國立成功大學

物理治療研究所

碩士論文

比較手肘支撐
對有無頸痛之智慧型手機使用者的
肌肉活性與姿勢之效果

Comparing the Effect of Elbow Support on Posture and Muscle Activities between the Smartphone Users With and Without Chronic Neck Pain

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中華民國 111 年 8 月

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Abstract

Background and purposes: With the development of technology, smartphones have become a necessity of life. With the high penetration of smartphones, the prevalence of musculoskeletal disorders (MSDs) also increased. The common locations of the MSDs among smartphone users are: neck, shoulders, upper back, upper limbs, and lower back. Among them, the prevalence rate of neck is the highest (17.3%-89.9%). There are three main risk factors for the MSDs of the smartphone users, including awkward posture, excessive use time, and high repetitive movements. The common faulty postures are excessive neck flexion and humpback position, which may be associated with neck pain. How to improve posture while using the smartphone is very important. Recent studies have explored how to reduce muscle activity and improve posture while using the smartphone. The researchers found that typing with elbow support could improve the head and neck flexion angle, and significantly reduce the muscle activities of the cervical erector spine and upper trapezius. Also, the users had less fatigue and neck discomfort. However, no studies have examined the effect of forearm support in young smartphone users with neck pain who may have higher muscle activity and worse posture while using smartphones. Therefore, the purposes of this study were: (1) to investigate the effect of elbow support and time on muscle activity and posture during smartphone use in young adults (2) to evaluate whether the elbow support is more effective in reducing their musculoskeletal load on the neck and upper extremities in young adults with neck pain.

Methods: Thirty-two young adults (mean age: 22.8 ± 2.6 y/o) were included in our study (16 healthy adults and 16 neck pain adults). The inclusion criteria for neck pain group are the visual analogue score greater than 2, and the neck disability index greater than 5. The experimental procedure consists of three parts: baseline data measurement, five minute-typing with elbow support, and five minute-typing without elbow support. First, resting posture and muscle activities were recorded in the static sitting position as the baseline data. Then both groups randomly performed five-minute typing tasks (with and without elbow support). There was a five-minute break between the two tasks to reduce muscle fatigue bias. Before the start of the typing task and immediately after typing task, the subjects' upper trapezius pain pressure threshold and neck discomfort were recorded. The 3D motion analysis system and the wire EMG system were used to record the changes in posture and muscle activity. The subjects' muscle activities and postural changes were recorded for 30 seconds right after the typing task start, and 30 seconds before the end. A three-way repeated measures analysis of variance (RMANOVA) was used to analyze the joint angle, EMG signals, perceived neck discomfort, and pain pressure threshold for the effects of group, elbow support, and time.

Results: Elbow support significantly improved the typing posture (reduced head/ neck flexion: $p<0.001$), and reduced wrists tension (increased wrist extension, $p<0.001$). It also reduced muscle activities of bilateral cervical erector spine (right: $p<0.001$, left: $p=0.014$), right upper trapezius ($p=0.006$), flexor digitorum superficialis ($p=0.042$) and neck discomfort ($p<0.001$). After five minutes typing, the head flexion ($p=0.024$), and wrist extension angle ($p=0.018$) significantly increased, while elbow flexion angle ($p=0.002$), muscle activity of flexor digitorum superficialis ($p=0.018$), and pain pressure threshold of bilateral upper trapezius (right, left: $p<0.001$) significantly decreased. A significant interaction among support x time x group ($p=0.002$) was found for neck flexion angle. Under the no support condition, the neck pain group significantly decreased their neck flexion angle after five minutes typing task ($p=0.015$). However, the healthy group had an increasing trend ($p=0.131$). A significant interaction among time x group ($p=0.01$) for wrist extension angle was found. After five minutes typing, wrist extension angle increased more in the healthy group than the neck pain group (p=0.022). A significant interaction among time x group (p=0.03) was found for the pain pressure threshold of the left upper trapezius. After the typing task, the pain pressure threshold of the healthy group decreased more than the neck pain group. A significant interaction among support x time (p=0.045) was found for the pain pressure threshold of right upper trapezius. Typing under the elbow support condition, the pain pressure threshold tended to decrease less than under no elbow support.

Conclusion: Using the elbow support is effective in improving posture and reducing not only neck muscle activities but also neck discomfort among the young adults while using smartphones. Five-minute typing task can affect posture, muscle activity, and neck discomfort. After a five-minute typing task, both groups moved the smartphone closer to the body. For the group difference, two groups use different posture strategies when they are using smartphones, especially under no support condition. Above all, our results suggested that use smartphones with elbow support could improve the posture and muscle activities. Future studies could increase the usage time to explore the effect of time, and recruit the subjects with greater neck disability to explore the group differences.

Key words: Elbow support, Smartphone, Posture, Muscle activity, Pain pressure threshold

摘要

背景與目的：科技日益發展，智慧型手機已成為生活必需用品。隨著智慧型手機的高普及率，肌肉骨骼系統疾病盛行率也提高。智慧型手機族常見的肌肉骨骼系統疼痛位置為：頸部、肩膀、上背、上肢、下背，其中以頸部盛行率為最高(17.3%~89.9%)。分析其危險因子，主要三項包括： 1. 錯誤的身體姿勢 2. 過長的使用時間 3.高重複性動作。常見錯誤姿勢為頸部彎曲和駝背，此姿勢與頸部疼痛可能有關聯，因此如何改善姿勢相當重要。近年的研究多探討，如何降低使用智慧型手機時的肌肉活動以及姿勢改善。研究者發現在手肘支撐下進行打字任務，頭頸屈曲角度會改善、豎頸肌與上斜方肌的肌肉活動會顯著降低，且較不會感到疲累與不適。然而，先前研究多專注在健康年輕使用者使用智慧型手機時的姿勢與肌肉活動，對於有頸部疼痛的年輕使用者尚無研究。因此，本研究目的包括：(1) 評估年輕人使用智慧型手機時，肘部支撐、使用時間對肌肉活動和姿勢的影響。(2) 探討使用肘部支撐是否能更有效地減輕患有頸部疼痛的年輕人頸部和上肢的肌肉骨骼負荷。

方法：本研究選取 32 名年輕成人（平均年齡：22.8 ± 2.6 歲 ）參與實驗，包括 16 名健康組、16 名頸部疼痛組。頸部疼痛組，視覺疼痛分數需大於兩分、頸部失能量表需大於五分。實驗程序共有三個步驟，包括：靜態坐姿測量、五分鐘肘部支撐打字、五分鐘無肘部支撐打字。首先，在靜態坐姿下紀錄休息時的姿勢與肌肉活動作為基準。接著隨機執行有無支撐的五分鐘打字任務，且任務間給予五分鐘的休息時間。用 3D 動作分析系統與肌電系統記錄打字任務時前後 30 秒的姿勢及肌肉活動變化。打字任務開始前與結束後，皆測量頸部不適程度與雙側上斜方肌疼痛壓力閾值。本實驗使用三因子變異數重複測量分析（重複因子為時間及支撐)來比較兩組受試者在執行打字任務時的測量結果。

結果：肘部支撐顯著改善打字時的姿勢（減少了頭部與頸部彎曲角度。頭、頸 : $p<0.001$)，且手腕會較為放鬆（手腕伸直角度增加 : $p<0.001$)。同時它可以減少雙側頸椎豎脊肌（右側 : $p<0.001$、左側：$p=0.014$)、右上斜方肌（$p=0.006$)和指淺屈肌（$p=0.042$)的肌肉活動以及打字所造成的頸部不適程度（$p<0.001$)。在五分鐘打字後，頭屈曲角度($p=0.024$)、腕伸直角明顯增加（$p=0.018$)，而肘屈曲角

度（$p=0.002$）、指淺屈肌肉活動（$p=0.018$）、雙側斜方肌上痛壓閾值（右側、左側: $p<0.001$）明顯下降。在頸部屈曲角度的分析發現三因子間有顯著交互作用($p=0.002$)，在無肘部支撐下打字，頸部疼痛組頸屈曲角度隨打字時間顯著減少($p=0.015$)，而健康組卻是有增加的趨勢($p=0.131$)。在腕伸直角度的分析發現時間 x 組別雙因子間顯著交互作用($p=0.022$)，隨著打字時間增加，健康組腕關節伸直角度增加較頸部疼痛組多。在左上斜方肌疼痛壓力閾值分析發現時間 x 組別雙因子顯著交互作用($p=0.03$)。打字任務後，健康組左上斜方肌疼痛壓力閾值比頸部疼痛組降低多。在右上斜方肌疼痛壓力閾值分析發現支撐 x 時間雙因子顯著交互作用($p=0.045$)。在肘部支撐下完成打字任務，兩組的右上斜方肌疼痛壓力閾值比無肘部支撐時下降的少。

結論：肘部支撐可有效改善智慧型手機使用者的姿勢並減少頸部肌肉活動以及頸部不適。 五分鐘的打字任務後會改變年輕人的使用姿勢、肌肉活性和頸部不適。兩組在打字任務時，都會將智慧型手機拿的更靠近身體。在無肘部支撐下，兩組有著不同的姿勢策略。綜合以上結果，我們建議年輕人可以使用肘部支撐來使用智慧型手機，以保持良好的使用姿勢及減少頸部肌肉活動。未來建議可以延長打字時間來探討時間對姿勢與肌肉活性的影響，同時也可以招募更嚴重的頸部失能受試者來探討組別差異。

關鍵字：肘部支撐、智慧型手機、姿勢、肌肉活動、疼痛壓力閾值

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「堅持不一定成功，但放棄一定失敗。」秉持此理念，促使我在這兩年學習更為扎實，憶起在碩士班求學的這段日子裡，要完成碩士學位要感謝的人不在少數。感謝每位在學習階段指導過我的老師，在老師們身上學到的不僅僅是專業知識更是對追求自我期許的堅持，也期許自己能在學術的路途上有些許的影響力。特別感謝我指導教授卓瓊鈺老師，總是不厭其煩的指導，平時待我們如家人一樣，在我深陷迷惘時總能開導並帶領我一起解決問題。感謝楊政峰老師不吝指教，不論在學術研究亦或待人處事都從老師身上您獲益良多，此外感謝論文口試委員黃英修老師與成戎珠老師，謝謝老師們在研究的建議使這篇研究更加完整。

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林信宇 謹誌

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Chapter 1 Introduction

1.1 The penetration rate of smartphone and the prevalence of musculoskeletal symptoms

The first mobile phone in the world was patented by Motorola in 1973 (Dunnewijk, & Hultén 2007). The price of a mobile phone was quite expensive originally. However, since mobile phone was not necessary for life, it was not popular at that time. With the development of technology, the price of mobile phones has gradually become cheaper and their functions have become more and more diversified (Rothman et al., 2017; Stalin et al., 2016). Nowadays, people's lives are almost inseparable from mobile phones, and the penetration rate is gradually increasing. A recent survey pointed out that the higher the economic development of the country, the higher the prevalence of mobile phones (Poushter, 2016). The survey also pointed out that 88% of South Koreans, 77% of Australians, 74% of Israelis, and 72% of Americans have at least one smartphone at the time. In Taiwan’s latest market survey in 2021, it was found that Taiwanese smartphone ownership is nearly 90% (創市際雙週刊第一七一期，取自 https://www.ixresearch.com/reports/創市際雙週刊第一七一期 -20210302). The high penetration rate of smartphones has made people pay attention to the health problems (e.g. eye soreness, musculoskeletal disorders) they cause.

1.1.1 Common musculoskeletal disorders for the smartphone users

Musculoskeletal disorders (MSDs) is prevalent for the smartphone users. Xie et al (2017) discussed the relationship between musculoskeletal symptoms (neck, shoulder, upper back, lower back, upper extremity) and mobile handheld devices. The study pointed out that among the users of the mobile handheld devices, the prevalence of musculoskeletal symptoms is between 1.0% and 67.8%. Among all symptoms, the neck complaints are the most prevalent, ranging from 17.3% to 67.8% (Xie et al., 2017).

In another systematic review, Eitivipart et al (2018) pointed out that the use of smartphones will cause some clinical (e.g. range of motion, tendon diameter, and pain) and sub-clinical (e.g. thumb performance, and discomfort) changes in the musculoskeletal system (Eitivipart et al., 2018). In addition, a recent systematic review, Zirek et al (2020) found that the incidence of musculoskeletal symptoms in mobile phone users ranged from 8.2% to 89.9%. In particular, the discomfort rate of the neck and upper back was the highest (55.8 % to 89.9%). The most common uncomfortable symptom is pain, other symptoms such as myofascial pain syndrome, and fibromyalgia are also reported (Zirek et al., 2020). From the above systematic review, it can be seen that smartphone users are prone to have musculoskeletal problems in the shoulders and neck, upper back, upper extremity, and lower back, and the prevalence of neck pain is the highest.

1.1.2 Definition and prevalence of chronic neck pain

Neck pain was a common musculoskeletal disorder and the fourth leading cause of disability between 1990 and 2010 (Vos et al., 2012). Nowadays, chronic neck pain is still a common disorder for modern people. In a cross sectional study in Iran in 2017, it pointed out that the proportion of chronic neck pain accounted for 15.34% between 30 and 70 years old people (Noormohammadpour et al., 2017). Another study in 2019, Jiménez-Trujillo et al. found that the incidence of chronic neck pain was 25.68% (women) and 12.54% (men) in Spain (Jiménez-Trujillo et al., 2019). Mäkela et al. found that the prevalence of chronic neck pain was 9.5% for men between 30 and 64 years old, and

13.5% for women (Mäkela et al.,1991). They defined the chronic pain should be lasted at least three months. However, the definition of the location of chronic neck pain was not very clear. The region was widely applicable to the neck area.

Besides, the International Association for the Study of Pain (IASP) in 1994 defined the location of chronic cervical pain (Merskey et al., 1994). The association stated that chronic neck pain should be located at the back of the cervical spine and range from the superior nuchal line to the spinous process of the first thoracic vertebra. Therefore, chronic neck pain can be defined as the pain at the back of the cervical spine, ranging from the superior nuchal line to the spinous process of the first thoracic vertebra, and the pain is at least three months. In a recent systematic review of the global prevalence of neck pain, it was pointed out that from 1990 to 2017, the number of people suffering from neck pain increased by approximately 124 million (Safiri et al., 2020). The region with the highest prevalence rate is in the East Asia (approximately 4,600 per 100,000 people), and Taiwan is also in this region.

It can be inferred that chronic neck pain is a common musculoskeletal disorder recently. Smartphone users are prone to neck pain. Therefore, how to improve and avoid neck pain is an important issue for the smartphone users.

