
Wrist	0.770	0.848	<0.001 *	<0.001 *
Neck	0.526	0.746	<0.001 *	<0.001 *
Trunk	0.948	0.365	<0.001 *	<0.001 *
Legs	1.000	1.000	1.000	1.000
Final Score	0.770	0.647	<0.001 *	<0.001 *

6.2 Effects of the Intervention on Self-Reports of MSDs (NMQ)

At baseline, 65.2% of the Intervention and 69.6% of the Control group reported having experienced neck trouble in the previous two months (Table 6). Similar proportions of both the Intervention and Control groups reported experiencing wrist/hand trouble (73.9% and 69.5% respectively) while 73.9% of the Intervention and 82.6% of the Control group reported having had shoulder trouble. Reported trouble in the two months prior to baseline for all other anatomical sites was 17.4% or less for both groups. There was no association between study group (Intervention and Control group) and experience of trouble in the two months prior to baseline for any of the nine anatomical sites recorded using the NMQ (Fisher's Exact Test; Table 6, all p-values range from 0.722 to 1.000).

There was no association between study group (Intervention and Control group) and the post-intervention NMQ results for any of the nine anatomical sites (Fisher's Exact Test; Table 6, all $p \geq 0.346$).

Post-intervention, 13.0% of the Intervention group and 21.7% of the Control group reported having experienced neck trouble in the previous two months compared with 65.2% and 69.6% at baseline. The differences in reported neck trouble at baseline and post-intervention for both the Intervention and Control groups were statistically significant (McNemar's Test; $p<0.001$ and $p=0.003$ respectively).

Table 6: Results of NMQ for the Intervention and Control groups at baseline and post-intervention with p-values of statistical tests

	Baseline				Post-Intervention				*Fishers Exact Test*		*McNemar Test*	
	Intervention (1)		Control (2)		Intervention (3)		Control (4)		*Baseline*	*Post-Intervention*	*Intervention group*	*Control group*
	n	%	n	%	n	%	n	%	*(1 vs 2) p-value*	*(3 vs 4) p-value*	*(1 vs 3) p-value*	*(2 vs 4) p-value*
Neck	15	65.2%	16	69.6%	3	13.0%	5	21.7%	1.000	0.699	<0.001 *	0.003 *
Shoulders	17	73.9%	19	82.6%	5	21.7%	7	30.4%	0.722	0.738	0.002 *	0.002 *
Elbows	0	0.0%	1	4.3%	0	0.0%	0	0.0%	1.000	n/a	n/a	n/a
Wrists/Hands	17	73.9%	16	69.5%	2	8.7%	3	13.0%	1.000	1.000	<0.001 *	<0.001 *
Upper back	3	13.0%	4	17.4%	1	4.3%	2	8.7%	1.000	1.000	0.500	0.500
Lower back	3	13.0%	2	8.7%	2	8.7%	2	8.7%	1.000	1.000	1.000	1.000
Hips/Thighs/Buttocks	1	4.3%	1	4.3%	1	4.3%	1	4.3%	1.000	1.000	1.000	1.000
One or both knees	2	8.7%	2	8.7%	1	4.3%	4	17.4%	1.000	0.346	1.000	0.625
One or both Ankles/Feet	0	0.0%	1	4.3%	0	0.0%	0	0.0%	1.000	n/a	n/a	n/a

The percentages of the Intervention and Control groups who reported having experienced shoulder trouble post-intervention were 21.7% and 30.4% respectively, compared to 73.9% and 82.6% respectively at baseline. The difference of reported shoulder trouble between baseline and post-intervention for both the Intervention and Control groups were statistically significant (McNemar's Test; both $p=0.002$).

Post-intervention, 8.7% of the Intervention and 13.0% of the Control group reported having experienced wrist/hand trouble in the previous two months compared to 73.9% and 69.5% respectively at baseline. The differences of reported wrist/hand trouble between baseline and post-intervention for both groups were statistically significant (McNemar's Test; both $p<0.001$).

The change of reported trouble between baseline and post-intervention for all other anatomical sites was not statistically significant for either the Intervention or Control group (McNemar's Test; all $p \geq 0.500$).

