

CHAPTER V

RESULTS AND DISCUSSION

5.1. Muscle Contraction Analysis

Table 4.2 presents the result of extension posture in performing typing activity on *Flexor Digitorum Superficialis* (FDS) muscle. In 10° extension, the percentage of maximum voluntary contraction (%MVC) on FDS muscle is 8.891% for male and 8.815% for female while the average is 8.853% of MVC. In 20° extension, the average of percentage of maximum voluntary contraction on FDS muscle is 9.568 % for male and 9.735 % for female and the average is 9.651 % of MVC. In 30° extension, the average of percentage of maximum voluntary contraction on FDS muscle is 17.715 % for male and 17.746 % for female and the average is 17.731 % of MVC. The last experiment in extension posture is 40° extension, with the average of %MVC on FDS muscle is 23.270% for male, 22.359% for female and the average is 22.814% of MVC. The result of the experiment shows that the muscle contraction was increasing as the angle inclination increases as referred in Figure 5.1 below. Criswell (2011) stated that the higher the percentage value of MVC from muscle contraction, the muscle endurance will tend to be weaker and the muscle will experience fatigue faster. Referring to Stalling et al. in Criswell (2011), the sustained and prolonged muscle contraction will disclose the sign of muscle fatigue and begins at 11 %MVC. It shows that 10° and 20° extension of wrist posture in typing activity still safe to use. On the contrary, the wrist posture of 30° and 40° extension already considered as unsafe posture for typing. The same result is shown in the percentage of maximum voluntary contraction on APB muscle in extension motion as presented in Table 4.3.

On APB muscle, the percentage of maximum voluntary contraction in 10° extension for male is 9.960%, 9.404% for female while the average is 9.682 % of MVC as shown in Table 4.3. In 20° extension, the average of percentage of maximum voluntary contraction on FDS muscle is 10.761% for male and 10.643% for female and the average is 10.702% of MVC. In 30° extension, the average of percentage of maximum voluntary contraction on FDS muscle is 22.279% for male and 18.014% for female and the average is 20.147% of MVC. The last experiment in extension motion is 40° extension, with the average of %MVC on FDS muscle is 27.633 % for male, 24.861% for female and the average is 26.247% of MVC.

