# The Musculoskeletal Disorder Effects on the Use of Single and Dual Monitor Workstations

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***Abstract*—Technological advances make computers important part of every workplace. However, excessive exposure to computers brings a number of health concerns. Previous studies showed that user's performance and efficiency were positively affected by the use of dual and/or multiple screen monitors; however the effects on the use of single/dual screen monitors on musculoskeletal disorder in upper extremities is not yet fully explored. In this regard, this paper intends to identify the effects on the use of single and dual monitors on the musculoskeletal disorder. Three different tasks of reading, searching/finding, and typing were used in the study. Using various monitor setups, the participants' response times were recorded, body postures were analyzed and movement of head and neck postures was assessed. Results indicated that the musculoskeletal discomfort experienced by participants was significantly affected by the monitor layout and the type of tasks. Users adopted more rotated head neck postures while working with dual monitor compared to single monitor. Working postures with respect to the monitor layout were found to depend on the type of task. Typing task obtained higher postural load followed by search/find, and reading tasks. Results also showed that age and gender significantly affect musculoskeletal discomfort experienced by participants.**

***Keywords—Multimedia video task analysis; musculoskeletal disorder; rapid upper limb assessment; single/dual visual display unit***

## I. INTRODUCTION

Technological advances make computers important part of every workplace. Employees use single and/or dual monitors in some companies to perform their tasks. Studies showed that users are significantly more productive and satisfied in using large monitors and/or multiple monitors [1]. However, excessive exposure to computers brings a number of health concerns. Many individuals who work at a computer report a high level of job-related complaints and symptoms, including increased prevalence of neck and shoulder musculoskeletal disorders among the VDU (visual display unit) users [2], [3], [4], [5], [6], [7], [8], [9].

Moreover, user adopted asymmetrical, more rotated, head and neck postures while working with dual screen monitors. Working postures and muscle activity pattern with respect to the monitor layout were found to depend on the type of the task. Typing task elicited higher postural and muscle activity load followed by search and find, and reading tasks. Independent of the tasks, right sternocleidomastoid muscle showed higher activity levels for dual screen layout. This increased activity level may be due to increased head rotation associated with the dual screen monitors [10]. Moreover, mouse users are also exposed to the same recognized risk factors associated with keyboard use as well as the additional risk factor of arm abduction during mouse use. Additional risk factors related to mouse use have the potential to increase prevalence of computer-related injuries [11], [12].

This paper aimed to study and assess the effects of different arrangement of monitor layouts and the type of tasks on musculoskeletal disorders among the employees of a financial company working on dual monitor in the Philippines. Specifically, the objectives of the study are the following:

1) To determine the significant factors affecting the use of single/dual monitor on musculoskeletal disorder according to a) monitor angle, b) type of task, c) age, and d) gender.
2) To determine relationship between identified significant factors to the musculoskeletal discomfort.
3) To recommend efficient layout design for the single and dual monitor based on the tasks performed.

## II. METHODS

An experimental study was conducted to determine the factors that directly contribute to the participant's musculoskeletal disorder. The variables used were age, gender, type of tasks and the different arrangement of monitor layout. The different arrangement of VDU Layouts varies on the monitor angle, while mouse and keyboard remain in fixed position. The monitor angles for single monitor were adjusted into 30$^{o}$, 15$^{o}$, 0$^{o}$, -15$^{o}$, -30$^{o}$ while that of the dual monitor the monitor angles were set to 180$^{o}$ (with respect to horizontal), 165$^{o}$ (with respect to V-shaped), 165$^{o}$ (with respect to L-shaped), 150$^{o}$ with respect to (V-shaped), and 150$^{o}$ (with respect to L-shaped) as shown in Fig. 1.

Typically, the VDU layout for the single monitor is zero degree, however, 15 and 30 degrees angles were included since some users of VDU place their monitor on either the left or right side of the table at a given angle due to space limitation.