6.3 Effects of the Intervention on General Health (SF-36V$_2$)

At baseline, there was no difference in any of the SF-36V$_2$ norm-based domain scores between the Intervention and Control groups (Table 7, Mann-Whitney U test; all $p>0.05$). Post-intervention, only the Vitality, Social Functioning, Role Emotional and Mental

Health domain scores differed significantly between the two groups (all p<0.001).
There was a significant difference in the baseline and post-intervention norm-based scores for the Intervention group for all domains (Wilcoxon signed-Rank test; all p<0.001) where the scores post-intervention tended to be higher than at baseline. For the Control group differences were observed in the Physical Functioning, Role Physical, Bodily Pain, General Health and Social Functioning domains (all p<0.05) and again, the post-intervention scores tended to be higher than the baseline scores. Although, the scores for Vitality, Role Emotional and Mental Health domains tended to be higher for the Control group post-intervention compared to baseline these differences did not reach statistical significance (all p>0.05).

Table 7: Results of the SF-36V2 using UK Norms for the Intervention and Control groups at baseline and post-intervention with p-values of statistical tests

	Baseline		Post-Intervention		Intervention versus Control Mann Whitney U Test		Baseline versus Post-Intervention Wilcoxon Paired Samples Test	
	Intervention (1)	Control (2)	Intervention (3)	Control (4)	Baseline (1) vs (2)	Post-Intervention (3) vs (4)	Intervention (1) vs (3)	Control (2) vs (4)
Physical Functioning Norm-Based Score	45.6 (6.5)	44.8 (6.2)	52.6 (4.5)	49.4 (6.9)	0.569	0.095	<0.001 *	0.001 *
Role Physical Norm-Based Score	33.4 (11.4)	32.4 (10.4)	50.3 (5.3)	51.5 (2.9)	0.715	0.927	<0.001 *	<0.001 *
Bodily Pain Norm-Based Score	35.1 (3.9)	34.3 (3.9)	52.8 (5.7)	49.2 (6.6)	0.460	0.066	<0.001 *	<0.001 *
General Health Norm-Based Score	43.7 (6.9)	43.0 (6.9)	50.1 (5.3)	50.9 (3.5)	0.545	0.377	<0.001 *	<0.001 *
Vitality Norm-Based Score	44.7 (11.0)	45.0 (10.8)	61.2 (3.8)	46.0 (10.4)	0.894	<0.001 *	<0.001 *	0.140
Social Functioning Norm-Based Score	42.1 (8.5)	39.4 (6.7)	54.4 (3.7)	42.6 (6.9)	0.303	<0.001 *	<0.001 *	0.005 *
Role Emotional Norm-Based Score	38.9 (11.0)	38.0 (8.6)	52.3 (4.1)	39.1 (11.0)	0.708	<0.001 *	<0.001 *	0.298
Mental Health Norm-Based Score	50.1 (7.1)	49.5 (7.1)	58.0 (3.1)	49.0 (7.0)	0.382	<0.001 *	<0.001 *	0.206

	Baseline		Post-Intervention		Intervention versus Control Independent Samples T-Test		Baseline versus Post-Intervention Paired Samples T-Test	
	Intervention (1)	Control (2)	Intervention (3)	Control (4)	Baseline (1(vs (2)	Post-Intervention (3) vs (4)	Intervention (1) vs (3)	Control (2) vs (4)
Physical Component Summary Score	36.8 (6.4)	36.0 (6.1)	49.4 (5.3)	52.0 (4.9)	0.645	0.087	<0.001 *	<0.001 *
Mental Component Summary Score	47.2 (9.2)	46.3 (8.2)	57.8 (2.9)	42.9 (9.2)	0.739	<0.001 *	<0.001 *	<0.001 *

Each of the domain scores tended to be below the UK norms at baseline for both groups (all means<50); the exception to this was the Mental Health domain which was 50.1 for the Intervention and 49.5 for the Control. Post-intervention all of the domain scores for the Intervention group were equal to or higher than the UK norms (all means>50) while the only domains that were higher for the Control group post-intervention when compared with the UK norms were Role Physical (mean=51.5) and General Health (mean=50.9).
There was no difference at baseline between the Physical Component Summary Score (PCS; p=0.645) or the Mental Component Summary Score (MCS; p=0.739) for the Intervention or Control groups. Post-intervention there was no difference between the two groups for the PCS (p=0.087) but the MCS was significantly higher for the Intervention group (p<0.001).
Both the PCS and MCS were significantly higher post-intervention compared to baseline for the Intervention group (paired samples t-test, both p<0.001). The PCS was significantly higher for the Control group post-intervention compared to baseline (p<0.001) while the MCS was actually significantly lower for the Control group after the

study (p<0.001).
The PCS and MCS were lower for both the Intervention and Control at baseline when compared to the UK Norms. Post-intervention, the PCS was similar to the UK Norm for the Intervention group (mean=49.4) while the MCS was higher (mean=57.8). The PCS post-intervention for the Control group was above the UK Norm (mean=52.0) while the MCS was much lower (mean=42.9).