1.2 The risk factors and mechanism of neck pain for the smartphone users

To avoid pain, we must understand the mechanism of neck pain. The causes of the neck pain can be found from the characteristics of smartphone users. Awkward posture and high repetitive use are two major risk factors for neck pain in smartphone users (Lee et al., 2015). Many studies have pointed out that when using smartphones (e.g., sending messages, playing games, watching videos), people usually stay in an awkward posture (e.g., flexed head position, humpback position) and they usually use it for a long time period ; both factors are related to musculoskeletal symptoms (Berolo et al., 2011; Gold et al., 2012; Maniwa et al., 2013; Bababekova et al., 2011). Recently, Namwongsa, et al. conducted a survey about smartphone users of the university students. They found that after using the mobile phone for a long period of time (12 months), the proportion of neck pain was the highest (32.5%). Similar to previous studies, they believed that using smartphone in flexed neck position is associated with neck pain (Odds ratio (OR): = 2.44) (Namwongsa et al., 2018). Using smartphones in awkward positions, the neck muscles are more activated to against the weight of the head and reduce the stress on the neck. The stress on the cervical spine at 30 degrees of flexion (40 lbs) is about four times of the stress that in the natural position (10-12 lbs), and the increased stress may lead to cervical spine degeneration and other musculoskeletal system problems (Hansraj, 2014). This explains the results in Namwongsa et al.'s study, why as neck flexion increases, so does the muscle activity of the cervical erector spine.

Highly repetitive movement is another factor that make the smartphone users vulnerable to injury (Korpinen et al., 2015; Ming et al., 2006). Previous study pointed out that highly repetitive movements can easily cause micro-traumas in the musculoskeletal system, which in turn can cause injury to the users. Derakhshanrad et al (2021) found that office workers who addicted to (Definition of Overuse: Smartphone Addiction Scale short version : Male≥ 30, Female ≥ 33) smartphones would significantly increase the chance of neck pain by 6 times (Derakhshanrad et al., 2021). Therefore, we can infer that repeated use of smartphones in awkward positions for a long time is likely to cause neck pain.

1.3 Characteristics of the smartphone users

Smartphones have transformed people's living habits and work styles. Many tasks that used to depend on computers are gradually being replaced by smartphones. Researchers started to wonder what characteristics do smartphone users have?

1.3.1 Posture

Using smartphone can be detrimental to posture. How does smartphone use affect the posture for the young adults?

Previous studies have investigated the impact of smartphone use on posture (Gold et al., 2012; Maniwa et al., 2013; Jung et al., 2016). Gold et al (2012) observed the posture changes of college students when using their mobile phones for one hour. They found that the flexed neck and non-neutral wrist were commonly observed during the one hour typing task. Under long-term use, people often fail to notice that their posture is getting worse (Gold et al., 2012). However, not only long-term use (e.g., one hour) smartphones will affect posture, short-term use (e.g., five minutes) can also affect posture (Maniwa et al., 2013). Maniwa et al (2013) found that when college students was performing a five-minute typing task, their posture changed significantly after five minutes compared with the first 30 seconds. The flexion angle of the head, neck, elbow and lower back increased significantly. In addition, Jung et al (2016) found that young adults who used smartphones for more than four hours a day had more forward head posture than those who used smartphones for less than four hours a day (Jung et al., 2016).

Not only the time factor, but also gender seems to be a factor affecting posture. (Gold et al., 2012; Guan et al., 2015). Gold et al (2012) pointed out that males were more likely to have more shoulder protraction than women. However, women were more likely to have non-neutral inner elbow angles than males (Gold et al., 2012). Guan et al (2015) compared the postural differences between standing and sitting smartphone use (Guan et al., 2015). They found when young adults (between 17 and 31 years old) were using a mobile phone in a standing position, the head tilt angle significantly increased, but the neck angle significantly decreased as compared to sitting. Men's head tilt angle was significantly higher than women's. While head tilt angle and gaze angle were positively correlated, but neck tilt was negatively correlated. Smartphone users seem to use different postures to cope with different tasks. In text messaging tasks, the amount of head flexion angle change was obviously greater than video watching movies or web browsing. The change in sitting posture was significantly higher than the change in standing (Lee et al., 2015). Neck pain also affect posture while using a smartphone. Kim (2015) compared the impact of neck pain on posture in young adults while using a smartphone. He found that young adults with mild neck pain have greater flexion angles in the upper and lower cervical spine than young adults without neck pain (Kim 2015).

From these studies, it was found that the posture of using a smartphone is affected by many factors (e.g., time, gender, task, neck pain). A five-minute typing task is enough to turn the user into awkward postures. Daily long-term users are prone to poor posture. In addition, men are also more likely to have larger head tilt angle and round shoulder than women. Among smartphone functions, typing tasks result in the worst posture.

1.3.2 Electromyography

Using smartphone has been shown to affect posture in young adults, but how about its effect on muscle activities?

Kim et al (2012) attempted to compare differences in repetitive movements between computer users and smartphone users. After computer typing, the median frequency of the upper trapezius muscle and flexor carpi radialis decreased significantly. However, after smartphone typing, the median frequency of the brachioradialis decreased significantly (Kim et al., 2012). Xie et al. also found that in the typing task, neck extensors (cervical erector spine) significantly increased whether using a computer or using a mobile phone with both hands, but there was no significant difference between groups. Computer users, however, had significantly higher muscle activity in the upper trapezius and lower trapezius. In the distal upper extremity, computer users have higher muscle activity in extensor carpi radialis and extensor digitorum. Smartphone users had higher muscle activity in abductor pollicis brevis (Xie et al., 2016). These results allow us to infer that there are still differences in muscle activation between smartphone users and computer users. We can conclude that both computer and smartphone use affect muscle activities. Both can affect neck muscle activities. However the effect on upper extremity muscle activities are different, which should be related to the different using strategies. Recently, Namwongsa et al (2019) discussed the effect of different neck flexion angles on neck muscle activity (Namwongsa et al., 2019). Cervical erector spine showed increased muscle activity with increased neck flexion, whereas upper trapezius decreased. Neck flexion angle is positively correlated with neck muscle activity. The greater the neck flexion angle, the greater muscle activity of the neck extensor muscles (Cervical erector spine).

We wondered whether neck pain will affect the neck muscle activity. Johnston et al (2008) found that there was no significant difference on the muscle activity of the cervical erector spine between workers with mild neck pain during texting task and workers without neck pain (Johnston et al,. 2008). However, there was a significant difference between no pain worker as compared with the moderate pain workers. Another study, Xie et al (2016) explored whether neck and shoulder pain can affect the activity of cervical erector spine and upper trapezius in young adults (Xie et al., 2016). They found that when young people with neck and shoulder pain send text messages with both hands or one hand, the muscle activity of the cervical erector and upper trapezius muscles is significantly higher than those without pain. However, Namwongsa et al. (2019) had different findings. They explored the influence of neck flexion angle on the neck muscle activity of smartphone users with or without neck pain. They found that whether there is neck pain or not, the greater the neck flexion angle, the greater the activity of the cervical erector spine and upper trapezius muscles (Namwongsa, et al., 2019). Although the muscle activity of the pain group was higher than that of the no-pain group, there was no significant difference between these two groups.

The relationship between neck pain and neck muscle activities, some scholars have found that people with neck pain have higher neck muscle activities (Johnston et al., 2008; Xie et al., 2016). Although others have yet to discover this feature (Namwongsa, et al., 2019). It seems inconclusive whether people with neck pain necessarily have high neck muscle activities. We can be sure that posture does affect neck muscle activities. When users have a greater angle of neck flexion, they have higher neck extensor activities.

1.3.3 Pain pressure threshold

Using a smartphone will not only induce neck pain, but also affect the pain pressure threshold of the upper trapezius. Kim and Lee both found that after using the smartphones, the user's pain pressure threshold of the upper trapezius will be significantly reduced (Kim et al., 2012; Lee et al., 2015). The pain pressure threshold of the upper trapezius was significantly lower with one-handed use than with two-handed use (Lee et al., 2015).

1.4 Common interventions for chronic neck pain

The common intervention strategies of therapists for neck pain patients are exercise therapy and manual therapy (Bogduk et al., 2007; Fredin et al., 2017). In addition, ergonomic intervention is also one of the strategies used to avoid and alleviate musculoskeletal symptoms (Driessen et al., 2010).

1.4.1 Manual therapy

Manual therapy is an intervention that therapists using their hands as the medium and gives the patient the force of the therapeutic purposes. Manual therapy techniques include massage, joint mobilization/manipulation, myofascial release, et al. (Smith, 2007). Two systematic reviews found that manual therapy not only improved short-term but also long-term symptoms in adults with acute or chronic neck pain (Fredin et al. 2017; Hidalgo et al., 2017). However, whether combined manual therapy with exercise therapy will have a better effect seems to be inconclusive. Hidalgo et al. found that combining manual therapy with exercise will be more effective in improving neck pain than single training (Hidalgo et al., 2017). However, Fredin et al. concluded that there seems to be no better effect (Fredin et al., 2017).

Even so, we can infer that manual therapy can improve neck discomfort. The mechanism of improving pain may be that manual therapy activates the endogenous pain inhibitory system of the central nervous system to reduce pain (Lascurain-Aguirrebeña ey al., 2016).

1.4.2 Physical activity or exercise

Physical activity is defined as any musculoskeletal activity that expends energy (e.g., usual activity). The difference between exercise and physical activity is intensity. Exercise is defined as any planned musculoskeletal repetitive activity such as strength training, aerobic training, etc (Chodzko-Zajko et al., 2009). Studies have demonstrated that both physical activity and exercise can improve neck pain severity and physical function in adults for long-term, thereby improving quality of life (Lorås et al., 2015; Gross et al., 2016; Geneen et al., 2017). The mechanism of reducing pain may be due to increasing in pain tolerance and decreasing in the temporal summation of pressure (Vægter et al., 2015).

1.4.3 Ergonomic intervention

From the above two interventions and the mechanisms of reducing pain, we can see that neither is targeting on the risk factors for neck pain. According to the definition of the International Ergonomics Association (IEA), ergonomics is human-centered, and explores the interaction with the surrounding environment when performing tasks. The concept of ergonomics is closer to our idea. We hope to improve neck pain by reducing exposure to risk factors when performing tasks with smartphones through ergonomics. Ergonomics can be divided into three categories: physical ergonomics, organizational ergonomics, and cognitive ergonomics. The purpose of all is to reduce pain and discomfort (Hoe et al., 2018). Are there any findings from previous research?

Physical ergonomic interventions (e.g., alternative mouse and arm support) which are the most appropriate interventions had moderate evidence of positive health benefits for office worker's MSDs of the neck or upper extremities (Boocock et al., 2007; Kennedy et al., 2010; Van Eerd et al., 2016). However, there is low to moderate evidence that it may not reduce the incidence of MSDs in the neck or shoulder (Hoe et al., 2018).

Organizational interventions (e.g., supplementary breaks or reduced work hours) are limited and moderate evidence for improving office worker's MSDs and symptoms (Kennedy et al., 2010; Van Eerd et al., 2016). There is low-quality evidence that supplementary rest can reduce discomfort, yet training with ergonomic guidelines does not seem to prevent work-related MSDs (Hoe et al., 2018). However, there are few interventional studies of cognitive ergonomics (Hoe et al., 2018). Above all we can deduce that among the ergonomic interventions, not all ergonomic interventions are effective. Physical ergonomic interventions should be more able to alleviate neck or upper extremities discomfort in office workers and more likely to reduce the incidence of shoulder and neck MSDs.

In the study of physical ergonomics of office workers, Cook et al. (2004) found that typing with sufficient forearm support for 12 weeks the worker's neck, back and wrist discomfort were significantly reduced (Cook et al., 2004). Additionally, Cook et al. continued to explore the long-term effect of forearm support (21 months) for the centre computer users. However, for the long term effect, only the neck discomfort is significantly reduced (Cook et al., 2008). We can make sure that the forearm support posture can effectively reduce neck discomfort for computer users. In recent years, due to the increase in smartphone users, scholars have begun to explore the effect of the elbow support on smartphone users. In 2018 and 2021, Syamala et al. and Tapanya et al. explore whether using elbow support can reduce the activity of the neck muscles and improve posture. Syamala et al (2018) found that when young adults are sitting and using mobile phones for typing tasks, the users with elbow and back support can significantly reduce the muscle activity of upper trapezius and splenius capitis muscle, and significantly reduce neck flexion, head flexion, cranio-cervical angle to improve posture. As the posture improved, the gravitational moment at C7-T1 also significantly reduced, which can help reduce the risk of neck pain (Syamala et al., 2018). Tapanya et al (2021) equipped young adults with ergonomic arm support devices during the standing video game tasks (20 mins). They found that the group wearing the ergonomic arm support device had significantly reduced shoulder and neck muscle activity (Anterior deltoid/ Upper trapezius/Splenius capitis muscle). In addition, the muscles were less prone to fatigue and less neck discomfort (Tapanya et al., 2021).

We can infer that the elbow support can improve posture and reduce neck extensors (Upper trapezius/Erector splenius capitis) muscle activities in healthy young smartphone users.

1.5 Research gap and Motivation

Smartphone users tend to position themselves in awkward postures while using their smartphones (Gold et al., 2012; Maniwa et al., 2013; Guan et al., 2015; Lee et al., 2015; Kim 2015; Jung et al., 2016). Awkward postures activate the neck muscles, and those with neck pain seem to have higher muscle activation (Xie et al., 2016; Namwongsa et al., 2019; Johnston et al., 2008). Prolonged use of smartphones in awkward positions can lead to musculoskeletal disorders (Namwongsa et al., 2018; Derakhshanrad et al., 2021). However, neither manual therapy, exercise nor combined both interventions targeted risk factors for neck pain users. Ergonomic interventions place more emphasis on the interaction between people and environment than manual or exercise. This is why in this experiment, we chose ergonomic intervention. We hope to reduce the risk factor for neck pain by modifying the environment in which people are using their smartphones. Previous researches have also shown that forearm support can improve posture and reduce muscle activity in healthy young smartphone users, thereby reducing neck musculoskeletal load (Syamala et al., 2018; Tapanya et al., 2021).

To the best of our knowledge, there are no studies examinate the effect of forearm support in young smartphone users with neck pain. In addition, the effect of forearm support on musculoskeletal load of upper extremities has not been discussed. Therefore we would like to investigate whether the forearm support is more effective in reducing musculoskeletal load on the neck and upper extremities in young smartphone users with neck pain.

1.6 Purposes and Hypotheses

The first purpose of this study was to evaluate the effect of elbow support and time on muscle activity and posture during smartphone use in young adults. The hypothesis was that the elbow support can effectively prevent postural deterioration and high muscle activity caused by short-term typing tasks in young smartphone users. The second purpose was to compare the effect of elbow support on the musculoskeletal load of the neck and upper extremities between young smartphone users with and without chronic neck pain. The hypothesis was that elbow support may be better to improve posture and reduce muscle activities for young adults with neck pain.