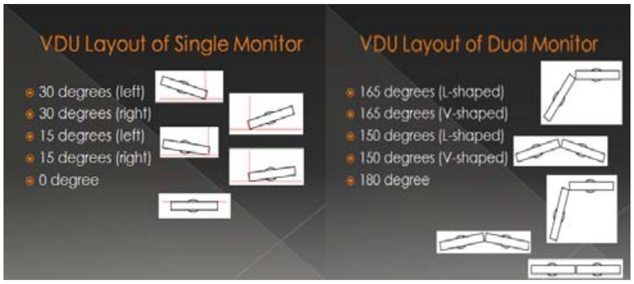


Fig. 1. VDU layout of single and dual monitors

The participants comprised of seven male (3 with ages less than 31 years old; 2 with ages between 31 years old and 40 years old; and 2 with ages greater than 41 years old) and eight female (2 with ages less than 31 years old; 3 with ages between 31 years old and 40 years old; and 3 with ages greater than 41 years old) employees from a financial company who use computers for a working duration of eight hours. Moreover, all participants were considered healthy and free from any type of musculoskeletal disorders.

Participants performed three different tasks such as typing, reading and searching and finding. These tasks are repeated depending on the number of arrangement of monitor layouts in the experimental study both for single and dual monitor. Their response times (commences when participants start doing the task and ends when the participants release hand from the mouse) in performing the tasks were recorded. Shorter response times are preferred in each task.

Survey questionnaires were administered to participants comprised of Basic Profile of the Participants to determine their demographic profile and Laptop Specific Cornell Musculoskeletal Disorder Questionnaire (LCMDQ) to determine how frequent the discomfort is experienced, the intensity of the discomfort, and the interference of the discomfort throughout the duration of the working period. To have an accurate result, the participants recorded the pain they had encountered one week before answering the survey questionnaires. The LCMDQ scores were computed by multiplying the frequency scores, discomfort scores and interference scores. The higher the scores, the greater is the risk of musculoskeletal disorder.

Furthermore, the researchers also conducted a Rapid Upper Limb Assessment (RULA) on the participants in order to analyze their posture and position of their body during the experimental study. This assessed the risk levels on the biomechanical and postural of the body specifically neck, trunk, arms, wrists and upper limbs along with muscle function and the external loads experienced by the body. The acceptable risk level scores are scores of 1 to 2, investigate further is to be undertaken with scores of 3 to 4, investigate further and change soon for scores 5 to 6, and investigate and change immediately for score of 7.

Selected participants were also videotaped to determine the motion of head neck postures and recorded their frequency and duration of flexion consisting of bending and twisting using the multimedia video task analysis (MVTA). The higher the bending and twisting scores, the effect of musculoskeletal disorder is also high.

The data gathered were then subjected to statistical tests using analysis of variance and correlation.

## III. Results

### A. RULA Analysis

Table 1 shows the results of participants RULA scores using a single monitor.

TABLE 1. RULA RISK INDEX SCORES OF PARTICIPANTS USING A SINGLE MONITOR

| VDU Angle | RULA Risk Index Scores Per Task | | | |
|---|---|---|---|---|
| | Reading | Search and Find | Typing | Average |
| 30ºL | 4.00 | 5.53 | 6.27 | 5.27 |
| 15ºL | 3.47 | 4.87 | 4.80 | 4.38 |
| 0º | 3.20 | 4.53 | 4.80 | 4.31 |
| 15ºR | 3.40 | 4.80 | 4.93 | 4.38 |
| 30ºR | 3.53 | 5.00 | 5.53 | 4.69 |
| Average | 3.52 | 4.95 | 5.27 | 4.58 |

The participants who performed the typing task using the single monitor obtained the highest RULA risk index score while the reading task got the lowest RULA score.

The high RULA risk index score in typing task may be due to participants bending their heads while doing the task which may expose them to upper limb musculoskeletal discomfort. Based on the RULA results, the participants usually bend their head from 0° to 20°, bend their body from 0° up to 20°, the shoulder and upper arm have a degree of flexion of between $20^0$ and $45^0$, move their forearm from 0° up to 60° along with the use of mouse and keyboard, twist their wrist in mid-range, and some of their legs and feet were not supported while performing their typing task.