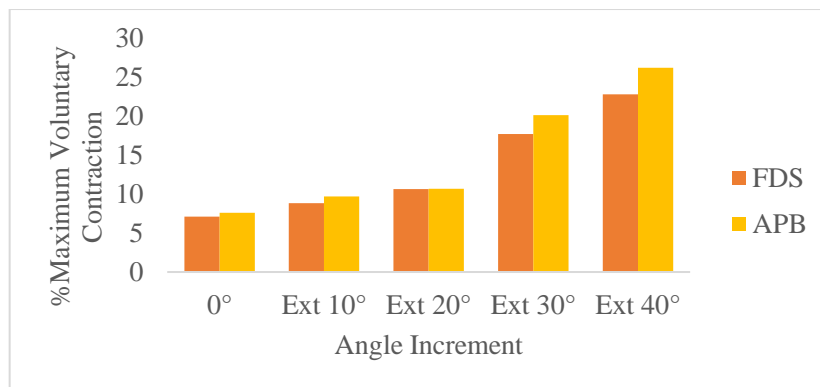


Figure 5.1. %MVC in Extension Wrist Posture

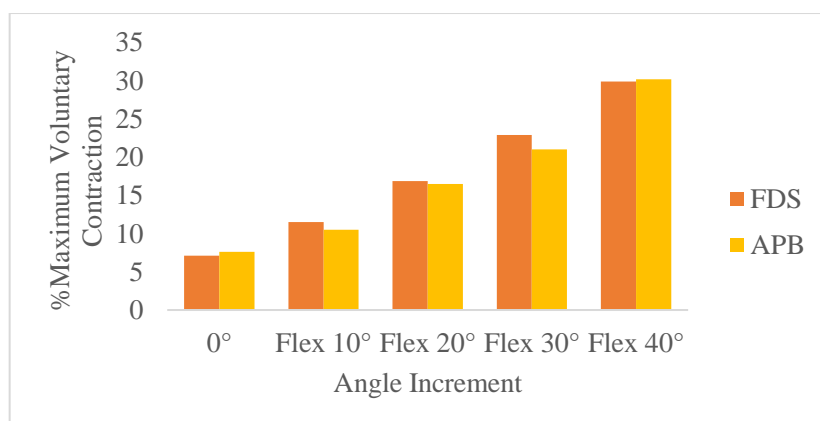


Figure 5.2. %MVC in Flexion Wrist Posture

The %MVC graph as seen in Figure 5.2 above illustrates the incline muscle contraction as the angle increment increases. The percentage of maximum voluntary contraction on FDS muscle in 10° flexion wrist posture as presented in Table 4.2 shows the value of 11.796% for male and 11.206% for female with the average of 11.501% of

MVC. In 20° flexion, the percentage of maximum voluntary contraction is 16.234% for male, 17.577% for female, and 16.851% on average. In 30° flexion, the average of percentage of maximum voluntary contraction on FDS muscle is 24.653 % for male and 21.118 % for female and the average is 22.885 % of MVC. In 40° flexion, the average of percentage of maximum voluntary contraction on FDS muscle is 33.403 % for male, 26.325 % for female and the average is 29.864 % of MVC. Referred to Stalling, 10° flexion can be used to work safely. In contrary, the average of muscle activity in 20° to 40° flexion shows that it is considered as unsafe posture for work. The same result is shown in the percentage of maximum voluntary contraction on APB muscle in flexion motion as presented in Table 4.3.

Referring to Table 4.3, the percentage of maximum voluntary contraction on APB muscle in 10° flexion is 11.502% for male, 9.512% for female while the average is 10.507% of MVC. In 20° flexion, the average of percentage of maximum voluntary contraction on FDS muscle is 17.341% for male and 15.653% for female and the average is 16.497% of MVC. In 30° flexion, the average of percentage of maximum voluntary contraction on FDS muscle is 21.876% for male and 20.098% for female and the average is 20.987% of MVC. The last experiment in flexion motion is 40° flexion, with the average of %MVC on FDS muscle is 28.589% for male, 31.737% for female and the average is 30.163% of MVC.

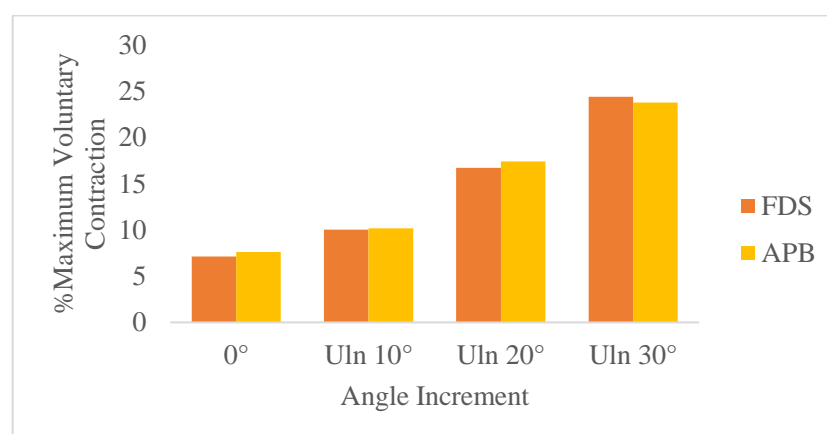


Figure 5.3. %MVC in Ulnar Wrist Posture

Figure 5.3 above illustrates the percentage of maximum voluntary contraction in ulnar wrist posture. Referred to Table 4.2, in 10° ulnar, the percentage of maximum