Chapter 2 Materials and methods

2.1 Participants

In this study we included 32 young adults (20-40 years old) who have at least 6 months of experience using mobile phones and spend at least 2 hours on smartphones a day (Tapanya et al., 2021; Namwongsa et al., 2019). The inclusion criteria for neck pain group are VAS (Visual Analogue Scale) score greater than 2 (Jensen et al., 2003) , and NDI (Neck disability index) score greater than 5. The participants were excluded if they have history of neck trauma and surgery in the past year (Kim et al., 2012, Kim 2015, Xie et al., 2016), any medical conditions problems which have negative effects on upper extremities and spine (Kim et al., 2012, Xie et al., 2016), any chronic diseases that may affect the musculoskeletal system (Kim 2015, Xie et al., 2016), neurological disorders, visual problems, dizziness, vertigo, sensory deficit (Xie et al., 2016), and other orthopedic disorders (Lee et al., 2015) Additionally, participants were excluded if they have taken sedative drugs or alcohol in the past 48 hours (Kim et al., 2012), or neck range of motion is restricted.

This study was approved by the Human Experiment and Ethics Committee of the National Cheng Kung University Hospital (IRB No.B-ER-111-006).

2.2 Experimental procedures

After the recruitment process, subjects were asked to fill in their basic demographic characteristics (e.g. age/sex/smartphone use history/physical activity/daily use). Then the subjects were divided into two groups (healthy group and neck pain group). For those included in neck pain group were asked to fill in more information about neck pain (e.g. neck pain duration, neck pain intensity). Both groups performed the same experimental procedures. In this experiment we used reflective markers to detect subjects' postural changes and surface electromyography (EMG) to record the upper extremities and neck muscle activities.

The reflective markers were placed on the dominant side canthus, tragus, cervical vertebra level seven, dominant side acromion, dominant side lateral epicondyle, midpoint between radial and ulnar styloid process, dominant side distal end of the 3rd metacarpal. Six infrared motion analysis cameras (Qualisys AB, Gothenburg, Sweden) were used to record the position of the reflective markers, and the sampling frequency was set at 120 Hz. Then, using MATLAB to calculate the angle of the subject's head, neck and upper extremities, to evaluate the posture changes when the subjects using the smartphone in two different conditions (with/ without elbow support).

The EMG patches were placed on the bilateral cervical erector spine (RCES, LCES), bilateral upper trapezius (RUT, LUT), dominant abductor pollicis brevis (APB), dominant extensor digitorum (ED), dominant wrist flexor digitorum superficialis (FDS), and dominant wrist extensor carpi radialis brevis (ECRB). Use Delsys eight-channel surface electromyography (Delsys, Bagnoli 8-channel Desktop EMG system, USA) to record muscle activities during rest and typing tasks, and the collection frequency were set to 1200 Hz. Before applying EMG patches, the skin were exfoliated and cleaned with alcohol. All EMG signals were filtered from 20 to 400 Hz, and 300 Hz, 180 Hz, and 60 Hz were filtered out. The EMG signals of subjects in a static sitting position were used as the standard for normalization. After the reflective markers and EMG patches were attached to the subjects, the interventional procedure was started.

2.2.1 Test procedures

In this experiment, the resting posture data of the two groups were collected first as the standard for normalization. The standardized test postures were as follows: the subjects were asked to place their feet on the ground and both hands on the thighs, keep bodies relaxed, and look straight ahead. The researchers recorded 10-second static data for three times. Then the average of these three trials was taken as the standard of the resting posture EMG signal. After the static data recording, both groups performed interventional procedures. The interventional procedure was to perform a five-minute sitting typing tasks for two times (with and without the elbow support). There was a five-minute break between the two tasks to reduce muscle fatigue bias. All subjects in this experiment used the same smartphone for the experiment to reduce the bias of different smartphones (OPPO A72 screen size: 6.5 inch, length: 162 mm, width: 75.5 mm, thickness: 8.9 mm, weight: 192 g).

Tang et al. found that forearm support reduced the height of smartphone use, which increased head flexion and reduce neck discomfort (Tang, et al. 2022) Therefore, when performing the typing task with support, subjects were reminded to place only their elbows on the cushion, not entire forearms. There was a five-minute rest period between typing tasks to ensure subjects had adequate rest and reduce muscle fatigue bias. The flow chart of the experiment was shown in Figure 1. The elbow support instrument used in this experiment is a combination of balance pad and chair lumbar pad (Figure 2). Gerr et al. suggested that the effects of postural interventions might be more observable if the workstation were easier to adjust and allowed more complete compliance with postural interventions (Gerr et al., 2005). We choose common items of the daily life usage as our physical ergonomic intervention.

The balance pad is used as the supporting plane, and the length and width are 47 cm and 38 cm respectively. The chair lumbar pad is used to provide support height, similar to the function of the armrest of a chair. The height of the chair lumbar pad plus balance pad is 15 to 19 (cm). The different heights are designed to accommodate subjects' anthropometry to get comfortable elbow support during the typing task.

2.2.2 Outcome measures

Before the start of the typing task, the subjects' upper trapezius pain pressure threshold and neck discomfort were recorded. The subjects’ muscle activities and postural changes were recorded for 30 seconds right after the typing task start (T1) and 30 seconds before the end (T2). Immediately after typing task, the subjects' upper trapezius pain pressure threshold and neck discomfort were also recorded. The data collection process of this experiment is shown in Figure 3.

Postural measurements were recorded by six infrared motion analysis cameras recording the position of the reflective markers during typing tasks. Then the researchers used Matlab to calculate the change of angles (Figure 4). The postural angles in this experiment were defined as follows: head angle was the angle between the vertical line and the line from canthus to tragus; neck angle was the angle between the vertical line and the line from tragus to cervical vertebra level seven; shoulder angle was the angle between the vertical line and the line from acromion to lateral epicondyle (Straker et al., 2009) The elbow angle was the angle between the line from acromion to lateral epicondyle and the line from lateral epicondyle to midpoint between radial and ulnar styloid process. The wrist angle was the angle between the line from lateral epicondyle to midpoint between radial and ulnar styloid process and the line between end of the 3rd metacarpal.

The mean angle of posture were calculated by recording 30-secs typing tasks. EMG recording time was the same as the posture. The EMG signals of three static sitting postures were averaged as the standard value. In this experiment the change of EMG signal was the subtraction of EMG signal recorded in typing task and static sitting posture.

The EMG data presented in this experiment were based on the normalization of the root mean square (RMS) of the signal during the typing task and the root mean square of the signal during the static sitting posture. The normalized formula was as follows:

$$\text{Percentage of RMS change} = \frac{\text{RMS of typing - RMS of static sitting}}{\text{RMS of static sitting}} \times 100\%$$

2.2.3 Statistical analysis

Independent t was used to analyze and compare the basic data (age, BMI, weekly physical activity time, daily walking, daily sitting, smartphone experience, daily smartphone usage time, daily smartphone tablet and notebook computer usage time, resting position, resting EMG) between the two groups. Chi-square test was used to compare whether there were differences in physical activity time in the past seven days and three months between the two groups.

In this experiment the independent variables were group, elbow support, and time (30 seconds after the typing task starts and 30 seconds before the typing task ends). A three-way repeated measures analysis of variance (RMANOVA) was used to analyze the joint angle, EMG signals, perceived neck discomfort, and pain pressure threshold for the effects of neck pain, elbow support, and time. Post-hoc analysis was conducted for multiple comparisons when there were an interaction among factors. If there were an interaction between three factors, two-way ANOVA was used for further analysis. Moreover, if there were an interaction between two factors, paired t test, independent t test, or one-way ANOVA were used. All analyze were perform by SPSS version 17.0 (SPSS, Inc., Chicago, IL, USA).The statistical significance level was accepted at $p \leqq 0.05$.

Chapter 3 Results

3.1 Demographic data

Thirty-two young adults (16 males, 16 females, mean age (±SD): 22.8 ± 2.6 years old), participated in this experiment. According to the inclusion criteria, they were divided into two groups, the healthy young adults and young adults with chronic neck pain. The gender ratios and numbers were the same in both groups. All participants were found to be right-handed by observation as they filled out the questionnaire. Also they were using two-handed typing as their typing strategy while they were using smartphones. The demographic data of the two groups were shown in Table 1. There was no significant difference for most of the basic data. However, there were significant differences between the neck pain group and the healthy group in terms of the difference in physical activity between the past seven days and the past three months (p=0.004), and daily smartphone/tablet/laptop use time (p=0.016). Less recent physical activity and higher daily smartphone/tablet/laptop use time were presented in the neck pain group.

3.2 Posture

The head, neck, shoulder flexion angles were measured at the static position, 30 seconds after the typing task start (Time 1), and 30 seconds before the end (Time 2). The effect of neck pain, elbow support, and time on head, neck, shoulder, elbow and wrist flexion angles were analyzed. The static sitting posture was shown in Table 2. There were no significant differences in head, neck and shoulder flexion angles between two groups.

3.2.1 Head flexion angle

In the three-way ANOVA, significant main effects were found on elbow support ($F_{(1,30)}$=107.181, p<0.001) and time factors ($F_{(1,30)}$=5.694, p=0.024) (Table 3). Typing with elbow support significantly reduced head flexion angle (p<0.001) (Figure 5, Table 4). After five minutes typing, head flexion angle increased significantly (p=0.024) (Figure 6, Table 5).

3.2.2 Neck flexion angle

In the three-way ANOVA, a significant main effect was found on elbow support ($F_{(1,30)}$=51.173, p<0.001). A significant interaction was also found on support x time x group ($F_{(1,30)}$=11.930, p=0.002) (Table 6). Typing with elbow support reduced neck flexion angle significantly when comparing with no elbow support (p<0.001) (Figure 7, Table 4).

There was a significant interaction existed among support x time x group. Under the no support condition, the neck pain group significantly decreased their neck flexion angle after five minutes typing task (t=2.755, p=0.015). However, the healthy group increased their neck flexion angle but it did not reach the significant level (t=-1.598, p=0.131). Under the support condition, both groups maintained their neck flexion angle at the same level after the typing task (Figure 8).

3.2.3 Shoulder flexion angle

In the three-way ANOVA, a significant main effect was found only on elbow support ($F_{(1,30)}$=251.587, p<0.001) (Table 7). Typing with elbow support significantly increased shoulder flexion angle (p<0.001) (Figure 9, Table 4).

3.2.4 Elbow flexion angle

In the three-way ANOVA, a significant main effect was found on time ($F_{(1,30)}$ =11.956, p=0.002) (Table 8). After five minutes typing, elbow flexion angle decreased significantly (p=0.002) (Figure 10, Table 5).

3.2.5 Wrist extension angle

In the three-way ANOVA, there were significant main effects found on the elbow support ($F_{(1,30)}$ =36.280, p<0.001), and time factors ($F_{(1,30)}$ =31.312, p<0.001) for wrist extension angle. A significant interaction was also found on group x time ($F_{(1,30)}$=7.533, p=0.01) (Table 9). When typing with the elbow support, wrist extension angle increased significantly (p<0.001) (Figure 11, Table 4). After five minutes typing, wrist extension angle increased significantly (p<0.001) (Figure 12, Table 5). There was a significant interaction existed among group x time. Wrist extension increased more in the healthy group than the neck pain group after five minutes typing task (t=2.420, p=0.022) (Figure 13).

3.3 Electromyography

The static sitting electromyography (EMG) of all muscles was shown in Table 10.

3.3.1 Neck muscles

In the three-way ANOVA, a significant main effect of the elbow support was found on right cervical erector spine ($F_{(1,30)}$=21.637, p<0.001), left cervical erector spine (F=6.806, p=0.014), and right upper trapezius ($F_{(1,30)}$=8.782, p=0.006) (Table 11, Table 12, Table 13, Table 14). There was no group effect among these neck muscle activities.

Typing with elbow support significantly reduced activities of these muscles (right cervical erector spine : p<0.001, left cervical erector spine : p=0.014, right upper trapezius : p=0.006) (Table 15, Figure 14, Figure 15, Figure 16). However, there was no significant main effect of the elbow support on left upper trapezius, but there was still a trend ($F_{(1,30)}$=3.545, p=0.069). A significant main effect of the time factor was found only on the left upper trapezius ($F_{(1,30)}$=6.056, p=0.020). After five-minute typing, the muscle activity of left upper trapezius significantly reduced (Figure 16, Table 23).

3.3.2 Upper extremity muscles

In a three-way ANOVA, significant main effects of elbow support ($F_{(1,30)}$=4.521, p=0.042) and time factors ($F_{(1,30)}$=6.288, p=0.018) were found only on flexor digitorum superficialis (Table 17, Table 18, Table 19, Table 20). Typing with elbow support significantly reduced flexor digitorum superficialis muscles activity (p=0.042) (Figure 18, Table 28). After five minutes typing, the muscle activity of the flexor digitorum superficialis significantly reduced (p=0.018) (Figure 19, Table 16).

3.4 Perceived neck discomfort

In a three-way ANOVA, significant main effects of elbow support ($F_{(1,30)}$=46.632, p<0.001), time ($F_{(1,30)}$=27.649, p<0.001), and group factors ($F_{(1,30)}$=48.595, p<0.001) were found on perceived neck discomfort (Table 21). Typing with elbow support significantly reduced perceived neck discomfort (Table 22, Figure 20). After five minutes typing, perceived neck discomfort significantly increased (Table 23, Figure 21). Perceived neck discomfort was significantly higher in the neck pain group than the healthy group (Table 24, Figure 22). There were two significant interactions existed among support x time ($F_{(1,30)}$=46.632, p<0.001), and time x group ($F_{(1,30)}$=5.461, p=0.026) (Table 30). Under the no support condition, both groups significantly increased perceived neck discomfort after five minutes typing task. However, under the support condition both groups maintained their perceived neck discomfort at the same level after the typing task (Figure 23). After the typing task, both groups perceived neck discomfort significantly increased. However, the healthy group increased perceived neck discomfort significantly higher than the neck pain group (t=2.710, p=0.011) (Figure 24).

3.5 Pain pressure threshold

In a three-way ANOVA, a significant main effect of time factors ($F_{(1,30)}$=43.640, p<0.001) and a significant time x group interaction ($F_{(1,30)}$=5.172, p=0.03) were found on left upper trapezius (Table 25). The left upper trapezius pain pressure threshold significantly decreased after five minutes typing (p<0.001) (Figure 25, Table 26). There was a significant time x group interaction ($F_{(1,30)}$=5.172, p=0.03) among left upper trapezius pain pressure threshold (Figure 26). After five minutes typing task, the pain pressure threshold of the both group decreased significantly. However, the healthy group decreased significantly more than the neck pain group.