Considering the five monitor angles, it was noticeable that angle of 0° resulted in the lowest RULA scores for all tasks performed. This can be attributed to the fact that the respondents do not have to twist or bend their heads while performing their tasks, thus they did not experience discomfort. On the other hand, monitor angle of 30° from left showed the highest RULA scores for all tasks performed which indicates that participants rotated their head from left to right frequently. The respondents have also to exert more twisting and bending of their heads in order to perform the tasks of reading, search and find, and typing the required data. Furthermore, this also indicates that as the angle of monitor is increased with respect to the horizontal position, participants find difficulty in performing the given task. Furthermore, younger participants tend to have the lowest RULA scores compared to older participants. This can be attributed to their age and their flexibility to perform the visual demand of the task.

On the other hand, the typing and reading tasks got the highest and lowest RULA scores, respectively, using the dual monitor as presented in Table 2. It is noticeable that the same results were obtained using both single and dual monitors.

TABLE 2. RULA RISK INDEX SCORES OF PARTICIPANTS USING A DUAL MONITOR

| VDU Angle | RULA Risk Index Scores Per Task | | | |
|---|---|---|---|---|
| | Reading | Search and Find | Typing | Average |
| 180° | 3.73 | 6.53 | 6.33 | 5.53 |
| 165° (V-Shaped) | 3.93 | 6.33 | 6.40 | 5.55 |
| 165° (L-Shaped) | 4.00 | 6.20 | 6.53 | 5.58 |
| 150° (V-Shaped) | 3.87 | 6.07 | 6.20 | 5.38 |
| 150° (L-Shaped) | 3.67 | 6.07 | 6.47 | 5.40 |
| Average | 3.84 | 6.24 | 6.39 | 5.49 |

The high RULA risk index score in typing task can be attributed to participants bending their heads while undertaking the task which may result to exposure to upper limb musculoskeletal discomfort. Based on the RULA results, the participants usually bend their head from 0° to 20°, bend their body from 0° up to 20°, the shoulder and upper arm have a degree of flexion of between $20^0$ and $45^0$, move their forearm from 0° up to 60° along with the use of mouse and keyboard, twist their wrist in mid-range, and some of their legs and feet were not supported while performing their typing task.

From the five monitor angles considered, the angle with the lowest RULA score was the $150^0$ L-shaped for the reading task, and $150^0$ V-shaped and $150^0$ L-shaped for search and find and $150^0$ V-shaped for typing tasks. On the other hand, the monitor angle with highest RULA scores was 165° L-shaped for the reading task, $180^0$ for the search and find and $165^0$ L-shaped for the typing task. These indicate that participants have to rotate their head frequently in performing their tasks using the dual monitor.

Furthermore, an L-shaped dual monitor showed a higher RULA scores compared to a V-shaped dual monitor. This means that the participants have difficulty in performing the tasks using the L-shaped dual monitors because they have to exert more bending and twisting while performing the given task.

The RULA scores for both single and dual monitors indicate an action to investigate further and changes in the work environment or work practice may be required soon.

### *B. MVTA Analysis*

The Multimedia Video Task Analysis (MVTA) was used to determine the participants' body posture performing the given experimental activities of the study. The actual actions of the participants were video-taped in order to record the time and motion obtained in the experimentation. The video cameras were placed at the right and front side of the participant to determine the side bending and twisting occurring. The activities were asses using MVTA Tool, herein for every task the time was split into 5 seconds and record the angle of bending and twisting undertaken.

Table 3 shows the total postural bending scores obtained by the participants in the single monitor. The data indicates the discomfort scores acquired from the different set of monitor angles with respect to the type of tasks.

Bending score refers to the frequency the participants look at the monitor and the keyboard while performing the tasks.