voluntary contraction (%MVC) on FDS muscle is 8.862% for male and 11.189% for female while the average is 10.025% of MVC. In 20° ulnar, the average of percentage of maximum voluntary contraction on FDS muscle is 16.486% for male and 16.934% for female and the average is 16.710% of MVC. In 30° ulnar, the average of percentage of maximum voluntary contraction on FDS muscle is 27.417% for male and 21.327% for female and the average is 24.372% of MVC. Based on Stalling, it is shown that 10° ulnar still considered as safe posture for work, whereas 20° and 30° ulnar already considered as unsafe posture. The %MVC value on APB muscle in ulnar wrist posture also has the similar result.

Table 4.3 shows the result of ulnar posture in performing typing activity on APB muscle. In 10° ulnar, the percentage of maximum voluntary contraction (%MVC) on APB muscle is 10.607% for male and 9.737% for female while the average is 10.172% of MVC. In 20° ulnar, the average of percentage of maximum voluntary contraction on APB muscle is 19.796% for male and 15.007% for female and the average is 17.402% of MVC. In 30° ulnar, the average of percentage of maximum voluntary contraction on APB muscle is 26.546% for male and 20.954% for female and the average is 23.750% of MVC.

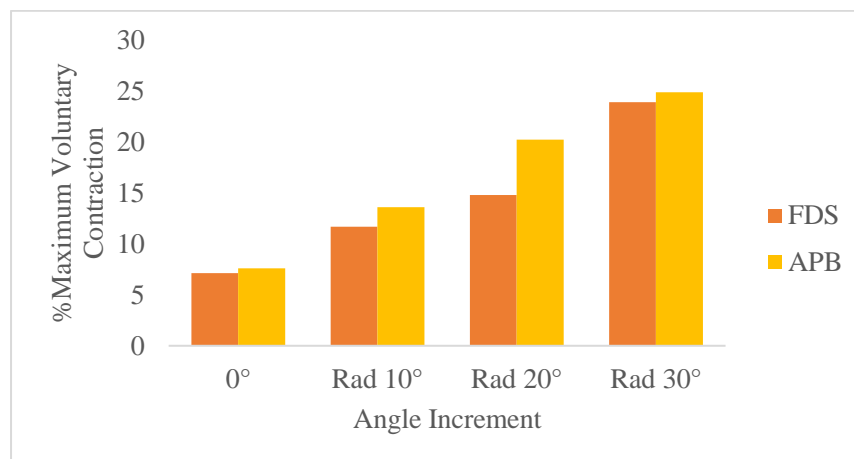


Figure 5.4. %MVC in Radial Wrist Posture

In radial wrist posture, the percentage of maximum voluntary contraction is increasing along with the increasing of angle increment as seen in Figure 5.4 above. Table 4.3 presents the result of radial posture in performing typing activity on APB muscle. In 10° radial, the %MVC on APB muscle is 16.225% for male and 10.981% for female with

the average of 13.603% of MVC. In 20° radial, the average of percentage of maximum voluntary contraction on APB muscle is 23.084% for male and 17.406% for female and the average is 20.245% of MVC. In 30° radial, the average of percentage of maximum voluntary contraction on APB muscle is 26.701% for male and 23.082% for female and the average is 24.892% of MVC. Based on Stalling, it is shown that the posture greater than 10° radial already considered as unsafe posture.

Based on Table 4.2, the percentage of maximum voluntary contraction (%MVC) on FDS muscle in 10° radial is 11.696% for male and 11.698% for female while the average is 11.697% of MVC. In 20° radial, the average of percentage of maximum voluntary contraction on FDS muscle is 16.019% for male and 13.547% for female and the average is 14.783% of MVC. In 30° ulnar, the average of percentage of maximum voluntary contraction on FDS muscle is 27.121% for male and 20.672% for female and the average is 23.896% of MVC. Referred to Stalling, it is shown that 10° radial still considered as safe posture for work, whereas 20° and 30° radial already considered as unsafe posture. However, the smallest angle that is still safe to use will be used as the ergonomic maximum angle. Thus, in radial motion, the posture greater than 10° radial already considered as unsafe posture.