On the other hand, a significant main effect of time ($F_{(1,30)}$=32.565, p<0.001) and a significant support x time interaction ($F_{(1,30)}$=4.390, p=0.045) were found on right upper trapezius (Table 27). The right upper trapezius pain pressure threshold also significantly decreased after five minutes typing (p<0.001) (Figure 27, Table 26). There was a significant interaction support x time ($F_{(1,30)}$=4.390, p=0.045) among right upper trapezius (Figure 28). Both groups significantly decreased pain pressure threshold after five minutes typing task. However, typing under the elbow support the pain pressure threshold tended to decrease less than typing under no elbow support.

Chapter 4 Discussion

4.1 Main findings

The purpose of this study was to evaluate and compare the effects of elbow support and time on muscle activities and posture during smartphone use in young adults with and without neck pain. In this study, we found that the support factor affected most of the results. The elbow support significantly improved the neck posture (reduced head/neck flexion angles), and increased wrist extension angle when using the smartphone. It also significantly reduced the muscle activities of bilateral cervical erector spine, right upper trapezius and flexor digitorum superficialis. The time factor affected the head, elbow flexion angle, wrist extension angle, left upper trapezius, flexor digitorum superficialis muscle activities. After five minutes typing, the head flexion angle, and wrist extension angle significantly increased. However, the elbow flexion angle, left upper trapezius, and flexor digitorum superficialis muscle activities significantly decreased.

These results supported our hypothesis that elbow support may effectively prevent young smartphone users from turning into awkward postures and reduce muscle activities during short-term typing task. Some interactions were also found in our study. Under elbow support, both groups were able to maintain the same posture level for five-minute typing. However, when typing under no elbow support, the neck flexion angle significantly decreased in the neck pain group. In contrast, the healthy group had an increasing trend. Besides after five-minute typing task, the wrist extension angle increased more in the healthy group than the neck pain group. Less group differences were found. Therefore, insufficient findings could support our second hypothesis. That elbow support may be better for improving posture and reducing muscle activities for young adults with neck pain was rejected.

4.2 Demographic data

From the baseline data, there were significant differences in recent physical activity and daily smartphone/tablet/laptop use time between healthy young adults and young adults with neck pain. Those with neck pain had less recent physical activity and more daily smartphone/tablet/laptop use time. It can be inferred that young adults with neck pain seem to be more inactive and spend more time with smartphones/tablet/laptop per day, which is consistent with previous studies (Mansfield et al., 2018; Scarabottolo et al., 2017). Physical activity is significantly associated with pain. Leisure and work-related physical activity decreases when neck pain is present (Mansfield et al., 2018). Lack of physical activity in sports and occupational context may increase the chance of neck pain (Sports OR:1.39, Occupational OR:1.5) (Scarabottolo et al., 2017). Therefore, reducing physical activity might be related to neck pain (Lorås et al., 2015; Gross et al., 2016; Geneen et al., 2017). As a physical therapist, we usually recommend that young adults should avoid sedentary lifestyle and maintain physical activity in order to avoid neck pain.

4.3 Posture

Previous studies indicated that smartphone users were prone to awkward posture, which is associated with musculoskeletal disorders (Toh et al., 2017; Namwongsa et al., 2018). Reducing head and neck flexion angles can reduce excessive stress on the neck (Hansraj, 2014). Therefore, it is important to prevent the increase of the head and neck flexion angles during typing.

4.3.1 Elbow support did improve postures in the young adults while using smartphones

In our study, both groups significantly reduced head and neck flexion angles by using elbow support (Figure 4, Figure 6). These results were supported by Syamala (2018) and Tang (2022). Syamala et al. considered that using the elbow support would increase the height of the smartphone using, which significantly reduced head and neck flexion angles and gravitational moments (Syamala et al., 2018). In addition, they indicated that the elbow support would have better posture improvement effect when using the smartphone at the lower position (lap position). Tang et al. showed that adjusting the height of the seat armrest moderately can effectively reduce the head flexion angle (Tang et al., 2022). However, excessively high armrests can cause the user to change their support position from elbow support to forearm support. Using a smartphone with forearm support results in more shoulder protraction and more head flexion than elbow support, resulting in less support effect. This is why we used different support heights to make appropriate adjustments for the different body heights of the subjects. Our results found that typing with elbow support could significantly increase shoulder flexion angle (Figure 10). We inferred that the use of elbow support increases the angle of shoulder flexion, which increases the height of the smartphone. Thereby improving the user's posture and reducing awkward postures caused by smartphone using.

4.3.2 Neck pain affect neck and wrist postures while using a smartphone

There was no main effect found on group factor. However, we did find group x time x support interaction for neck flexion and group x time interaction for wrist extension angles. When typing without elbow support, the healthy group maintained their neck posture in the same position during the whole typing task. On the contrast, the neck pain group decreased neck flexion significantly after the typing task. While typing with elbow support, there were no such findings. We speculate that neck discomfort is responsible for this interaction. When typing without elbow support the neck pain group might avoid more neck discomfort due to the excessive neck flexion angle. Therefore, they choose another typing strategy (reduce the neck flexion angle) to complete the typing task. The speculation was supported by our finding that the perceived neck discomfort increased higher in the healthy group than the neck pain group after the typing task.

These results contrasted with Kim's research, which they found that the young adults with mild neck pain had a greater degree of cervical flexion when using a smartphone (Kim 2015). This may be related to the greater neck disability score (NDI: 16.9 ± 7.1) in their neck pain group. Higher neck disability scores may be associated with poorer use posture.

4.3.3 The head flexion angle increased after the typing task

After five minutes typing, we found a significant increase in head flexion angle which was supported by Maniwa (2013). The maintenance of tense in the upper extremities while typing, may increase the head, and neck flexion angle (Maniwa et al., 2013). However in our study only head flexion angle significantly increased. It may be caused by the different typing strategy. Maniwa’s participants were asked to typing by one hand, however, in our study all participants were two-handed typing. One-handed typing had significant higher muscle activity in right upper trapezius than two-handed typing (Lee et al., 2015). The different levels of upper trapezius muscle activity may affect the smartphone using posture, which made the findings different. Even the findings were slight different, we still confirmed that short-term smartphone typing can worsen posture in young adults.

4.4 Electromyography

4.4.1 Elbow support reduced most of the neck muscle activities, but less forearm muscle activities

When typing without elbow support, Namwongsa et al. pointed out that the less neck flexion, the upper arm must be raised in order to improve vision. Under this typing strategy, cervical erector spine muscle activities were reduced, while upper trapezius muscle activities were increased (Namwongsa et al. 2019). This typing strategy can improve the user's posture and reduce cervical erector spine activity, which can reduce the chance of musculoskeletal diseases caused by prolonged awkward postures (Namwongsa et al., 2018; Berolo et al., 2011; Gold et al., 2012; Maniwa et al., 2013; Bababekova et al., 2011). However, this strategy still caused discomfort of neck and shoulders as the upper trapezius muscle activities increased.

In recent years, the influence of elbow support on smartphone user’s neck muscle activities has been explored (Syamala et al., 2018; Tapanya et al., 2021). Using elbow support improved posture and reduced both cervical erector spine and upper trapezius muscle activities (Syamala et al., 2018; Tapanya et al., 2021). These were consistent with our findings that elbow support was effective in improving neck muscle activities while using the smartphone. In our study, it was found that both groups when typing with elbow support significantly reduced bilateral cervical erector spine, and right upper trapezius muscle activities (Figure 14, Figure 15, Figure 16). The possible mechanism is that the elbow support transferred the gravitational moment of the upper extremities to the support device and distributed the load, thereby reducing the load on the neck muscles (Tapanya et al., 2021). In addition, it may be that elbow support can help improve posture, thereby reducing neck and shoulders gravitational moments and muscle activities (Syamala et al., 2018).

Additionally, to our knowledge, we are the first to investigate the effect of elbow support on forearm muscle activity during smartphone use. Our findings pointed out that when typing with elbow support, the flexor digitorum superficialis muscle activity reduced significantly (Figure 18). We speculate that typing with elbow support also altered the biomechanics of the upper extremity. We found that typing under elbow support, the wrist extension angle increased significantly. Probably because the users can rest the arm by transferring the weight of the forearm and smartphone to the support (Tapanya et al., 2021). Therefore, the flexor digitorum superficialis muscle activity significantly reduced. To sum up, we found that elbow support reduces not only neck muscle activities, but also forearm muscle activity (only flexor digitorum superficialis).

4.4.2 The group difference of the muscle activities was not significant

In this study, we did not find any group difference of the muscle activities. We inferred that mild neck pain did not affect neck and forearm muscle activities during the smartphone use. The result is consistent with Johnston and Namwongsa et al.. There were no significant difference in neck muscle activities between non-neck pain and mild pain, although neck pain groups tended to have higher muscle activities (Johnston et al., 2008; Namwongsa et al., 2019). However, Xie et al. pointed out that neck-shoulder pain may affect neck muscle activities in young adults. Young adults with neck-shoulder pain had higher neck muscle activities during typing (Xie et al., 2016). Such contradictory findings may be due to different neck pain intensities. Johnson et al. also pointed out that office workers with moderate neck pain had higher EMG amplitude than those without pain. Additionally O'Leary et al. found superficial muscle activities and pain intensity were significantly and positively correlated in patients with chronic neck pain (O'Leary et al., 2011). Also typing task involved sustained stabilization by the proximal muscles and less force generated by the forearm muscles. There is no significant difference in upper trapezius EMG amplitude between neck pain and health groups with movements below the shoulder (Castelein et al., 2015). Above all, it can be inferred that the effect of neck pain on neck muscle activities for typing tasks may be found in groups with higher pain levels.

4.4.3 The time factor only affected some data of the muscle activities

The muscle activities of the left upper trapezius and flexor digitorum superficialis decreased significantly after five-minutes typing (Figure 21, Figure 23). The results of neck muscle activities were not fully consistent with Tapanya et al.. Their subjects were asked to play the smartphone game for twenty minutes. They found significant difference in bilateral upper trapezius muscle activities after fifteen minute playing. While in cervical erector spine muscle activities only the left side showed significant difference after five minutes playing (Tapanya et al., 2021). The different findings may be due to the task time (five minutes v.s. twenty minutes) and task intensity. Castelein (2015) pointed out that in activities below the shoulder, the proximal muscles (upper trapezius) continuously contracted to maintain posture (Castelein et al., 2015). However, the strength of contractions required to maintain posture typically less than 5% of maximal voluntary electrical activation (Veiersted et al., 1993). Thus, Tapanya (2021) found most neck muscle activity differences after fifteen minutes. Therefore, we infer that five minutes typing task may not be long enough and low strength demands, which does not effectively detect the effect of time on most neck muscle activities. In addition, flexor digitorum superficialis muscle activity decreased after a five-minute typing task. We speculate that it is due to visual distance. However, the opposite direction of neck flexion resulted in a difference in the required wrist extension angle between the two groups. At constant visual distance, the healthy group required greater wrist extension to increase visual distance due to increased head and neck flexion.

4.5 Using the elbow support can reduce perceived neck discomfort

Typing under elbow support, the perceived neck discomfort of both groups can maintain as the same level before typing task. However, typing under no elbow support significantly increased the perceived neck discomfort of both groups. These results supported that typing with elbow support can effectively reduce neck discomfort in health young adults during smartphone use (Tapanya et al., 2021; Tang et al., 2022).

We also found that the perceived neck discomfort increased higher in the healthy group than the neck pain group after the typing task. We speculated that it was related to our neck flexion findings. The healthy group had a tendency to increase the neck flexion angle, whereas the neck pain group had the opposite finding. This resulted in a different degree of increased neck discomfort between the two groups. To sum up, it is important for the young adults to using ergonomic interventions (elbow support) when using smartphones, which could be effective in avoiding perceived neck discomfort.

4.6 Pain pressure threshold was affected by time factor

After the typing task, bilateral upper trapezius pain pressure threshold decreased significantly. These were supported by Kim (2012) and Lee (2015). They found that using smartphones can significantly reduce the upper trapezius pressure pain threshold (Kim et al., 2012; Lee et al., 2015). The mechanism may be that the repetitive movements during using smartphone may increase the percentage of reference voluntary isometric contractions (RVIC), which cause micro-trauma to muscles, nerves, etc (Kim et al., 2012; Park et al., 2013). Micro-trauma may increase susceptibility to musculoskeletal disorders (Kim et al., 2012; Lee et al., 2015). Therefore, a short-term (e.g., five minutes) typing task is sufficient to lower the upper trapezius pain pressure threshold.

We found that left upper trapezius had a significant group x time interaction, and right upper trapezius had a significant time x support interaction. After the typing task, the pain pressure threshold of left upper trapezius for the healthy group decreased more than the neck pain group. We speculate that this is because the healthy group had a significantly higher pain pressure threshold before the typing task. Combined with the floor effect, it is easier for the pain group to reach their lowest level of pain pressure threshold. However, our speculation contradicted previous research findings. Nunes et al (2021) investigated the pain pressure threshold in neck pain office workers. In their review, there was no significant difference between the chronic neck pain and healthy workers, but the chronic neck pain group tended to have smaller pain pressure thresholds compared to the healthy group (Nunes et al., 2021). However, they pointed out that this finding is based on a small sample of existing research. In the future, more research is needed to determine whether patients with chronic neck pain have lower pain pressure thresholds than the healthy adults.

The pain pressure threshold of right upper trapezius tended to decrease more when typing without elbow support than with elbow support. This may be due to better typing posture when typing with the elbow support. When neck extensor muscle activity reduced, head and neck posture can be improved and the pain pressure threshold increased (Kim et al., 2018; Kim et al., 2016). Therefore, elbow support may reduce the effect of the time factor to the pain pressure threshold. More research is needed to explore the effect of elbow support on pain pressure threshold in the future.

4.7 Limitation

There are some limitations to the experiment. First, the typing task time may be relatively short (5 minutes). Since the intensity of the typing task may not be strong enough. Some long-term changes may not be detected when the typing time is too short. Second, this experiment is the first to discuss the muscle groups of the forearm. However, the result suggested that elbow support improves head and neck posture by increasing the shoulder flexion angle. Therefore, the effect of elbow support on muscle activities of shoulder flexor muscles (e.g., anterior deltoid) should be explored. Third, the neck pain group in this study had low neck disability scores. As a result, there were only few significant difference between groups in posture and muscle activity. Future research could explore the effect of elbow support on people with more severe neck disabilities.

Despite these limitations, this experiment to our knowledge is the first experiment that investigated the effect of elbow support on young smartphone users with neck pain. Although, there were no significant findings between the neck pain group and healthy group. We found that elbow support helped improve posture and reduce muscle activities when using smartphones in young adults. Also, elbow support can significantly reduce the neck discomfort scores when typing in young adults. However, young adults do not use smartphones only in sitting position. They may use smartphones in some other positions (e.g., prone, supine). Whether the use of elbow support also helps to improve posture and reduce muscle activity in these worsen positions is worth to investigate in future research.