TABLE 3. AVERAGE BENDING LOADING CONSTANT SCORES OF PARTICIPANTS USING A SINGLE MONITOR

| Type of Task | Monitor Angle | | | | | |
|---|---|---|---|---|---|---|
| | 30° | 15° | 0° | -15° | -30° | Average |
| Reading | 1.45 | 1.21 | 1.08 | 1.11 | 1.28 | 1.23 |
| Search and Find | 3.25 | 2.58 | 2.35 | 3.06 | 3.26 | 2.90 |
| Typing | 3.42 | 2.74 | 2.38 | 3.11 | 3.63 | 3.06 |
| Average | 2,71 | 2.18 | 1.94 | 2.43 | 2.72 | 2.40 |

From the above results, reading task discomfort score seemed to be the lowest while the typing task showed the highest discomfort score. In terms of monitor angle, a $0^0$ angle got the lowest bending loading score while $30^0$ monitor angle obtained the highest score. This means that as the angle increases, more musculoskeletal discomfort is experienced by participants.

Table 4 presents the twisting scores obtained in head neck motion for single monitor with respect to the factors considered such as monitor angle and the type of task. Twisting scores specify the frequency the participants rotate their head from the left and/or to the right side of the monitor.

With regard to the type of task, the search and find task showed the highest twisting load score while the reading task obtained the lowest score. The search and find task involves more twisting of head to accomplish the required activity while reading has the least twisting movement involved in performing the task.

In terms of monitor angle, a $0^0$ angle got the lowest twisting loading score while $30^0$ monitor angle obtained the highest score. This only showed that as the angle increases, more musculoskeletal discomfort is experienced by participants.

TABLE 4. AVERAGE TWISTING LOADING CONSTANT SCORES OF PARTICIPANTS USING A SINGLE MONITOR

| Type of Task | Monitor Angle | | | | | |
|---|---|---|---|---|---|---|
| | 30° | 15° | 0° | -15° | -30° | Average |
| Reading | 2.67 | 2.25 | 1.77 | 2.25 | 2.89 | 2.37 |
| Search and Find | 3.11 | 2.54 | 1.78 | 2.19 | 3.23 | 2.57 |
| Typing | 3.47 | 2.46 | 1.38 | 2.15 | 3.27 | 2.55 |
| Average | 3.08 | 2.42 | 1.64 | 2.2 | 3.13 | 2.50 |

Based on the results of ANOVA of MVTA scores for single monitor considering the postural load index obtained for bending as shown in Table 5, it showed that monitor angle (p = 0.0361) and the type of task (p = 2.22E-07) indicated significance on the head-neck bending posture. However, their interaction (p = 0.8429) between them showed no significant difference. This means that the higher the postural loading scores in the type of task and monitor angle would indicate higher severity of discomfort that may be felt by the participants. Thus in the type of task, the typing task showed higher discomfort level followed by search and find and reading tasks. This is mainly due to the reason that the typing task has more bending motions compared to the other tasks since it has to frequently look into the keyboard while typing and checking the typed data in the monitor. On the other hand, the reading task has he least motion involved with respect to keyboard and monitor interaction.

TABLE 5. ANALYSIS OF VARIANCE OF BENDING AND TWISTING LOADING CONSTANT SCORES OF PARTICIPANTS USING A SINGLE MONITOR

| Factors | Bending | | Twisting | |
|---|---|---|---|---|
| | P-value | Interpretation | P-value | Interpretation |
| Type of Task | 2.22E-07 | Significant | 0.5624 | Not Significant |
| Monitor Angle | 0.0361 | Significant | 0.0002 | Significant |
| Interaction | 0.8429 | Not Significant | 0.8199 | Not Significant |

Considering the postural load index obtained in twisting using a single monitor, the results of ANOVA as shown in Table 5, indicated that the type of task (p = 0.5624) and the interaction of the type of task and monitor angle (p = 0.8199) showed no significant difference on the head-neck twisting posture It was only the monitor angle that showed significant difference on the twisting loading score of participants. As such as the angle of monitor increases, the discomfort level also increases.

