# EFFECTS OF UPPER LIMB POSTURES ON SELF PACED CYCLE TIME (SPCT)

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ABSTRACT ■ This experiment was designed to see the effect of upper limb postures on Self Pace Cycle Time (SPCT). The experiment was conducted in four parts. A group of five right handed males participated in every parts of this experiment. The considered postures were (i) upper arm abduction (ii) shoulder flexion/extension (iii) shoulder rotation (adduction) and (iv) elbow flexion. The results showed that SPCT was significantly affected by upper arm abduction ($p<0.028$). It was also observed that SPCT was more as the upper arm abducted more towards $90^0$. Shoulder flexion/extension was highly significant on SPCT ($p=0.006$). Shoulder rotation (adduction) was not found significant but increase in angle towards midline showed slight decrease in SPCT as per profile plot. SPCT was not significant for elbow flexion angle but profile showed that decrease in discomfort was evident of low SPCT (i.e. higher productivity) with increase in angle of elbow flexion. The practical relevance of this study is to avoid the postures which are highly discomfort and decreases the productivity in Industries.

**Key words:** Self Paced Cycle Time (SPCT), discomfort, gripping, productivity.

## INTRODUCTION

In occupational tasks, the physical symptoms of disorder are generally experienced in the upper limbs, especially the shoulders and elbows (Gil Coury et al., 1997b). In western countries, the prevalence of work-related neck–shoulder complaints is significant. In the Netherlands, 22% of the working population reported work related complaints in the neck, shoulders, arms or hands (Hupkens, 2002). Despite the low force levels required, computer workers are at a considerable risk of developing neck–shoulder complaints (Bongers et al., 2002; Jensen, 2003). Many computer workers may develop chronic complaints that eventually resulted in absenteeism from work, leading to high costs for society. The action of grouping small products together and lifting in between both hands to pack them is also very frequent when handling boxes without handles. These tasks involve shoulder adduction combined with forward flexion and internal rotation of the humorous. Gil Coury et al. (1997) studied the same simulated task in experimental conditions, and reported a positive association between shoulder and elbow discomfort and the magnitude of the force

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generated.

If the workers, who are at risk to develop chronic neck–shoulder complaints, could be identified, then early application of ergonomic interventions might help to reduce absenteeism from work. Conventional diagnostic tools such as medical imaging or neurography largely failed to discriminate cases with neck–shoulder complaints from control subjects. During the past decades, extensive research has been done to investigate the possibility of using deviations in muscle activation patterns to discriminate between cases and controls. It is well known that physical training programs have a positive effect on physical capacity of workers (Hunt, 2003; Rhea et al., 2003).

Since in industries the working duration is approximately 8 hours per day, therefore Self Pace Cycle time (SPCT) plays an important role for working without discomfort and muscular injuries (Finneran and O'Sullivan, 2010). SPCT is the cycle time (exertion time and rest duration for a single exertion i.e. inversely proportional to frequency of exertion) set by the worker himself for performing the task at his/her comfortable pace, for a particular assumed for a working day of 8 hours duration. So that he could do the work for longer time to give maximum productivity with reduced risks of WMSDs and/or injuries. Many studies have been reported the relation between risk factors causing WMSD's, discomfort and productivity. This study was an attempt in the same direction to get some more information regarding the effect of postures on SPCT and productivity. The experiment was conducted in four parts and the objectives of all parts were to investigate the effects of (1) upper arm abduction, (2) Shoulder flexion/extension (3) shoulder adduction, and (4) elbow flexion, on SPCT for gripping tasks.

## METHOD

### Experimental Design

A group of five right handed males free from past injuries and WMSDs participated in every part of this experiment after giving their prior consent. One way ANOVA was used for the analyses of the data of each part of this experiment where different levels of single posture were used to investigate the effect on SPCT. Each part of the experiment had one of the following postures to be investigated: (i) upper arm abduction ($0^0$, $45^0$, & $90^0$), (ii) Shoulder rotation (Flexion/Extension) ($-45^0$, $0^0$, $45^0$, & $90^0$), (iii) Shoulder Rotation towards midline (Adduction) ($0^0$, $45^0$, & $90^0$) and (iv) Elbow flexion ($45^0$, $90^0$, & $135^0$).