Grandjean (1986) and Criswell (2011) stated that as long as the percentage of maximum voluntary contraction value is still below 50-60 %MVC, it has not shown a major disturbance as muscle failure and blood circulation disruption. Nevertheless, a study suggested to use keyboard no longer than 20 hours per week to avoid the risk of having carpal tunnel syndrome (Rempel et al., 2008). Callegari et al (2018) also found that there is an evidence of muscle fatigue on forearm and wrist muscle (*trapezius*, *biceps brachii*, and *flexor digitorum communis* muscles) after performing one hour typing task in neutral posture. It is possible that the wrist posture which exceeding the neutral posture will produce muscle fatigue faster. However, further research is needed to determine the duration where the maximum wrist posture in both extension, flexion, ulnar, and radial are started to show fatigue.

The lowest muscle contraction in both *Flexor Digitorum Superficialis* and *Abductor Pollicis Brevis* in typing activity is in 0° neutral posture with the average for male and

female is 6.525 %MVC and 7.716 %MVC respectively and total average is 7.120 %MVC in FDS as seen in Table 4.2. In APB muscle contraction in typing activity, the result shows 8.297 %MVC and 6.929 %MVC respectively for male and female average, with total average of 7.613 %MVC as seen in Table 4.3. Some studies highly suggest neutral posture as the safest posture especially for long duration of work (Rempel et al., 2008; Qin et al., 2013; Loh and Muraki, 2015). It verifies that neutral posture is the safest posture for work.

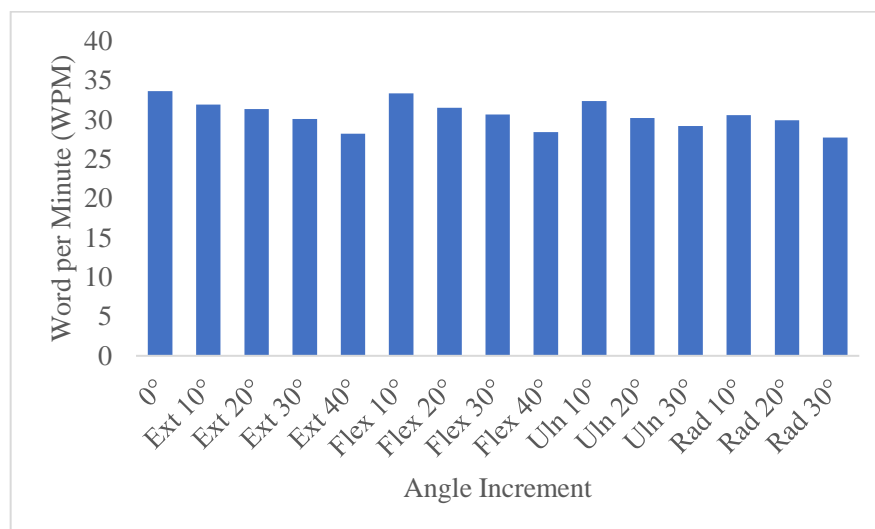


Figure 5. 5. Typing Work Performance

Muscle load also can affect the work performance in typing (Suhartana et al., 2016). The work performance measured by the typed characters divided by time, or simply stated as word per minute (WPM). Based on correlation test result, it shows that the work performance has strong reverse correlation with hand muscle load. In this study, based on the result, it can be shown that the typing performance which showed WPM were decreased as the angle inclination and muscle contraction increases as seen in figure 5.2. The highest WPM was in 0° posture with the average of 33.643 WPM, and the lowest average work performance on each motion is in 40° extension, 40° flexion, 30° ulnar, and 30° radial with 28.214, 28.429, 29.214, and 27.714 WPM, respectively, as presented in table 4.6. It is associated with the muscle load contraction which increases along with the angle inclination. However, the statistical test does not show the significant difference between the decreases typing performance.