6.4 Interview Results

The final template encompassed six *a priori* themes with each of these themes divided into four sub themes as show in Figure 3.

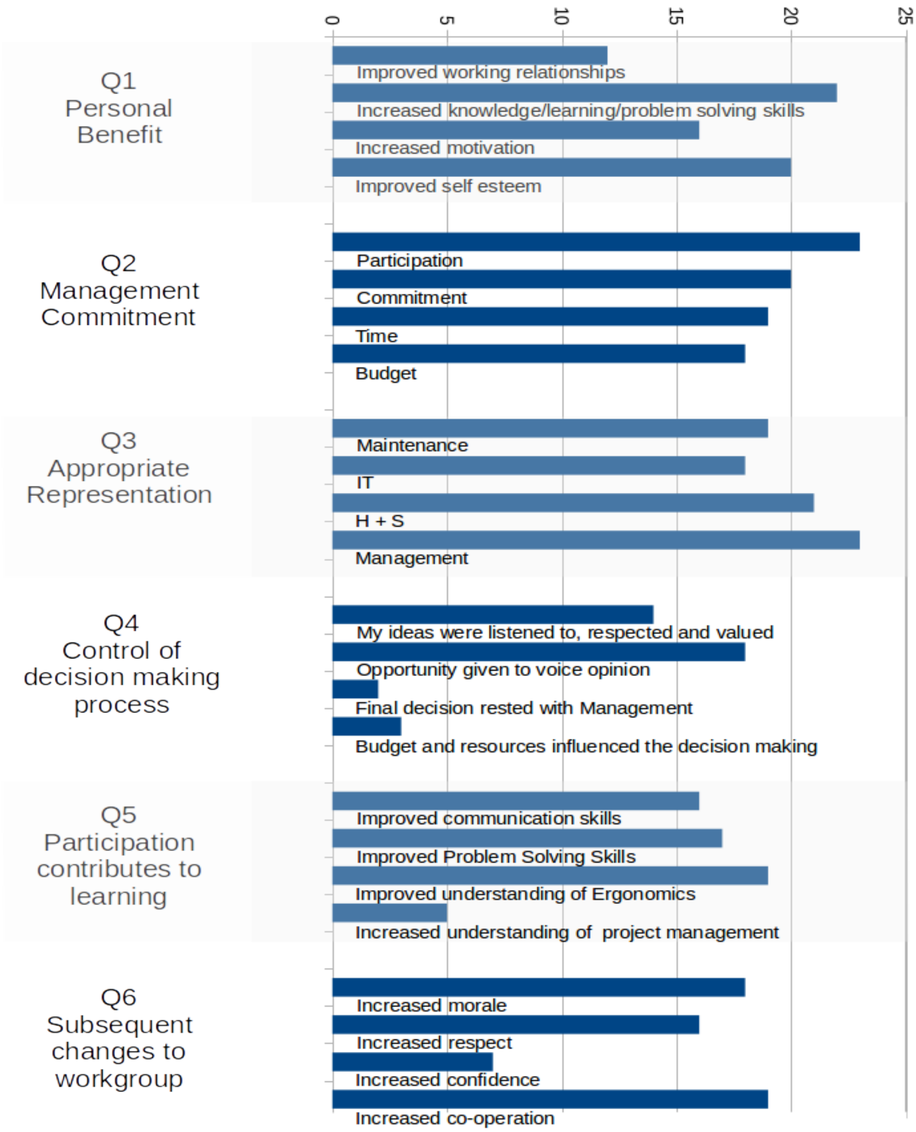

Figure 3: Interview Themes and Subthemes.

Below, each main theme is outlined and a sample of verbatim extracts to illustrate the findings is listed under each subtheme.