Chapter 5 Conclusion

This experiment demonstrated that ergonomic intervention (elbow support) is effective in improving posture and reducing not only neck muscle activities but also neck discomfort among the young adults while using smartphones. Five-minute typing task can affect posture, muscle activity, and neck discomfort. However, less time effect was found on muscle activity. After a five-minute typing task, both groups moved the smartphone closer to the body. For the group difference, two groups use different posture strategies when they are using smartphones, especially under no elbow support condition. Above all, our results indicate that young adults using smartphones with elbow support could improve their posture and EMG. Future study may focus on the using time to explore the effect of time, and recruit some subjects with higher neck disability to explore the group differences.

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Table 1. Demographic data of participants

	Healthy young adults	Neck pain young adults	P value
Number (Male:Female)	16 (8:8)	16 (8:8)	
Age (y/o)	23.1±2.4	22.5±2.9	0.551
BMI	23.47±3.76	23.09±3.65	0.778
Physical activity time per week (hours)	3.45±2.60	4.83±6.99	0.465
Difference in physical activity between the past seven days and the past three months (less/similar/more)	2:11:3	11:3:2	0.004*
Daily walking time (hours)	1.94±2.50	0.66±1.24	0.08
Daily sitting time (hours)	8.34±3.12	10.29±3.38	0.1
Smartphone experience (years)	8.6±1.8	8.9±2.7	0.703
Daily smartphone use time (hours)	5.3±2.9	5.2±2.2	0.891
Daily smartphone/tablet/ laptop use time (hours)	9.60±3.17	12.03±2.79	0.016*
Neck Disability Scale (NDI score)	0	6.4±1.6	<0.001*
Pain intensity at rest (VAS score)	0	3.9±1.2	<0.001*

Values are mean ±SD, *:Significant difference of groups (p<.05)

Table 2. Resting sitting position

Mean angle(°)	Healthy young adults	Neck pain young adults	P value
Head flexion	49.8±7.9	46.3±7.8	0.211
Neck flexion	43.0±7.3	44.5±6.2	0.531
Shoulder flexion	20.6±7.8	17.5±5.2	0.197

Values are mean ±SD, *:Significant difference of groups (p<.05)

Table 3. Head flexion angle(°) under different conditions and at different time points for both groups

		Healthy young adults			Neck pain young adults		Main effect or Interaction
Factors	Resting	Without elbow support	Elbow support	Resting	Without elbow support	Elbow support	
Time 1	49.8±7.9	66.0±9.3	50.3±9.3	46.3±7.8	69.4±9.4	48.2±8.4	Elbow support (F=107.181, p<0.001) Time (F=5.694, p=0.024)
Time 2		68.1±10.0	51.3±9.2		68.6±9.3	50.2±7.7	

Table 4. Condition difference of postural results

Mean angle(°)	Without elbow support	Elbow support	F	df	p value
Head flexion	68.0±9.4	50.0±8.5	107.181	1,30	0.024*
Neck flexion	62.6±9.1	53.7±7.2	51.173	1,30	<0.001*
Shoulder flexion	16.4±8.0	40.0±6.4	251.587	1,30	<0.001*
Elbow flexion	110.5±2.7	111.3±1.2	0.105	1,30	0.749
Wrist extension	15.8±1.4	21.0±1.4	36.280	1,30	<0.001*

Values are mean ±SD, *:Significant difference of conditions (p<.05)

Table 5 Time difference of postural results

Mean angle(°)	Time 1	Time 2	F	df	P value
Head flexion	58.5±13.0	59.6±12.6	5.694	1,30	0.024*
Neck flexion	58.4±1.3	58.0±1.3	0.657	1,30	0.424
Shoulder flexion	28.3±1.1	28.1±1.0	0.550	1,30	0.464
Elbow flexion	70.4±1.7	67.7±1.6	11.956	1,30	0.002*
Wrist extension	17.2±1.4	19.6±1.3	11.956	1,30	0.002*

Values are mean ±SD, *:Significant difference of time points (p<.05)

Table 6. Neck flexion angle(°) under different conditions and at different time points for both groups

	Health young adults			**Neck pain young adults**			**Main effect or Interaction**
Factors	Resting	Without elbow support	Elbow support	Resting	Without elbow support	Elbow support	
Time 1	43.0±7.3	62.4±8.0	54.7±8.4	44.5±6.2	63.7±9.9	52.7±6.9	Elbow support (F=51.173, p<0.001) Support x time x group (F=11.930, p=0.002)
Time 2		63.7±8.8	54.0±7.4		60.7±10.1	53.5±6.6	

Table 7. Shoulder flexion angle(°) under different conditions and at different time points for both groups

	Healthy young adults			Neck pain young adults			Main effect or Interaction
Factors	Resting	Without elbow support	Elbow support	Resting	Without elbow support	Elbow support	
Time 1	20.6±7.8	18.0±5.2	41.0±6.0	17.5±5.2	14.7±10.8	39.6±7.2	Elbow support (F=251.587, $p<0.001$)
Time 2		18.8±3.8	40.4±5.5		14.3±9.9	38.8±7.2	

Table 8. Elbow flexion angle(°) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	70.4±13.3	71.1±6.8	71.0±17.8	69.1±8.4	Time (F=11.956, p=0.002)
Time 2	68.1±14.2	68.2±7.5	68.3±15.3	66.2±5.5	

Table 9. **Wrist extension angle(°) under different conditions and at different time points for both groups**

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	16.0±9.5	20.2±8.7	14.1±7.7	18.3±6.8	Elbow support (F=36.280, p<0.001) Time (F=31.312, p<0.001) Time x group (F=7.533, p=0.1)
Time 2	19.4±8.3	24.2±9.0	13.8±7.2	21.2±7.4	

Table 10. RMS of static EMG

RMS	Health young adults	Neck pain young adults
Left cervical erector spine	0.0046±0.0037	0.0080±0.0057
Left upper trapezius	0.0082±0.0065	0.0127±0.0157
Right cervical erector spine	0.0031±0.0013	0.0057±0.0045
Right upper trapezius	0.0057±0.0063	0.0073±0.0074
Flexor digitorum superficialis	0.0068±0.0065	0.0121±0.0095
Extensor digitorum	0.0148±0.0170	0.0177±0.0128
Extensor carpi radialis brevis	0.0046±0.0030	0.0081±0.0097
Abductor pollicis brevis	0.0070±0.0045	0.0086±0.0057

Values are mean ±SD, *:Significant difference of groups (p<.05)

Table 11. Muscle activity of the right cervical erector spine (percentage %) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	40.19±47.06	5.96±20.13	18.81±34.98	0.28±20.01	Elbow support (F=21.637 p<0.001)
Time 2	34.92±50.64	3.81±20.00	17.82±30.48	1.71±27.76	

Table 12. Muscle activity of the left cervical erector spine (percentage %) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	19.30±48.08	-6.05±24.61	20.70±63.31	-2.47±23.09	Elbow support (F=251.587, p<0.001)
Time 2	17.57±61.32	-8.47±28.54	20.38±60.66	-2.21±33.34	

Table 13. **Muscle activity of the right upper trapezius (percentage %) under different conditions and at different time points for both groups**

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	70.53±89.26	1.32±33.27	128.85±197.85	36.30±125.98	Elbow support (F=8.782, p=0.006)
Time 2	53.31±86.89	-4.35±29.44	129.10±187.56	27.22±76.07	

Table 14. **Muscle activity of the left upper trapezius (percentage %) under different conditions and at different time points for both groups**

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	33.70±94.46	-9.43±37.63	21.93±138.40	-11.11±21.69	Time effect (F=6.065, p=0.02)
Time 2	12.23±62.41	-10.60±43.30	-0.36±71.54	-19.39±22.49	

Table 15. Condition difference of electromyographic results (percentage %)

Muscle activity	Without elbow support	Elbow support	F	df	P value
Right cervical erector spine	27.9±41.8	2.9±21.8	21.637	1,30	<0.001*
Left cervical erector spine	19.5±57.2	-4.8±27.1	6.806	1,30	0.014*
Right upper trapezius	95.4±150.2	15.1±77.0	8.782	1,30	0.006*
Left upper trapezius	0.2±0.2	-0.1±0.1	3.545	1,30	0.069
Flexor digitorum superficialis	94.7±23.0	57.9±28.3	4.521	1,30	0.042*
Extensor digiturom	0.4±0.1	0.3±0.1	0.801	1,30	0.378
Extensor carpi radialis brevis	1.9±0.7	1.8±0.7	0.131	1,30	0.720
Abductor pollicis brevis	19.8±2.9	18.7±2.4	0.825	1,30	0.371

Values are mean ±SD, *:Significant difference of conditions (p<.05)

Table 16. Time difference of electromyographic results (percentage %)

Muscle activity	Time 1	Time 2	F	df	P value
Right cervical erector spine	0.2±0.1	0.1±0.1	0.943	1,30	0.339
Left cervical erector spine	0.1±0.1	0.1±0.1	0.315	1,30	0.579
Right upper trapezius	0.6±0.2	0.5±0.1	0.667	1,30	0.420
Left upper trapezius	8.8±86.7	-4.5±53.4	6.056	1,30	0.020*
Flexor digitorum superficialis	87.8±160.1	64.8±140.4	6.288	1,30	0.018*
Extensor digiturom	0.3±0.1	0.3±0.1	0.304	1,30	0.585
Extensor carpi radialis brevis	1.8±0.7	1.9±0.7	0.429	1,30	0.517
Abductor pollicis brevis	19.1±2.5	19.4±2.8	0.054	1,30	0.818

Values are mean ±SD, *:Significant difference of conditions (p<.05)

Table 17. Muscle activity of the flexor digitorum superficialis (percentage %) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	150.49±185.30	91.75±219.23	61.01±106.33	47.99±85.45	Elbow support (F=4.521, p=0.042) Time effect (F=6.288, p=0.018)
Time 2	122.72±143.55	70.05±216.30	44.66±80.91	21.84±52.90	

Table 18. Muscle activity of the extensor digitorum (percentage %) under different conditions and at different time points for both groups

	Healthy young adults		Neck pain young adults		Main effect or Interaction
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	36.39±69.52	22.88±50.87	22.92±54.80	38.67±78.95	
Time 2	43.55±100.37	22.18±69.90	39.44±71.34	25.70±52.29	

Table 19. Muscle activity of the extensor carpi radials brevis (percentage %) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	258.38±513.62	232.26±479.96	131.60±194.99	109.01±147.30	
Time 2	252.81±507.87	284.46±639.11	121.62±173.06	113.01±207.33	

Table 20. Muscle activity of the abductor pollucis brevis (percentage %) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Without elbow support	Elbow support	Without elbow support	Elbow support	
Time 1	1574.68±1185.73	1836.19±1407.64	2243.98±1817.44	1975.99±1410.73	
Time 2	1653.66±1157.59	1474.66±734.01	2429.19±2252.51	2197.72±1951.71	

Table 21. Perceived neck discomfort score under different conditions and at different time points for both groups

	Healthy young adults		Neck pain young adults		Main effect or Interaction
Factors	Before typing	After typing	Before typing	After typing	
Without elbow support	0.0±0.2	2.1±0.4	2.9±0.2	4.1±0.4	Support (F=46.632, p<0.001) Time (F=27.649, p<0.001) Group (F=48.595, p<0.001) Time x Group (F=5.461, p=0.026) Support x Time (F=46.632, p<0.001)
Elbow support	0.0±0.2	0.3±0.4	2.9±0.2	2.6±0.4	

Table 22. Perceived neck discomfort under different conditions

Perceived neck discomfort	Without elbow	Elbow support	F	df	P value
Perceived neck discomfort	2.3±0.2	1.5±0.2	46.621	1,30	<0.001*

Values are mean ±SD, *:Significant difference of conditions (p<.05)

Table 23. Perceived neck discomfort at different time points

Perceived neck discomfort	Time 1	Time 2	F	df	P value
Perceived neck discomfort	1.4±0.1	2.3±0.2	27.649	1,30	<0.001*

Values are mean ±SD, *:Significant difference of time points (p<.05)

Table 24. Perceived neck discomfort in different groups

Perceived neck discomfort	Healthy group	Neck pain group	F	df	P value
Perceived neck discomfort	0.6±0.3	3.1±0.3	48.595	1,30	<0.001*

Values are mean ±SD, *:Significant difference of groups (p<.05)

Table 25. Pain pressure threshold of the left upper trapezius (kg) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Before typing	After typing	Before typing	After typing	
Without elbow support	2.23±0.68	1.95±0.67	1.82±0.46	1.73±0.61	Time (F=43.640, p<0.001) Time x group (F=5.172, p=0.03)
Elbow support	2.19±0.69	1.95±0.75	1.93±0.54	1.77±0.63	

Table 26. Pain pressure threshold of the left/ right upper trapezius at different time points

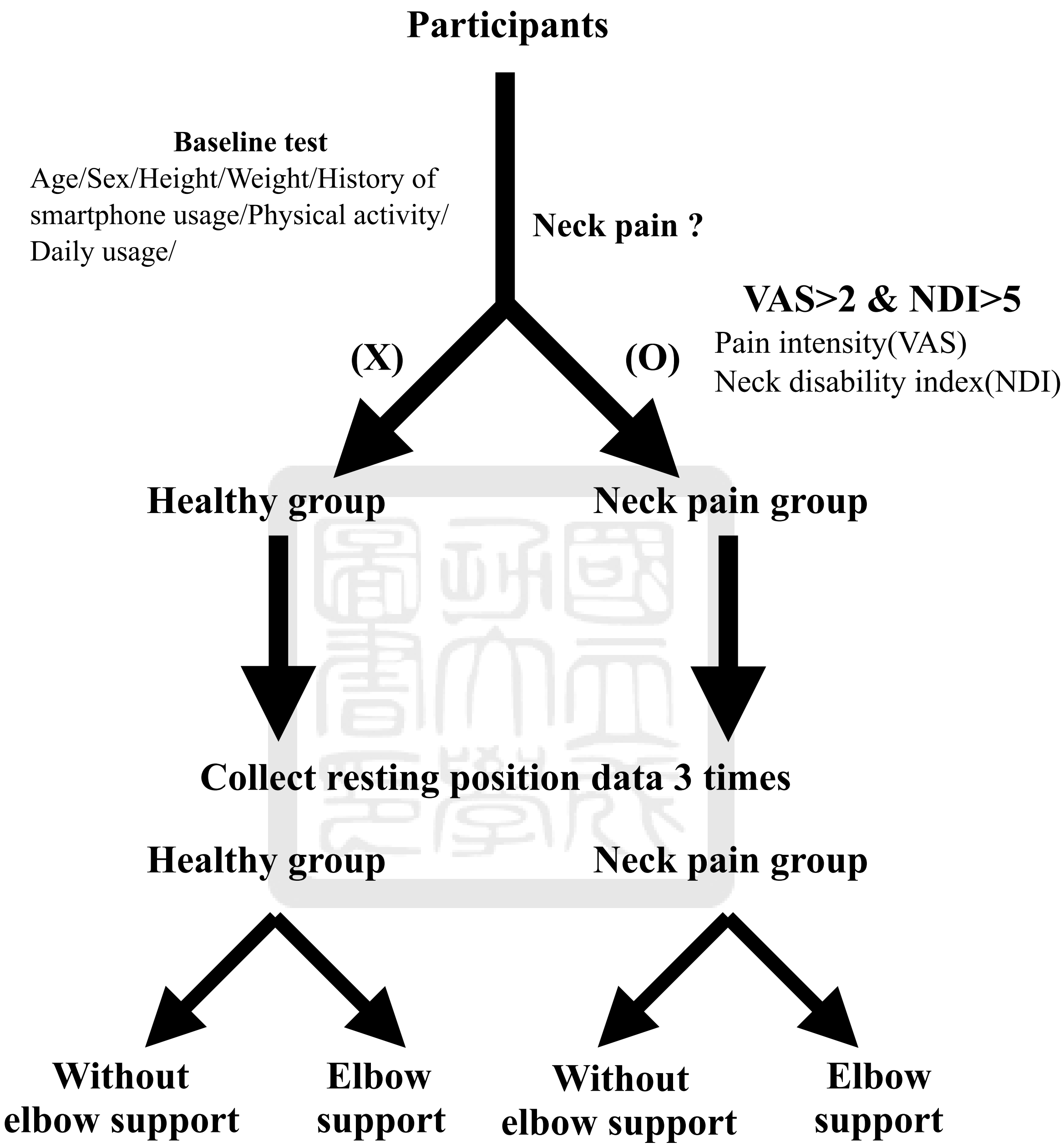
Pain pressure threshold	Time 1	Time 2	F	df	P value
Left upper trapezius	2.04±0.10	1.85±0.12	43.640	1,30	<0.001*
Right upper trapezius	2.20±0.11	2.02±0.12	32.565	1,30	<0.001*