5.2. Statistical Test Analysis

Kruskal-Wallis Test and Mann-Whitney difference test were used in this research as the non-parametric statistical test, since the data were not normally distributed and the sample size less than 30. In Kruskal-Wallis test result, the significance value for both FDS and APB muscle activity are <0.05 ($p=0.00$), thus it shows the significant difference for the experiment group tested. The significant differences are shown in the statistic result not specifically shows which angle that become a significant difference, therefore an independent difference test was carried out to find out the differences between each group experiment using the Mann Whitney Test. In this study, the sample size of each group data is fourteen ($n_1 = n_2 = 14$). Thus, the U table value of Mann Whitney Test refer to table 2.4 is 55.

Referring to Table 4.6, the result of Mann Whitney Test in comparing the %MVC on *Flexor Digitorum Superficialis* muscle between 0° and 10° extension is 70 for the U value and 0.198 for the significance value. The H_0 is accepted due to the U value $>$ U table, or $70 > 55$ and the significance value is > 0.05 . In a comparison of 0° and 20° extension on FDS muscle, the U value is 56 and the significance value is 0.054 as presented in Table 4.7. The H_0 is accepted due to the U value $>$ U table, or $56 > 55$ and the significance value is > 0.05 . The result of Mann Whitney Test between 0° and 30° extension on FDS muscle presented in Table 4.8 and shows 29 for the U value and 0.002 for the significance value. H_0 is rejected due to the U value $<$ U table, or $29 < 55$ and the significance value is < 0.05 or $0.002 < 0.05$. The last comparison in extension wrist posture on FDS muscle is between 0° and 40° as presented in Table 4.9 which gives the result of shows 12 for the U value and 0.000078 for the significance value. H_0 is rejected due to the U value $<$ U table, or $12 < 55$ and the significance value is < 0.05 . Based on statistical result, it shows that the wrist posture of 10° and 20° extension has not given any significant differences, whereas wrist posture of 30° and 40° extension give significant difference. The result of %MVC supported the statistical result which indicates that the wrist posture greater than 30° extension considered as unsafe posture.

Table 4.20 shows the result of Mann Whitney Test which compares the %MVC value of 0° and 10° extension on APB muscle. The U value is 64 and the significance

value is 0.118. The H_0 is accepted due to the U value $>$ U table, or $64 > 55$ and the significance value is > 0.05 . In a comparison of 0° and 20° extension on APB muscle, the U value is 42 and the significance value is 0.01 as presented in Table 4.21. H_0 is rejected due to the U value $<$ U table, or $42 < 55$ and the significance value is < 0.05 or $0.01 < 0.05$. The result of Mann Whitney Test between 0° and 30° extension on APB muscle presented in Table 4.22 and shows 11 for the U value and 0.000064 for the significance value. H_0 is rejected due to the U value $<$ U table, or $11 < 55$ and the significance value is < 0.05 . The last comparison in extension wrist posture on APB muscle is between 0° and 40° as presented in Table 4.23 which gives the result of 3 for the U value and 0.000013 for the significance value. H_0 is rejected due to the U value $<$ U table, or $3 < 55$ and the significance value is < 0.05 . Based on statistical result, it shows that the wrist posture of 10° extension does not give any significant difference, whereas wrist posture of 20° , 30° and 40° extension give significant difference. However, the %MVC value on 20° extension is 10.702, which still below the value which can will evince the sign of muscle fatigue according to Stalling. Thus, referring to muscle contraction and statistical test result, wrist posture greater than 30° extension considered as unsafe posture.