## TASK & EXPERIMENTAL SETUP

A repetitive grip force of 150 N (Farooq and Khan, 2012) for 10 minutes duration with the exertion time of 1 second in each cycle was considered (in line with the study of Finneran and O'Sullivan 2010). The rest was controlled using the self paced controlling system as shown to the subject using a LABVIEW VI. The screen shot of the LABVIEW VI was shown in Figure 1. The participants were instructed to select a pace of work (SPCT) during the 10 minutes duration, which they felt they could maintain for an 8 hour per day by adjusting the cycle time duration. All changes to SPCT were automatically recorded throughout the experiment and the final value at the end of each treatment was saved in the file automatically. An electronic, digital grip force dynamometer (MIE Medical Research Ltd Digital Analyzer, UK) was interfaced with the computer via RS232, the warning signal of out range force levels were set by red colour and a beep. A Rig was designed for the experiment. However, it was flexible to put different attachments as per the requirements of each part of this experiment. These attachments for all of the four parts are shown in Figures 2, 3, 4, and 5.

## PROCEDURE

The participants were asked to sit on the rig one by one and height was adjusted such that the fixture height was comfortable to the subjects to the computer screen. Before commencement of the first treatment the participant performed a trial run for 3 minutes, so as to gain familiarity with the task. In part one of the experiments, the upper arm was positioned and strapped in place with the centre of the wrist in line with the hinge of the fixture and the dynamometer aligned with the centre line of the participants forearm. Each level of the respective posture e.g. $0^0$, $45^0$ and $90^0$ were maintained for each experimental exercise. Repetition was set and participants were instructed to adjust the cycle time (repetition) to a level they felt they could perform for 8 hour working a day. Discomfort was recorded with the help of Visual Analogue Scale (VAS) marked with 0, 5 and 10, means No discomfort, Moderate discomfort and High discomfort at the end of 10 minutes trial. The same procedure was repeated for rest of the three parts of experiment. For each cycle the exertion time was set at 1 s throughout the entire experiment, therefore in line with Abu-Ali et al. (1996) and Finneran & O'Sullivan (2010).