Values are mean ±SD, *:Significant difference of time points (p<.05)

Table 27. Right upper trapezius pain pressure threshold (kg) under different conditions and at different time points for both groups

	Healthy young adults		**Neck pain young adults**		**Main effect or Interaction**
Factors	Before typing	After typing	Before typing	After typing	
Without elbow support	2.36±0.70	2.08±0.73	2.08±0.57	1.92±0.63	Time (F=32.565, p<0.001) Support x Time (F=4.390, p=0.045)
Elbow support	2.29±0.73	2.16±0.69	2.05±0.51	1.91±0.60	

Flow chart



Randomly, 5 minutes typing test, 5 minutes rest between the test

Figure 1. The flow chart of the experiment

Figure 2. Elbow support instrument left :front view, right :side view

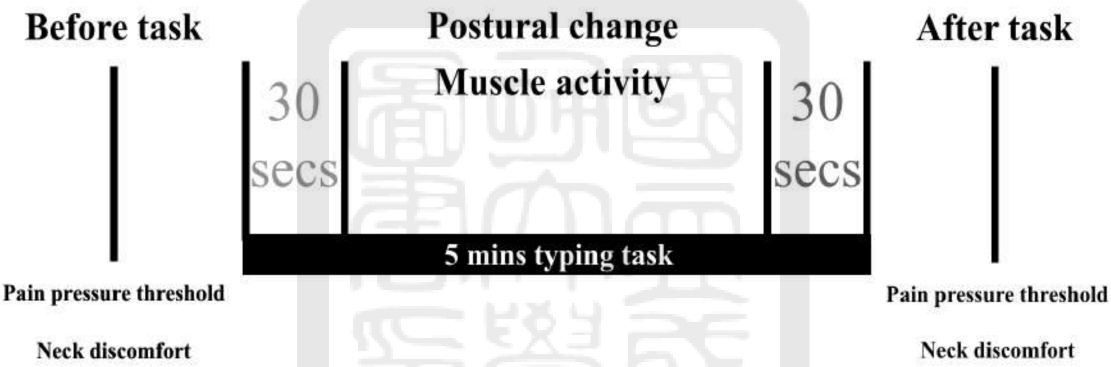


Figure 3. The data collection process

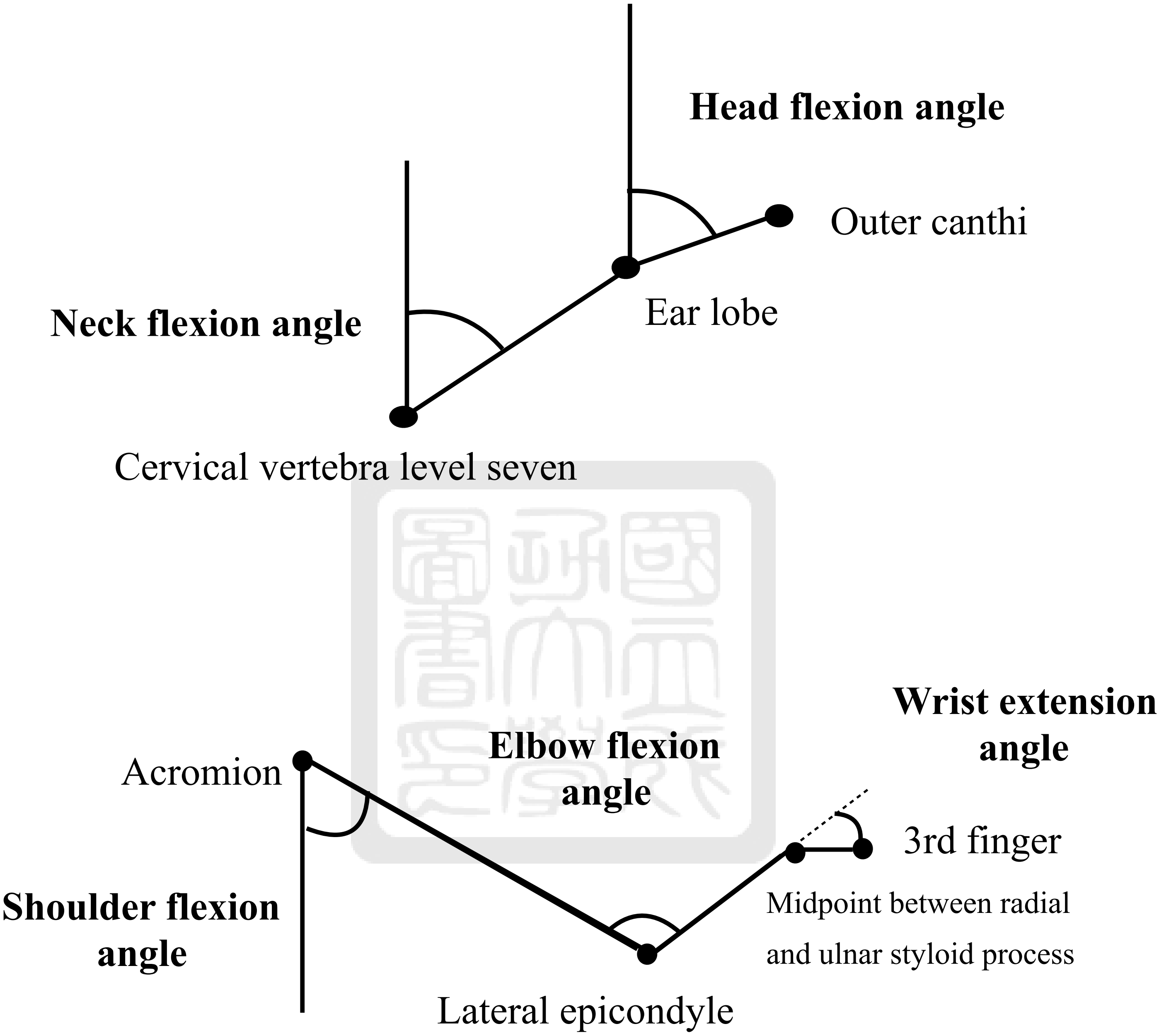


Figure 4. Marker placement and angle definition. The dotted line is an extension of the solid line.

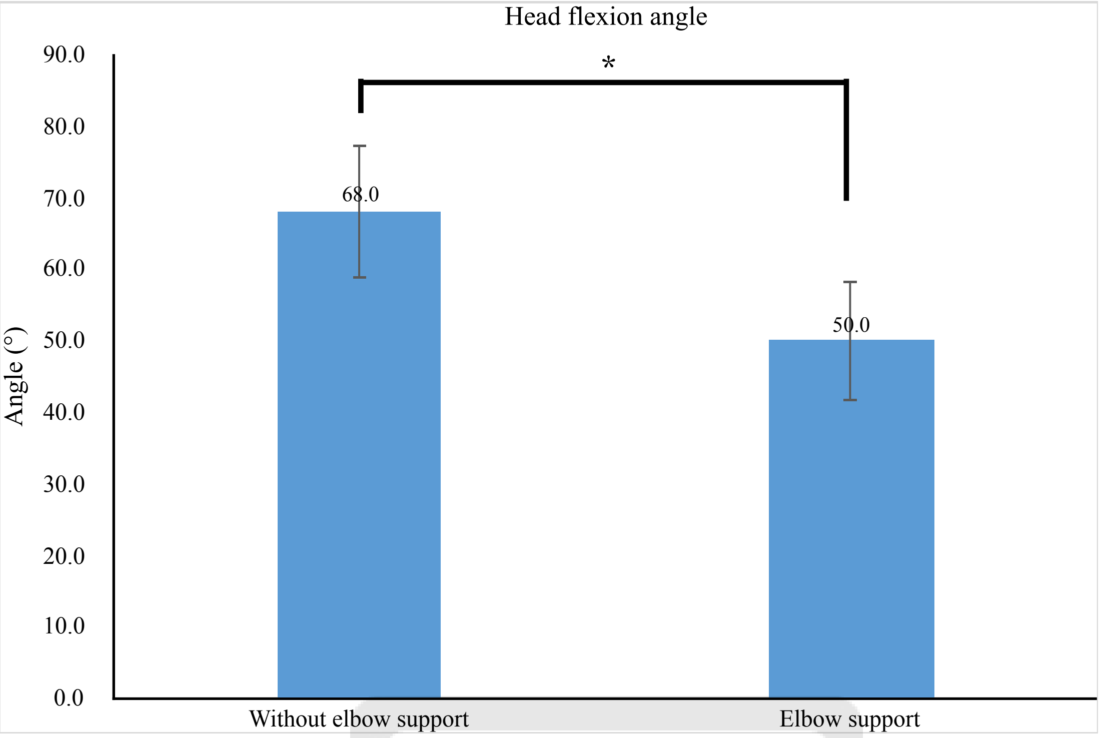


Figure 5. Comparison of the head flexion angle between two conditions *:Significant difference (p<.05)

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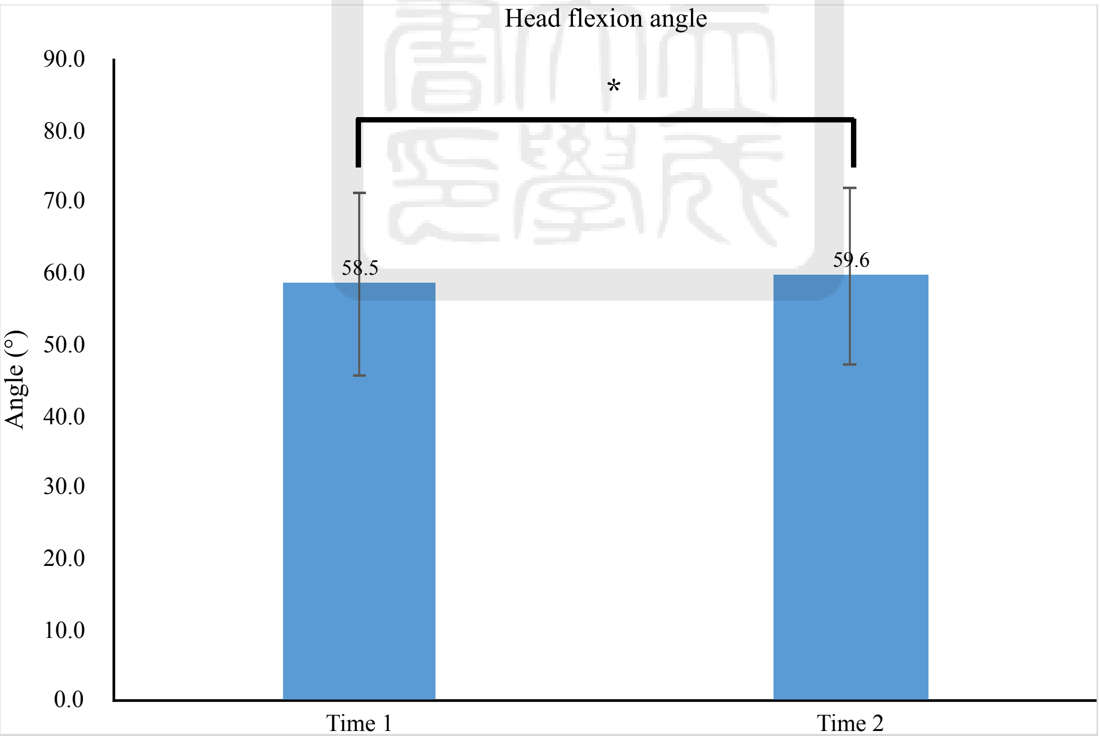

Figure 6. Comparison of the head flexion angle between two time points *:Significant difference (p<.05)