Referring to Table 4.10, the result of Mann Whitney Test in comparing the %MVC on *Flexor Digitorum Superficialis* muscle between 0° and 10° flexion is 57 for the U value and 0.06 for the significance value. The H_0 is accepted due to the U value $>$ U table, or $57 > 55$ and the significance value is > 0.05 . In a comparison of 0° and 20° flexion on FDS muscle, the U value is 33 and the significance value is 0.03 as presented in Table 4.11. H_0 is rejected due to the U value $<$ U table, or $33 < 55$ and the significance value is < 0.05 or $0.003 < 0.05$. The result of Mann Whitney Test between 0° and 30° flexion on FDS muscle presented in Table 4.12 and shows 16 for the U value and 0.000165 for the significance value. H_0 is rejected due to the U value $<$ U table, or $16 < 55$ and the significance value is < 0.05 or $0.000165 < 0.05$. The last comparison in flexion wrist posture on FDS muscle is between 0° and 40° as presented in Table 4.13 which gives the result of 5 for the U value and 0.000019 for the significance value. H_0 is rejected due to the U value $<$ U table, or $5 < 55$ and the significance value is < 0.05 . Based on statistical result, it shows that the wrist posture of 10° flexion does not give any significant difference, whereas wrist posture of 20° , 30° and 40° flexion give significant difference. The result of %MVC supported the statistical result which indicates that the wrist posture

greater than 20° flexion considered as unsafe posture. The same result shown for %MVC of flexion wrist muscle statistical test on APB muscle.

As presented in Table 4.24, the result of Mann Whitney Test in comparing the %MVC on *Abductor Pollicis Brevis* muscle between 0° and 10° flexion is 56 for the U value and 0.054 for the significance value. The H_0 is accepted due to the U value > U table, or $56 > 55$ and the significance value is > 0.05 . In a comparison of 0° and 20° flexion on APB muscle, the U value is 30 and the significance value is 0.02 as presented in Table 4.25. H_0 is rejected due to the U value < U table, or $33 < 55$ and the significance value is < 0.05 or $0.002 < 0.05$. The result of Mann Whitney Test between 0° and 30° flexion on APB muscle presented in Table 4.26 and shows 9 for the U value and 0.000043 for the significance value. H_0 is rejected due to the U value < U table, or $9 < 55$ and the significance value is < 0.05 or $0.000043 < 0.05$. The last comparison in flexion wrist posture on APB muscle is between 0° and 40° as presented in Table 4.37 which gives the result of shows 3 for the U value and 0.000013 for the significance value. H_0 is rejected due to the U value < U table, or $5 < 55$ and the significance value is < 0.05 .

Table 4.14 shows the result of Mann Whitney Test which compares the %MVC value of 0° and 10° ulnar on FDS muscle. The U value is 58 and the significance value is 0.66. The H_0 is accepted due to the U value > U table, or $58 > 55$ and the significance value is > 0.05 . In a comparison of 0° and 20° ulnar on FDS muscle, the U value is 33 and the significance value is 0.03 as presented in Table 4.15. H_0 is rejected due to the U value < U table, or $33 < 55$ and the significance value is < 0.05 or $0.03 < 0.05$. The result of Mann Whitney Test between 0° and 30° ulnar on FDS muscle presented in Table 4.16 and shows 11 for the U value and 0.000064 for the significance value. H_0 is rejected due to the U value < U table, or $11 < 55$ and the significance value is < 0.05 . Based on statistical result, it shows that the wrist posture of 10° ulnar does not give any significant difference, while the wrist posture of 20° and 30° ulnar give significant difference. The result of %MVC supported the statistical result which indicates that the wrist posture greater than 20° ulnar considered as unsafe posture. The same result shown for %MVC of ulnar wrist muscle statistical test on APB muscle.