TABLE 6. AVERAGE BENDING LOADING CONSTANT SCORES OF PARTICIPANTS USING A DUAL MONITOR

| Type of Task | Monitor Angle | | | | | |
|---|---|---|---|---|---|---|
| | 180 $^o$ | 165 $^o$ (V) | 165$^o$ (L) | 150 $^o$ (V) | 150 $^o$ (L) | Average |
| Reading | 1.44 | 1.10 | 1.22 | 1.00 | 1.14 | 1.18 |
| Search and Find | 3.35 | 2.89 | 3.09 | 2.26 | 3.30 | 2.98 |
| Typing | 3.97 | 3.64 | 3.86 | 3.06 | 3.59 | 3.62 |
| Average | 2.92 | 2.54 | 2.72 | 2.11 | 2.68 | 2.59 |

Table 6 shows the total postural bending scores obtained in dual monitor with respect to the factors considered namely monitor angle and the type of task. The reading task showed the lowest bending discomfort score while the typing task got the highest score. In terms of monitor angle, a $150^0$ V shaped angle got the lowest bending loading score while $180^0$ monitor angle obtained the highest score. It is evident that as the monitor angle increases, the participants experienced more musculoskeletal discomfort. Moreover, the V- shaped dual monitor angle showed a lower postural discomfort level compared to the L-shaped dual monitor.

Compared with the single monitor, the dual monitor indicated a lower bending discomfort score for reading, however, the bending scores obtained in dual monitor for typing and search and find task tend to be higher than the single monitor. In terms of monitor angle, the single monitor got the lowest bending loading score compared to the dual monitor.

TABLE 7. AVERAGE TWISTING LOADING CONSTANT SCORES OF PARTICIPANTS USING A DUAL MONITOR

| Type of Task | Monitor Angle | | | | | |
|---|---|---|---|---|---|---|
| | 180 $^o$ | 165$^o$ (V) | 165$^o$ (L) | 150 $^o$ (V) | 150 $^o$ (L) | Average |
| Reading | 4.82 | 3.95 | 4.31 | 3.48 | 4.24 | 4.16 |
| Search and Find | 5.39 | 5.03 | 5.33 | 4.36 | 5.10 | 5.04 |
| Typing | 3.51 | 3.00 | 3.29 | 2.28 | 3.12 | 3.04 |
| Average | 4.57 | 3.99 | 4.31 | 3.37 | 4.15 | 4.08 |

Table 7 presents the twisting scores obtained in head neck motion for the dual monitor with respect to the type of task and monitor angle. The typing task obtained the lowest score while the search and find got the highest score.

The search and find task got the highest twisting score because it requires more twisting motion in performing the task of searching and finding the data in one monitor and transferring to another monitor. On the other hand, the typing task got the lowest twisting score because of minimal twisting movement in the dual monitor

In terms of monitor angle, a $150^0$ V shaped monitor angle got the lowest twisting loading score while $180^0$ monitor angle obtained the highest score. This seemed to indicate that participants experience more musculoskeletal discomfort as the monitor angles increase. Based on the results, as the angle of the monitor is increased, the participants experienced higher twisting discomfort level. Also, the V-shaped dual monitor setup is better compared to the L-shaped dual monitor setup for the reason that the V-shaped monitor requires less eye and head and neck movement as compared to the L-shaped monitor where the participants have to exert more effort in performing the task because of the setup of the dual monitors where the twisting movement is focused only in one direction, either left or right position.

Comparing the twisting loading scores of participants using the single monitors and dual monitor showed the single monitor got the lowest twisting loading score for both the type of tasks performed and the monitor angle. His indicates that the participants experienced more twisting discomfort using the dual monitor setup as compared to the single monitor setup.

TABLE 8. ANALYSIS OF VARIANCE OF BENDING AND TWISTING LOADING CONSTANT SCORE OF PARTICIPANTS USING A DUAL MONITOR

| Factors | Bending | | Twisting | |
|---|---|---|---|---|
| | P-value | Interpretation | P-value | Interpretation |
| Type of Task | 1.69E-09 | Significant | 1.53E-07 | Significant |
| Monitor Angle | 0.0305 | Significant | 0.0033 | Significant |
| Interaction | 0.8738 | Not Significant | 0.9978 | Not Significant |

Moreover, the results of the ANOVA, as shown in Table 8, indicated that both type of task (p = 1.69E-09) and monitor angle (p = 0.0305) have significant differences on the head-neck bending posture for dual monitor. On the other hand, the interaction between them (p = 0.8738) showed no significant effect on the head-neck bending posture as experienced by the participants using the dual monitor. On the other hand, both the type of task (p = 1.53E-07) and the monitor angle (p = 0.0033) showed significant difference on the head-neck twisting posture. However, the interaction between the two factors (p = 0.9978) showed no significant effect on the head-neck bending posture as experienced by the participants.