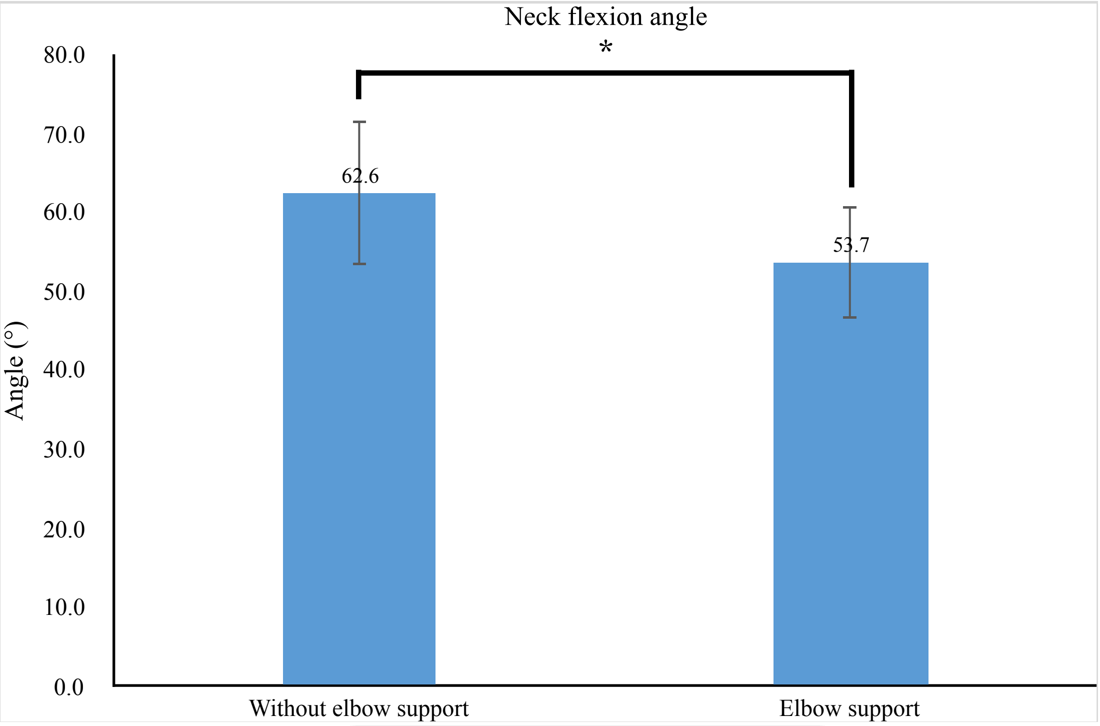

Figure 7. Comparison of the neck flexion angle between two conditions *:Significant difference (p<.05)

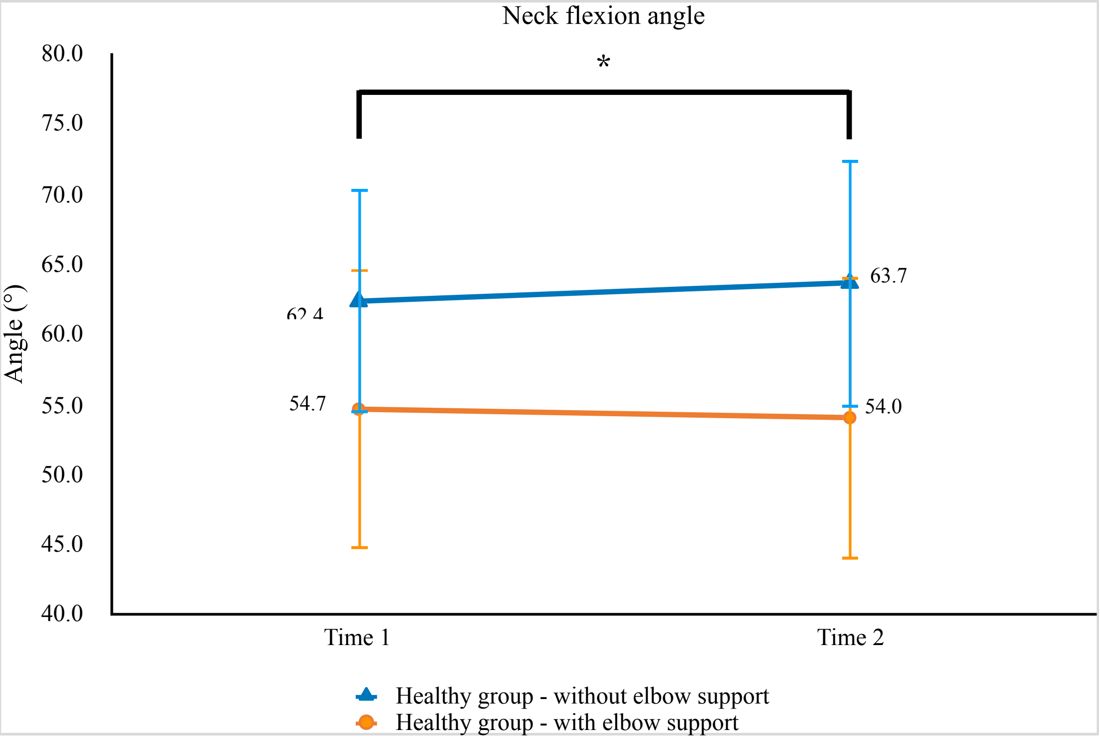

Figure 8-1. Neck flexion angle - Support x time x group interaction (The health group)
Under no elbow support condition, the neck flexion angle increased in the health group.
Under elbow support condition, the neck flexion angle maintained the same level in the health group.
"*" indicates that significant differences at Time 1 and Time 2 in neck pain group typing without elbow support (p<0.05)

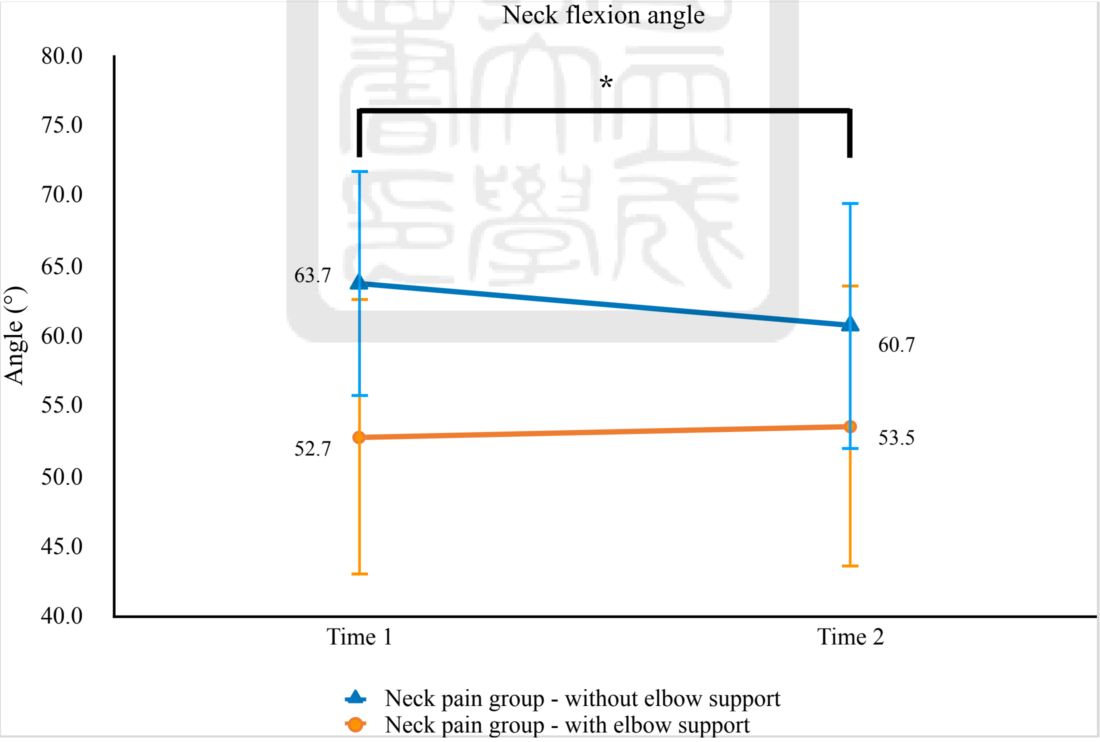

Figure 8-2. Neck flexion angle - Support x time x group interaction (The neck pain group)
Under no elbow support condition, the neck flexion angle decreased in the neck pain group.
Under elbow support condition, the neck flexion angle maintained the same level in the neck pain group.
"*" indicates that significant differences at Time 1 and Time 2 in neck pain group typing without elbow support (p<0.05)

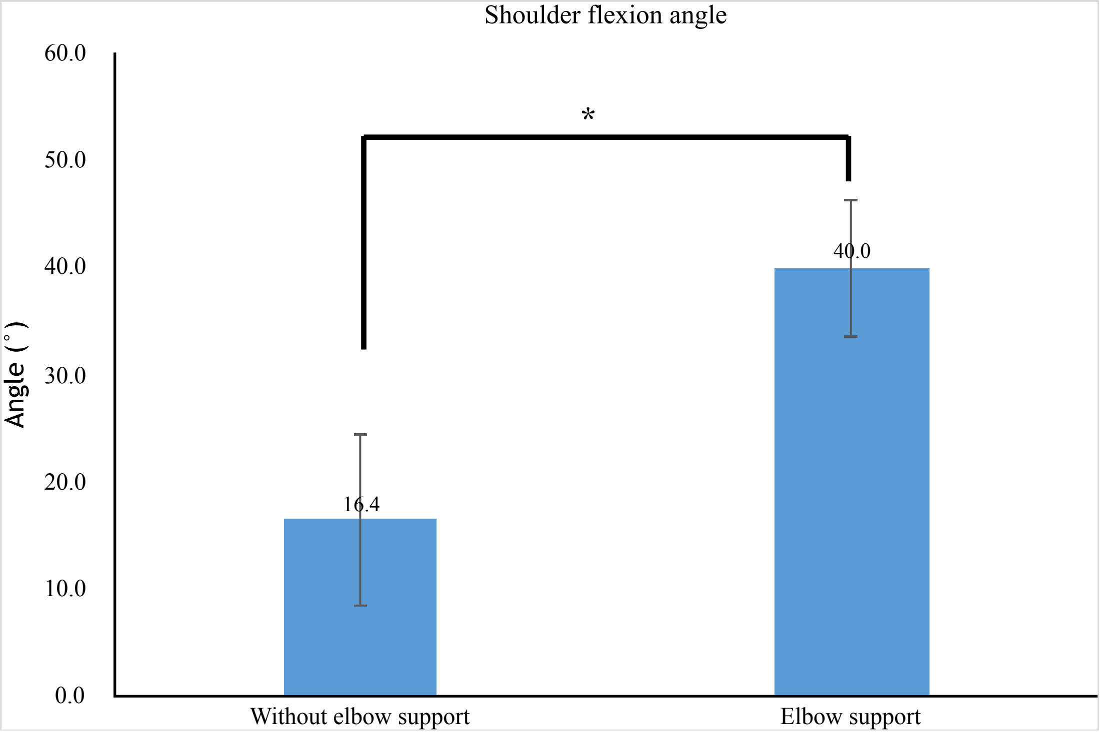

Figure 9. Comparison of the shoulder flexion angle between two conditions *:Significant difference (p<.05)

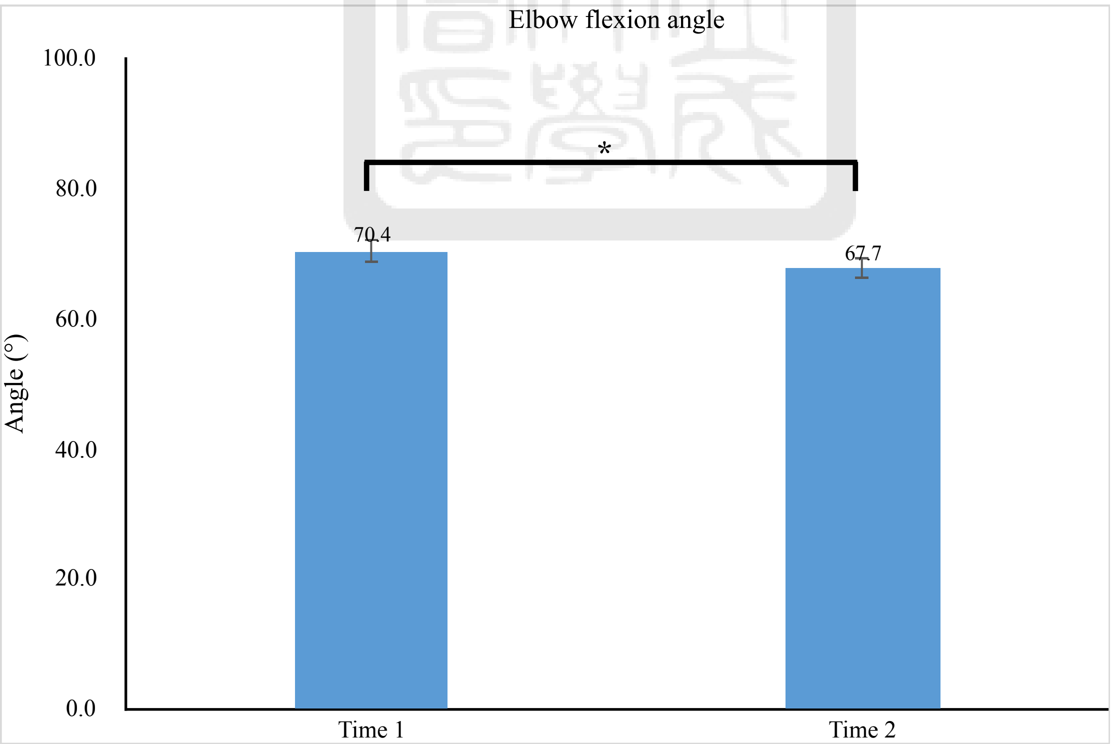

Figure 10. Comparison of the elbow flexion angle between two time points *:Significant difference (p<.05)

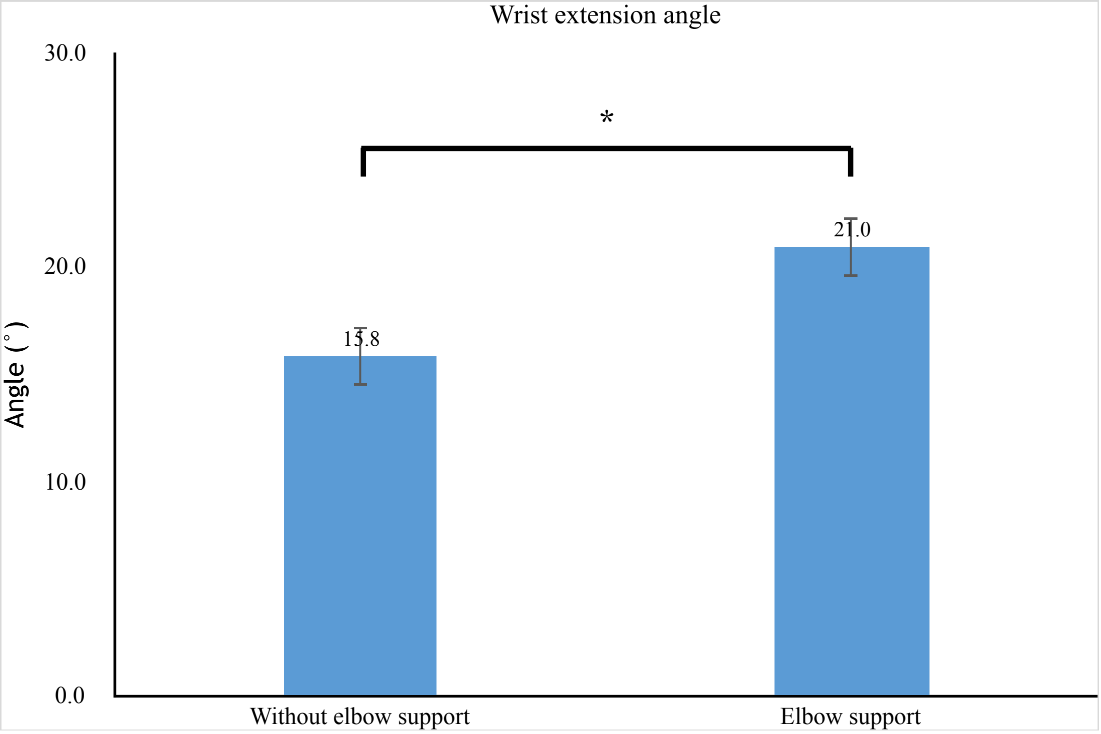

Figure 11. Comparison of the wrist extension angle between two conditions *:Significant difference (p<.05)