The result of Mann Whitney Test in comparison of *Abductor Pollicis Brevis* muscle contraction between 0° and 10° ulnar shows the U value of 57 and significance value of 0.06, referred to table 4.28. The H_0 is accepted due to the U value $> U$ table, or $57 > 55$ and the significance value is > 0.06 . In a comparison of 0° and 20° ulnar on APB muscle, the U value is 22 and the significance value is 0.000479 as presented in Table 4.29. H_0 is rejected due to the U value $< U$ table, or $22 < 55$ and the significance value is < 0.05 or $0.000479 < 0.05$. The result of Mann Whitney Test between 0° and 30° ulnar on APB muscle presented in Table 4.30 and shows the value of 9 for the U value and 0.000043 for the significance value. H_0 is rejected due to the U value $< U$ table, or $9 < 55$ and the significance value is < 0.05 or $0.000043 < 0.05$.

Referring to Table 4.17, the result of Mann Whitney Test in comparing the %MVC on *Flexor Digitorum Superficialis* muscle between 0° and 10° radial is 46 for the U value and 0.017 for the significance value. In a comparison of 0° and 20° radial on FDS muscle, the U value is 27 and the significance value is 0.001 as presented in Table 4.18. The result of Mann Whitney Test between 0° and 30° radial on FDS muscle presented in Table 4.19 and shows 6 for the U value and 0.000024 for the significance value. H_0 in both 10°, 20°, and 30° radial compared with 0° is rejected due to the U value $< U$ table and the significance value is < 0.05 . Based on statistical result, it shows that the wrist posture greater than 10°, 20°, and 20° radial give significant difference to the neutral posture. The result of %MVC supported the statistical result which indicates that the wrist posture greater than 10° radial considered as unsafe posture. The statistical test for %MVC of radial wrist muscle statistical test on APB muscle shown the same result.

The result of Mann Whitney Test in comparison of APB muscle contraction between 0° and 10° radial shows the U value of 34 and significance value of 0.03, referred to table 4.31. In a comparison of 0° and 20° radial on APB muscle, the U value is 16 and the significance value is 0.000165 as presented in Table 4.32. The last is the result of Mann Whitney Test between 0° and 30° radial on APB muscle presented in Table 4.33 and shows 7 for the U value and 0.000029 for the significance value. H_0 is rejected due to the U value $< U$ table, or $9 < 55$ and the significance value is < 0.05 or $0.000043 < 0.05$. H_0 in both 10°, 20°, and 30° radial compared with 0° is rejected due to the U value $< U$ table and the significance value is < 0.05 .

Some studies show that gender differences influence physical measurement, including body mass and height, blood pressure (Sakurai et al., 2006), and anthropometric size (Fragala et al., 2012). Based on the data obtained, the wrist muscle contraction on male tends to be greater than female had. However, the significance value of non-parametric independent difference test shows no significant differences at between as shown in table 4.34 and 4.35 (FDS $p = 0.756$, APB $p = 0.272$). Therefore, the threshold is possibly applied for both males and females. Nevertheless, this guideline only considering gender as variable and will be more accurate if other variables implicated. Figure 5.6 shows the illustration of maximum ergonomic wrist posture for Indonesian based on both muscle contraction analysis and statistical analysis, which are 30° for extension, 20° for flexion, 20° for ulnar, and 10° for radial.

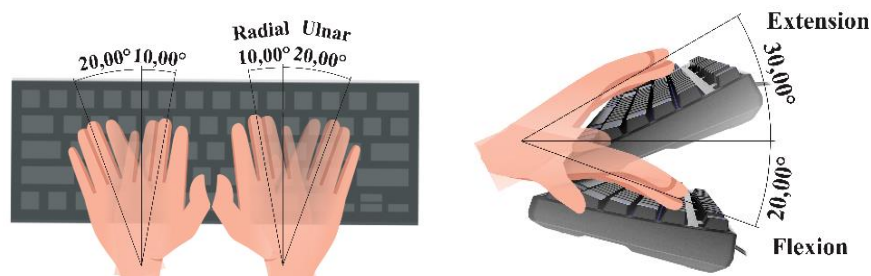


Figure 5.6. Ergonomic Maximum Wrist Posture Angle Result