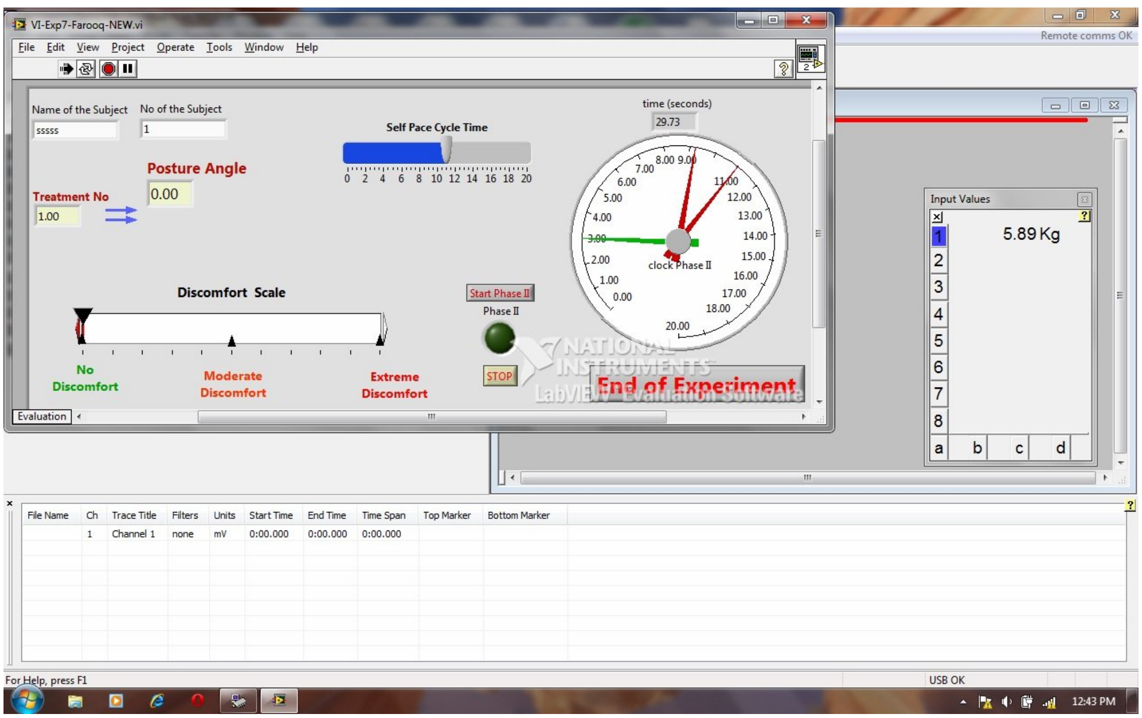


**Figure 1.** Screen shot for the experiment

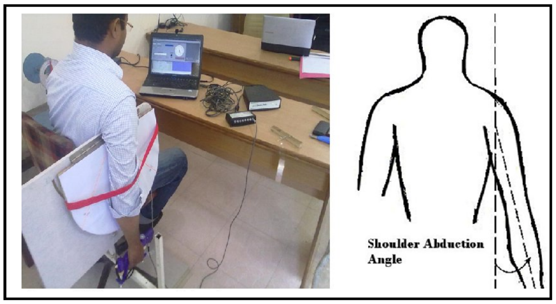


**Figure 2.** Upperarm abduction

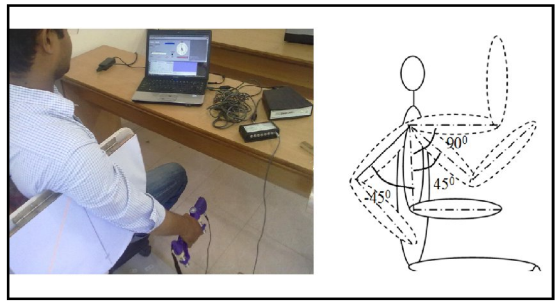


**Figure 3.** Shoulder flexion/extension

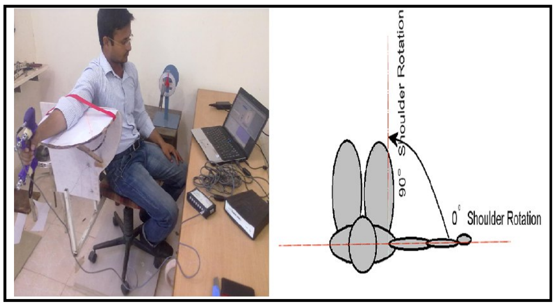


**Figure 4.** Shoulder rotation (adduction)

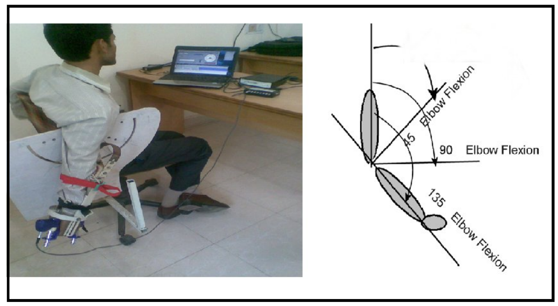


**Figure 5.** Elbow flexion angles

## RESULTS

**Part 1:** The data of SPCT were analysed using ANOVA, while participant was considered as random factor. The results were presented in Table 1 for the effect of upper arm abduction on SPCT. It was found that abduction angle was significant on SPCT (at p = 0.028). Further post hoc test using SNK showed that neutral upper arm was significantly different from 45$^0$ and 90$^0$ upper arm abduction angle. However, to see if there was any difference in the perceived discomfort score for this duration of test, ANOVA was also done for raw discomfort score and found that there were significant difference in discomfort for upper arm abduction angle at p = 0.008. Further, graphically, SPCT times were plotted against upper arm abduction angle and profile using linear regression was shown in Figure 6. This figure showed that SPCT was about 9 seconds that give a rest of 8 seconds after each exertion as per the experimental task.

**Part 2:** The ANOVA analyses of the data of SPCT with respect to shoulder flexion/extension showed that the shoulder flexion/extension was highly significant (p = 0.006) on SPCT (Table 1). The Post hoc test using SNK gave an idea that -45$^0$ shoulder extensions had high requirement of rest period after each experimental exertion. Although no significant differences were noticed for neutral, 45$^0$ and 90$^0$ shoulder flexion angles on SPCT. In this part of the experiment contrary to the results of Part 1, the RDS was not significantly affected due to postural angle. The Profile of SPCT was also drawn to get the idea of how SPCT changes with respect to shoulder flexion/extension (Figure 7). This figure also highlighted that on the extension side SPCT as desired by the participants were quite high of the order of 17 seconds compared to flexion side where this value was around 11 seconds.