The results indicated that the type of task and the monitor angle significantly affect the prevalence of musculoskeletal discomfort to the participants because they both require the bending and twisting of head and neck while performing the task.

### C. *Response Time of Participants in Using Single and Dual Monitors*

Table 9 shows the response time of participants in using the single and dual monitors with respect to the type of tasks. Results showed that it took longer time for participants to complete the reading task using the dual monitor as compared to the single monitor which showed significance (p = 7.56E-15). This was evident since participants have to deal with two monitors in accomplishing this task. However, in the search and find and typing tasks, the participant's response time is faster using the dual monitor compared to the single monitor and also showed significant difference as evidenced by the p-value of 1.27E-06 and 1.83E-05, respectively.

Table 9. RESPONSE TIMES (IN SECONDS) OF PARTICIPANTS USING A SINGLE AND DUAL MONITOR BY TYPE OF TASK

| Type of Task | Response Times (in seconds) | |
|---|---|---|
| | Single Monitor | Dual Monitor |
| Reading | 46 | 54 |
| Search and Find | 512 | 435 |
| Typing | 617 | 496 |

Moreover, as the participant's age increases, the response time in doing the task using either the single or dual monitor also increased. This may be due to the fact that older participants have difficulty in doing these three tasks compared to the younger participants. This was confirmed from the statistical test using ANOVA (p = 7.6E-17 for age; p = 1.34E-07 for type of Monitor; and 3.79E-06 for interaction) where the participant's age, type of monitor used, and interaction between age and type of monitor showed significant difference on the three types of task.

### D. *LCDMQ Analysis*

The results of the LCMDQ (Laptop Cornell Musculoskeletal Discomfort Questionnaire) indicated that majority of the participants feel no pain and if there is pain, it can be ignored. However, it was noticeable that older participants tend to have a high discomfort scores which indicated that as the participant's age increases, the prevalence of musculoskeletal disorder also increases. In addition, female participants obtained higher discomfort scores.

Furthermore, the top ten body parts with the highest percentage prevalence of musculoskeletal disorder are the neck (16.55%), shoulder (14.01%), upper back (13.62%), right wrist (9.83%), the right hand/finger (7.57%), left shoulder (6.72%), lower back (5.59%), left hand/finger (4.56%), left wrist (4.07%), and hip/buttocks (3.29%). These body parts are usually affected by musculoskeletal disorder because of the nature of work performed by people who usually are in the seated position. It is in these body parts where majority of the demands of work load contents are being utilized the most. Hence, the prevalence of the musculoskeletal disorder is evident.

Furthermore, Table 10 showed the results of the analysis of variance between age and gender. Age (p = 0.03137) and gender (p = .04832) of participants have significant effects with the musculoskeletal discomfort experienced by them. However, their interaction showed no significant difference on participants' musculoskeletal disorders.

TABLE 10. ANOVA RESULTS OF LCMDQ

| Factors | P-Value | Interpretation |
|---|---|---|
| Age | 0.03137 | Significant |
| Gender | 0.04832 | Significant |
| Interaction between Age and Gender | 0.17480 | Not Significant |

The results indicated that the tolerance of pain experienced by participants while doing their tasks differ significantly as they age and differences in their body structure.

### E. *Correlation Analysis*

A correlation analysis was performed in order to identify the significant relationship of the factors associated for single and dual monitor such as age, gender, types of task, duration of task, monitor layouts to the musculoskeletal disorders.

The results showed that the coefficient of correlation of participant's age (r = 0.7509) with respect to musculoskeletal discomfort data taken from the LCMDQ indicated that age has a strong positive linear relationship to the musculoskeletal discomfort which also showed significance (p = 0.0013). This means that age is a good factor in having an exposure to musculoskeletal disorder. As one ages, the likelihood of developing musculoskeletal disorder is also high.