Theme 1: Personal Benefits

Improved working relationships
"It helped develop relationships with other teams"
"It helped develop relationships with people I never met before"
"Having the opportunity to work with other disciplines gave a better understanding of the dfferent perceptions people have"

Increased knowledge/problem solving skils
"It helped develop an eye for ergonomics in respect to identifying potential risk factors"
"Increased my knowledge on ergonomic risk factors at home and at work".
"It taught me how to question how my work tools ought to be designed to make them more human friendly".

Increased motivation
"Increased work responsiblitiies which made me feel more motivated".
"Seeing what we accomplished instilled a sense of pride and motivated us to get more involved in work projects"
"It made work more interesting"
"The training taught me how to challenge assumptions and motivated me to find new ways of working".

Improved self-esteem
"Made me feel valued and for the first time, people in my team actually listened to me!"
"The knowledge gained from the training increased my confidence level"
"I felt a valued member of staff – my opinions were sought and given consideration"

Theme 2: Management commitment

Participation
"Regular management attendance at meetings"

Commitment
"A manager or delegate was visibly present at all meetings which showed commitment to the programme"
"Management were aware of and supported the goals and scope of the P.E. programme"
"The ergonomic re-design measures agreed by management at the P.E. meetings were implemented"
"Management ensured that adequate resources in term of people's time and money were available to carry out the changes"

Time
"Adequate time was allocated to attend meetings"
"Time was made available to attend training"

Budget
"Adequate budget agreed at onset of programme"
"The project budget was communicated clearly upfront and helped focus decision making accordingly"

Theme 3: Appropriate representation

Maintenance
"Appropriate people present from the maintenance team"

I.T
"Right people from the I.T department present at all meetings"

H & S
"Good level of representation from the H & S team"

Management
"Appropriate participation from the management"

Theme 4: Control of decision making process

Ideas were listened to, respected and valued
"Managers recognized our ability to contribute to improving working conditions and were willing to listen to our suggestions"
"Ideas and suggestions were treated with consideration and respect"
"Consideration was given to everyone's suggestion even it if was not realistic"

Opportunity given to voice opinion
"Any ideas put out there were listened to"
"Everyone's voice was heard including mine"
"Opinions and ideas were never imposed on the group members"

Final decision rested with management
"Ergonomic training and brainstorming helped with critical thinking which in turn helped in coming up with the final solution"
"Management had most control of the decision making at the start of the project however the final solution was a group decision"

Budget & Resources influenced the decision making
"The decisions regarding the final solution was dictated by cost, however as the budget was agreed upfront, we knew what our limits were"
"We were constrained on what we could do in terms of money and resources but we knew this from the start so our expectations were not unrealistic"

Theme 5: Participation contributes to learning

Improved communication skills
"Feel more confident in speaking in larger groups"
"I learnt now to communicate better within a team"

Improved problem solving skills
"It enhance my problem solving skills and gave me a better understanding on how to offer suggestions for workplace improvements"
"Better understanding of how to offer suggestions for workplace improvements"

Improved understanding of ergonomics
"Theoretical and hands on training increased understanding of ergonomic principles"
"Increased understanding of how working in awkward positions can cause muscular pain"

Increased understanding of project management
"It increased my knowledge in regard to project life cycle and project management"
"Increased understanding of how an organization functions"

Theme 6: Subsequent changes to workgroup

Increased morale
"Helped increase the team morale and increased self-esteem and self-image of the group"
"Group more energized and enthusiastic in general"
"Everyone very happy with the results which helped improve the team spirit"

Increased respect
"Co-workers listen more readily to suggestions from others"
"More mutual respect amongst team members"
"Team members consult each other more often for advice and support"

Increased confidence
"More confidence amongst team members in sharing ideas for future improvements"
"Increased confidence in offering suggestions as a group on other improvements"

Increased co-operation
"We are more compatible and share ideas more regularly now"
"More harmonization in the group"
"Improved relationships between team members and managers"