**Part 3:** The analyses of the data of SPCT to look the effect of Shoulder rotation towards midline were carried out using ANOVA as presented in Table 1. The results showed no significant effect of shoulder rotation on SPCT for these levels as chosen for the Part 3 of this experiment. Also similar to the findings of the Part 2 of this experiment there was not significant effect of shoulder rotation on discomfort for this duration of the experimental task. However there was not significant effect of shoulder rotation on SPCT but profile plot as shown in Figure 8 gave an indication towards decrease in SPCT time with the increase in shoulder rotation.

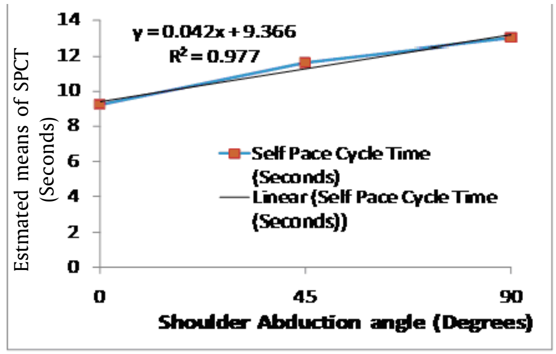


**Figure 6.** Profile plot of SPCT vs. Upper arm abduction angle

| Source | Sum of Squares | Degrees of freedom | Mean Square | F-value | p-value |
|---|---|---|---|---|---|
| **Abduction** | **36.93** | **2** | **18.47** | **5.741** | **0.028** |
| Participant | 10.27 | 4 | 2.57 | 0.798 | 0.559 |
| Abduction * Participant (Residuals) | 25.73 | 8 | 3.22 | | |
| **Shoulder Flexion/Extension** | **139.72** | **3** | **46.574** | **6.954** | **0.006** |
| Participant | 43.44 | 4 | 10.861 | 1.832 | 0.202 |
| Shoulder Flexion/Extension * Participant (Residuals) | 68.33 | 11 | 6.212 | | |
| Shoulder Adduction | 34.53 | 2 | 17.27 | 1.27 | 0.332 |
| Participant | 40.40 | 4 | 10.10 | 0.74 | 0.589 |
| Shoulder Adduction * Participant (Residuals) | 108.80 | 8 | 13.60 | | |
| Elbow Flexion | 53.733 | 2 | 26.867 | 3.148 | 0.098 |
| Participant | 46.933 | 4 | 11.733 | 1.375 | 0.324 |
| Elbow Flexion * Participant (Residuals) | 68.267 | 8 | 8.533 | | |

Table 1. Results of ANOVAs to see the effect of different postures selected in the experiment on SPCT

**Part 4:** The data of SPCT were analyzed using ANOVA considering participants as random factor. The results presented in Table 1 showed that there was no significant effect of elbow flexion angle on SPCT. But discomfort was found significantly affected due to change in elbow flexion angle at $p = 0.029$. The profile plot (Figure 9) of SPCT vs. elbow flexion angle showed that SPCT decreases with the increase in elbow flexion angle. That showed that rest time was less desired at $90^0$ and $135^0$ elbow flexion angles compared to $45^0$ elbow flexion angles.