If gender of participants is considered, the results indicated that the coefficients of correlation of male participants showed a positive correlation (r = 0.7046) but does not showed significant difference (p = 0.077). On the other hand, the coefficient of correlation of female participants showed positive linear relation (r = 0.9326) and showed significant difference (p = 0.00073). This indicates that the female participants are more prone to be exposed to musculoskeletal discomfort with regard to their ages. Another reason is the body structure of female makes them more prone to musculoskeletal disorder.

Results also showed a positive relationship between age, response time both for single and dual monitor and LCMDQ. The coefficient of correlation between age and response times of participants' using the single monitor and dual monitor was r = 0.851 and r = 0.799, respectively. These indicate that age showed significant difference with respect to the use of single (p = 5.79E-05) and dual (p = 0.00035) monitors. This showed that older participants obtained lower productivity compared to younger and middle-aged group participants. They cannot work fast as compared to the younger ones. Furthermore, it is evident that the response time of participants using dual monitor is much faster than doing them in the single monitor. This indicates that participants are more exposed on musculoskeletal discomfort in using dual compared to single monitor. The results of this correlation are relatively the same with the results gathered in RULA and MVTA analysis that participants in dual monitor are more exposed on musculoskeletal discomfort.

With regard to the type of monitor used by participants, the coefficient of correlation (r = 0.851) between the single and dual monitors showed a strong positive correlation which also showed significance (p = 5.8E-05). Moreover, the coefficient of correlation of the single and dual monitors with respect to the participant's LCMDQ indicated a positive correlation, however, the single monitor (r = 0.7533) indicates a strong correlation as against the dual monitor (r = 0.6611) which has a moderate relationship with LCMDQ. The single monitor and dual monitor manifested significant difference with a p-value of 0.0011 and 0.0073, respectively.

## IV. Conclusion

The following are the conclusions derived from the results of the study:

a) Monitor angle, type of task, age and gender are significant factors that may expose users to musculoskeletal disorder regardless of the type of monitor being used.

b) In order to minimize twisting discomfort, reading, search and find, and typing tasks are preferred to be performed using single monitor compared to the dual monitor.

c) The angle of single monitor should be at 0 degree or directly in front of the user in order not to expose the user to flexion that contributes to the prevalence of musculoskeletal discomfort. On the other hand, the angle of dual monitor should be placed at 150 degrees since this accumulated lowest RULA and MVTA scores compared to the other angles considered in the study.

d) In order to minimize the bending discomfort, reading task is preferred to be performed using dual monitor while the search and find and typing tasks are preferred to be performed using single monitor.

e) Female participants are more prone to be exposed to musculoskeletal discomfort with regard to their ages.

f) The top five body parts with the highest percentage prevalence of musculoskeletal disorder are the neck (16.55%), shoulder (14.01%), upper back (13.62%), right wrist (9.83%), and the right hand/finger (7.57%).

g) The pain experienced by participant in their task showed significant difference with regard to their age and gender.

h) There is a significant relationship between the age and type of monitor on the musculoskeletal discomfort of participants.

i) Typing task obtained higher postural load followed by search and find, and reading tasks.

j) With respect to response time, it is also recommended that for the reading task, it is better to use the single monitor while for search and find and typing tasks, it is recommended to use dual monitor.

## V. Recommendation

The following recommendations are proposed by the researchers:

a) In order to further improve the analysis of the study, include other factors such as work experience, monitor brightness and workstation environment such as humidity, room temperature and noise level to determine effects on the musculoskeletal disorders in using the single and dual monitors. These factors will be able to provide significant insights on adverse effects on the musculoskeletal discomforts to users of the single and dual monitors.

b) Identify other tasks, aside from the tasks mentioned in the study, that users perform in order to determine whether which of the task is appropriate for single monitor or dual monitor. This will provide administrators determine the type of monitor to use based on the tasks they frequently employed in their work.

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