7 Discussion

The purpose of this study was to assess the impact of a multi-component participatory ergonomic intervention on work posture, psychosocial and physical risk factors associated with mobile tablet computer workstations. Based on the pre-study results of physical outcome measures namely RULA, NMQ and SF-36V_2 (PCS), tablet users in this study demonstrated a high level of exposure to musculoskeletal risk factors, due to non-neutral postures. These results are consistent with previous studies whose findings showed that a large percentage of computer users worked in non-neutral position [39, 40].
The post-study physical outcome measures concluded that the ergonomic workstation modifications resulted in significant improvements in postural scores for both groups. In addition the self-reporting muscular symptoms decreased significantly. These results combined with the SF-36V_2 PCS scores indicate that the redesign of the existing workstations was effective in reducing ergonomic risk factors for the user, irrespective of their involvement in the participatory process. Due to the varied study designs, participants, ergonomic intervention and outcome measures in earlier studies, it is difficult to compare our results to other findings. A randomized control study [41] on VDU workers is the only one with a similar study design. Their results concluded that the P.E. intervention had a positive short term effect on MSD symptoms at their 2 month follow up and improvement in pain symptoms did not differ between the Intervention and Control groups. This is consistent with our findings.
The results of this current study may have implications for practice supporting the use of accessories to help adjust the screen height and mitigate against the potential adverse health effects from prolonged use of the virtual keyboard. Such accessories have been associated with increased comfort in comparison to stand-alone note book computers [42, 43, 44, 45].
In addition, the study results provide further evidence that ergonomic training is effective in terms of lowering postural risk and decreasing duration and frequency of pain in the upper back, neck, shoulder and wrists. As part of the P.E. process, the Intervention group received intensive training in ergonomics, while the Control group underwent one hour basic workstation set up training, in order to facilitate the acceptance of the changes made to the new workstations. This was deemed important as interventions can fail if the end users are not fully informed [46]. The current results support earlier studies [18, 47], who demonstrated using a similar study design, that a non-participatory ergonomic intervention which involves workstation adjustment and training was effective in reducing musculoskeletal symptoms in particular in the neck and the upper extremities.
Prior to the intervention, the *vitality*, *social functioning* and *role emotional* domain scores were lower for both groups in comparison to the UK norm. However, consistent with hypothesis (2), pre-intervention to post-intervention differences in these scales improved significantly in the Intervention group when compared to the Control group. Such positive impacts on psychosocial work factors were anticipated in this study due to the carefully designed P.E. approach. The interview results showed that the participants' level of ergonomic knowledge was increased by the interactive '*hands on*' ergonomic and problem solving training. The importance of providing a solid knowledge base is noted in a study [48]that suggests that without suitable training, the program will likely fail. From the positive interview feedback in this study, this training was perceived to have been very effective. The interview comments concur with another study[49] whose participants reported increased ability in problem solving and confidence in their own

personal contributions, due to the knowledge obtained from the ergonomic training. As a result of the training, the participants in this study reported that their confidence and ability to be actively involved in the decision making increased. In addition, they learned to communicate their knowledge and experience across the professional boundaries. Such skills can increase opportunities for personal development, influence, feedback and job control [50]. These very characteristics have been identified as predictors of good mental well-being [51].

It was evident from the high scores on the Role Emotional Scale (RE) for the Intervention group, that the P.E. process by encouraging workers to be involved in the decision making and by valuing their opinion increased their occupational self-efficacy. Occupational self-efficacy is “the confidence in one’s own ability to perform the job task successfully” [52]. The interviews with the participants illustrate this positive impact and the feedback from workers indicates that the P.E. process increased their feeling of control over their work and had a positive influence on their identity.

The ergonomic improvement implemented in this study, was what Hendrick (2008) [53] calls a “low hanging fruit”. Such initial micro ergonomic improvements has been regarded as facilitators in various studies [54, 55], to promote “buy in and commitment to the program” from management [56]. It also has the additional advantage according to [35] van Eerd et al (2010) of motivating participants as it results in positive improvement within a short period of time. The interview comments illustrate how effective this strategy was in increasing the motivation of the study participants. According to [57] Kubzansky *et al* (2007) motivated workers display a greater sense of energy and positive well-being in addition to being able to regulate emotions effectively. The increased scores of the SF-36V_2 vitality domain scores in this study clearly indicate that the Intervention group has been energized by the P.E. process. According to another study[58] workers with high vitality show higher energy levels and mental resistance and have been shown to invest more effort at work.

The presence of management and other stakeholders at the participatory ergonomic meetings in this study resulted in increased contact and interaction with all team members. This form of participation can increase opportunities for personal development, influence, feedback and job control. These are the very characteristics which have been identified as predictors of good mental well-being [51, 50]. Previous studies have shown that lack of support from management was a barrier to the success of their P.E. programme [59, 60, 61]. An evaluation by Laing *et al* (2005) [61] on a P.E. process in a manufacturing plant observed that lack of full commitment from management was potentially related to tensions with production demands. All of the participants interviewed in this current study, were positive about management commitment with regard to participation, commitment, time and financial resources.