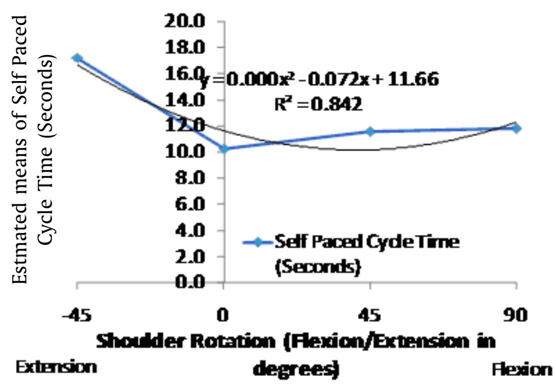


**Figure 7.** Profile plot of SPCT vs. shoulder rotation (flexion/extension)

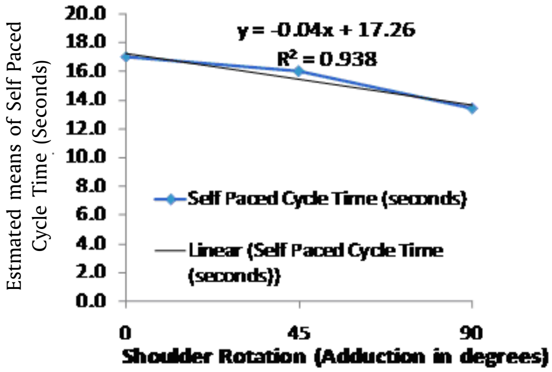


**Figure 8.** Profile plot of SPCT vs. shoulder rotation (adduction)

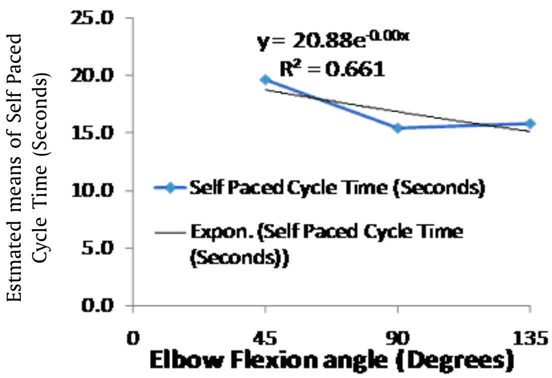


**Figure 9.** Profile plot of SPCT vs. elbow flexion angle

## DISCUSSION

The working postures may be improved and postural stresses may be reduced by controlling the force and levels/frequency of exertions etc. for working comfortably, enhanced productivity and to prevent WMSDs. Meerding et al. (2005) emphasized that there is a real requirement for more quantitative data to augment qualitative data on the relationship between perceptions of discomfort and its relationship with productivity. Higher levels of force resulted in higher discomfort and higher SPCT (Finneran & O'Sullivan, 2010). It was also documented that higher force levels require increased rest time for recovery (El ahrache & Imbeau, 2009). It was evident that requirement of rest duration is more for more deviated posture while away from neutral. Upper arm abduction and Shoulder flexion/ extension have shown significant effect on SPCT.

It was found that in some of the conditions (for abduction and shoulder flexion/ extension), the postures were significant and in some conditions (adduction and elbow flexion), the postures were not significant on SPCT, consequently it can be said that investigations were made to observe the effects of postures for very few levels, if more levels could be investigated the results will tell more interesting points. It is important either worker was able to finish the tasks in a given time or not to get the desired target of productivity, to see this point the perceived discomfort score was also recorded in this experiment at the end of the given 10 minute's duration. Kumar & Kumar (2008) in a survey of cleaning industry workers found that, where jobs were physically demanding and few ergonomics interventions were in place, operators were unable to complete tasks in the allotted time due to pain and discomfort. However, slightly unexpected results were noticed for this as the values of Raw discomfort score (RDS) were of the order of approximately less than 6 units in worse case (mean of RDS for part-1: 3.92 units, part-2: 3.60, part-3: 4.03, & part-4: 2.67). This showed that there was no any condition where subject was not able to finish the task. Hence participants were found to be fairly aware about the fact that they had to maintain the pace at which they could work for 8 hour job.

From Figure 7, it was observed that the shoulder rotation (Flexion/Extension) was the most strenuous posture specially the angle -$45^0$ was the toughest posture to complete the task the most participants reported the pain, in the arm. The effect of posture findings are in line with other studies. Carey and Gallwey (2002) investigated the effects of posture, pace and exertion on discomfort, and found that extreme flexion (60% ROM) resulted in higher discomfort than extreme extension or neutral postures investigated. There was a significant difference between SPCT for shoulder flexion compared to extension.

## CONCLUSIONS

- SPCT was significantly affected by upper arm abduction ($p < 0.028$). It was also observed that self paced cycle time was more as the upper arm abducted more towards $90^0$.
- Shoulder flexion/extension was highly significant on SPCT ($p = 0.006$).
- Shoulder rotation (adduction) was not found significant but increase in angle towards midline showed slight decrease in SPCT as per profile plot.
- SPCT was not significant for elbow flexion angle but profile showed that decrease in discomfort was evident of low SPCT (i.e. higher productivity) with increase in angle.

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