The qualitative interview data and the improved MCS scores in this study provide additional evidence for a worker participation approach to reduce job stressors and enhance mental health among workers. These results highlight that the overall success of the approach depends on good macro-ergonomic design of the program itself such as management commitment and support, appropriate team members, adequate training, agreed budget and the use of a prototype.

7.1 Limitations and Strengths of the Study

The study had several limitations that require consideration when interpreting the results. Firstly, the study may have been subject to the Hawthorne effect as there is a possibility that the Intervention group received more attention because of their participation in the P.E. program. Thus, they may have returned more socially desirable responses to the self-report questionnaires and interview process at follow up. Equally, the attention given to the Control group via the modifications of their workstations may have contributed to creating a positive outcome for the self-reports of musculoskeletal pain independent of whether they were or were not involved in the decision making. In addition, the presence of the researcher in their workplace on a regular basis over the two month period may have acted as a 'cue' for both groups, to adopt correct postural positions at the workstations.

Due to the particular workplace production schedule, the follow up assessment was completed two months after the intervention. This time period may have been too short to induce anticipated effects [18]. If it had been longer, it is possible that the cumulative impact of the participatory process in reducing physical symptoms might be more significant for the Intervention group. The effect of length of follow up is a frequent justification for the limited impact of the intervention in influencing outcomes in studies with similar follow up times [61,62].

Another shortcoming of this experiment was that the relatively small sample size may not yield adequate statistical power; thereby "the findings must be interpreted with caution" [31]. However, it could be argued that the small size allowed the practicalities of implementing an intervention programme to be tested [63]. In addition, the study sample was homogeneous in regard to gender and job role, the results of the present study may not apply to different populations and occupations.

This study had a number of strengths. This study as recommended by [31] Rivilis *et al* (2008) employed a broad range of measure tools to enhance the validity of the study findings in relation to the effectiveness of the micro (ergonomic changes) and the macro level (overall participatory process) changes. Tools such as RULA, NMQ and the SF-36V_2 (PCS) allowed the physical changes to be evaluated. The SF-36V_2 (MCS), the one minute survey and the qualitative interview data provided context to the qualitative analysis results. This multi-faceted method of evaluating the intervention relates to the multi-factorial nature of the development of MSDS.

Another major strength was the use of a Control group which composed of workers who performed the same jobs and tasks as those in the Intervention group. This is an improvement over the design used by previous studies [64, 65, 66, 67, 68]. The matched Control group diminished the existence of potential confounding explanatory variables and provide more reliable evidence of the effects of the P.E. process.

As the sample size was small, full participation of all participants was important for this intervention study. Hence motivation for participation warrants some comments. The researcher had built credibility with the workforce, by introducing successful visible improvements in the facility previously. This track record facilitated the acceptance and support from the workers' union health and safety representative. In turn, this representative provided a valuable liaison role with the workers and helped motivate them to view the project as a formal mechanism to have previously identified ergonomic issues resolved. This helped mitigate the challenges reported by earlier studies to recruit participants [54].

8 Conclusion

This study showed that a workstation redesign with the use of inexpensive external accessories can be effective in improving posture and reducing physical risk factors in tablet computer users. In addition, the results indicate that the participatory nature of the multi-component ergonomic intervention program, which was of short duration, can have a rapid effect in reducing exposure to work related psychosocial risk factors. This key finding of the study validates the importance of assessing and taking into consideration the employees' perception of the participatory process. This valuable feedback has not been previously documented in the literature to this extent [35].

The intervention designed for this study was grounded both in the literature and in the philosophies of participatory ergonomics and ergonomic principles. It capitalized on the cited success facilitators of earlier studies and followed the main key issues in order to make ergonomic interventions successful. The positive outcomes measures reported in this study will hopefully prepare the ground for more extensive participative strategies within organizations. In doing so, it will help create an increase "in house knowledge base" of ergonomics, where the workers will be competent in applying the concepts of ergonomics to any task. This acquired skill set will be a valuable asset in our rapidly changing technological environment.

8.1 Recommendations for Further Research

Future research, employing similar experimental design should 1) investigate whether these results can be generalized to the use of tablet computers in other typical tablet user positions 2) include additional follow up assessments to determine the effects of the intervention over time.

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