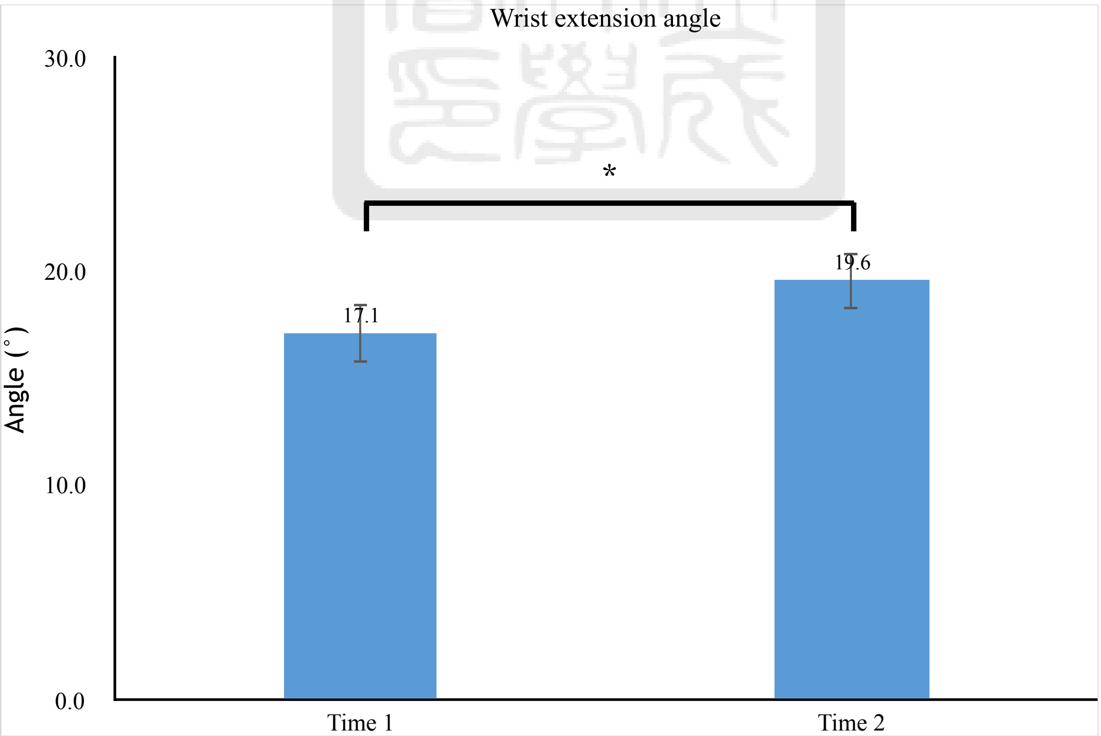

Figure 12. Comparison of the wrist extension angle between two time points *:Significant difference (p<.05)

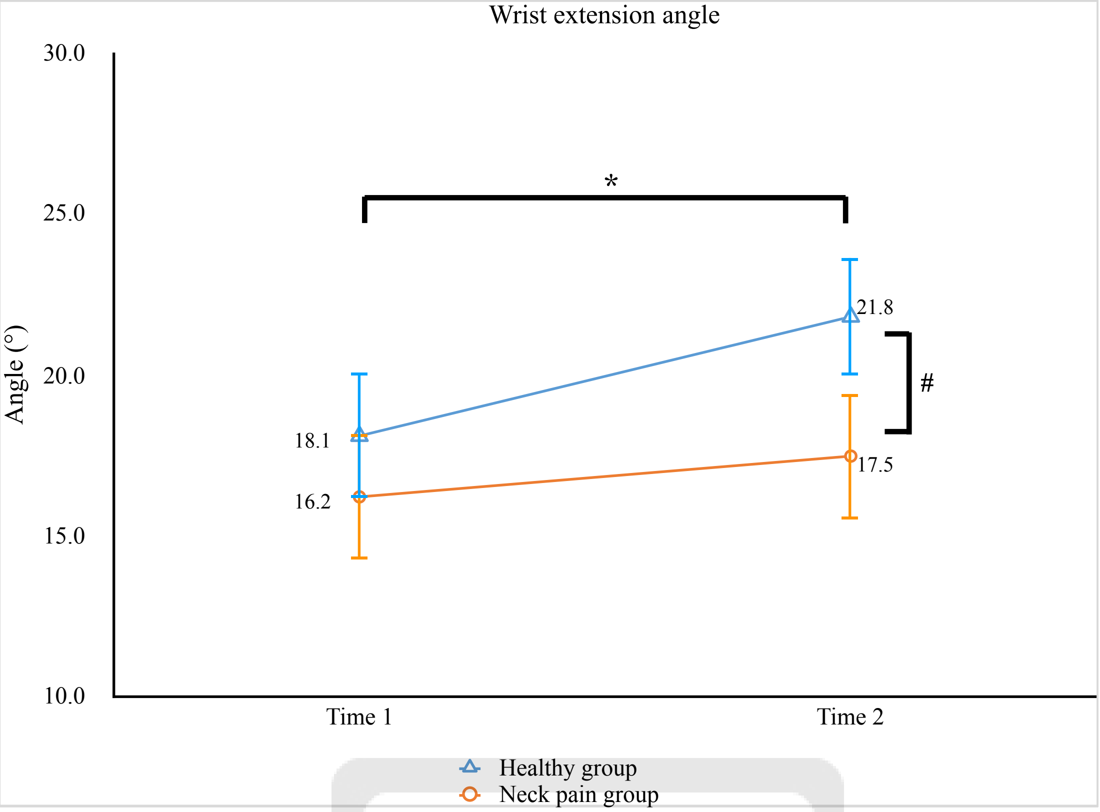

Figure 13. Wrist extension angle : a significant group x time interaction was found
The wrist extension increased more in the healthy group than the neck pain group after five minutes typing.
"*" indicates that significant difference at Time 1 and Time 2 in healthy group ($p<0.05$)
"#" indicates that significant difference between two groups at Time 2 ($p<0.05$)

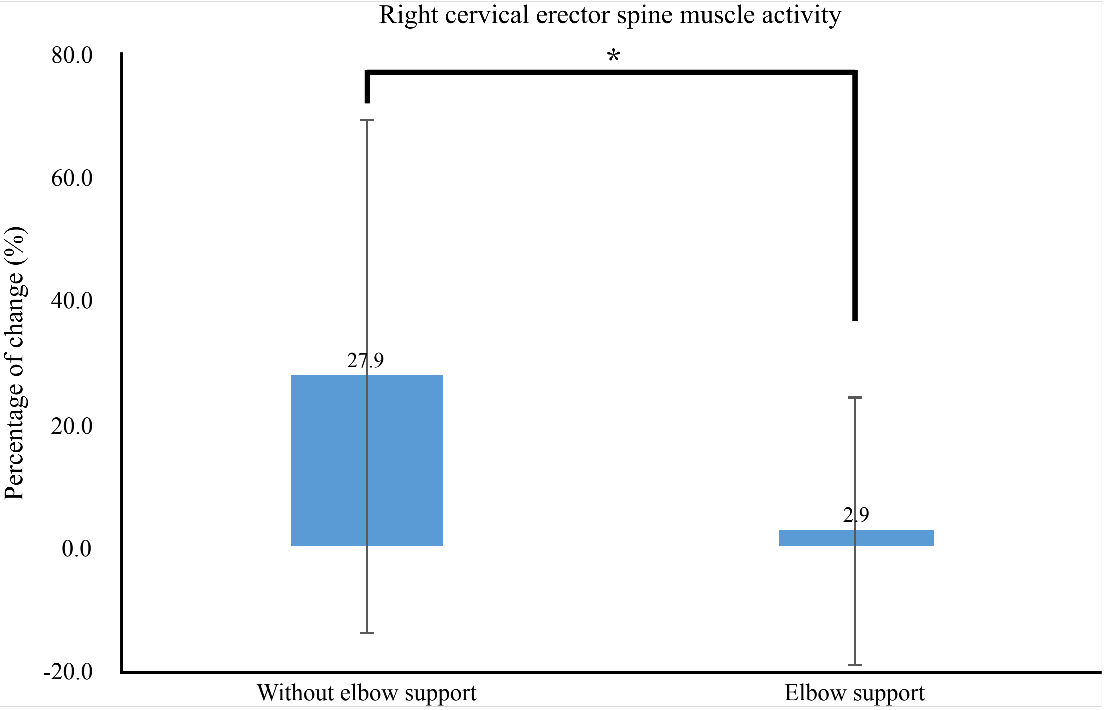

Figure 14. Comparison of the muscle activity for the right cervical erector spine between two conditions *:Significant difference (p<.05)

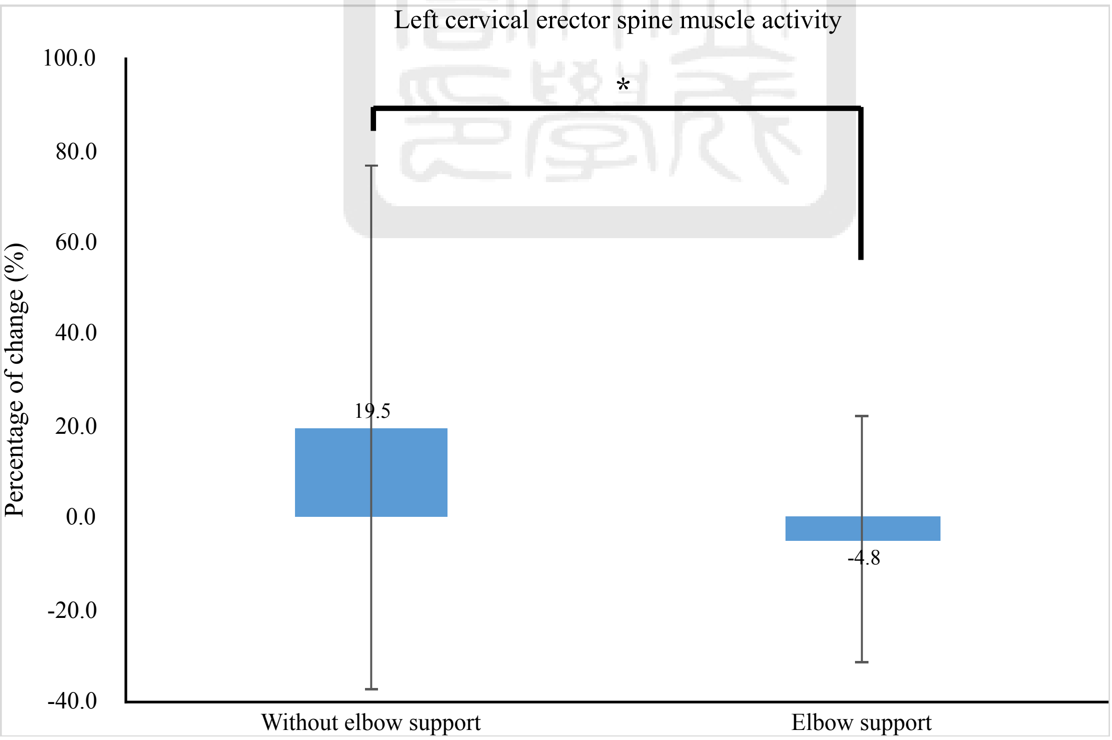

Figure 15. Comparison of the muscle activity for the left cervical erector spine between two conditions *:Significant difference (p<.05)

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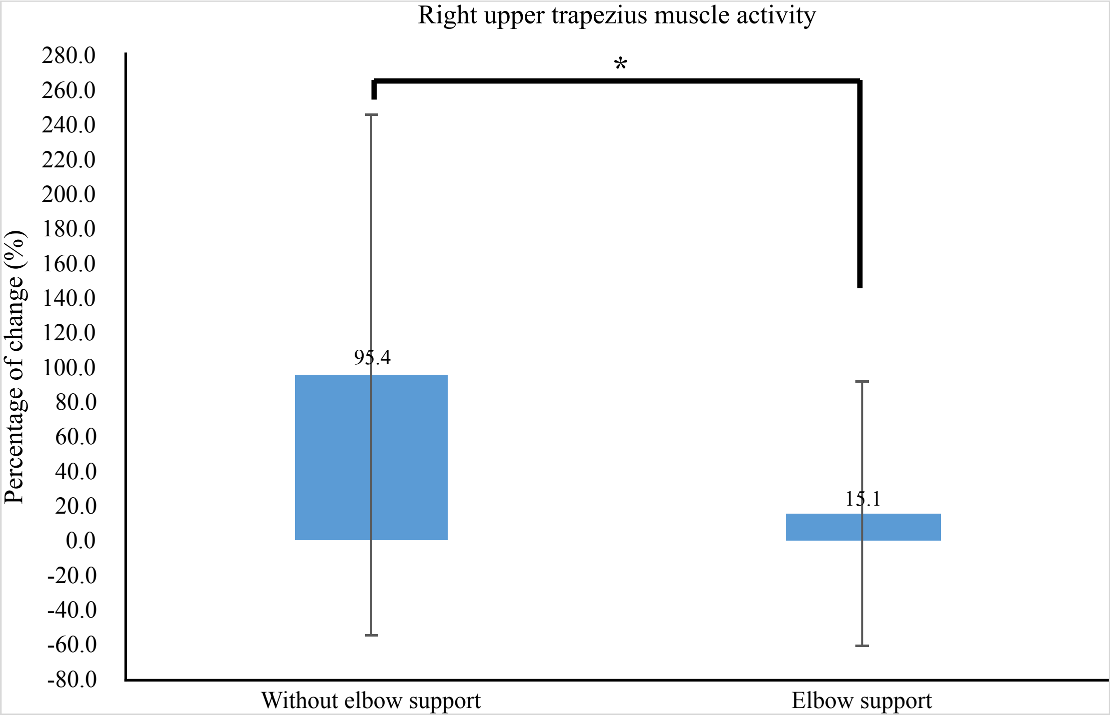

Figure 16. Comparison of the muscle activity for the right upper trapezius between two conditions *:Significant difference (p<.05)

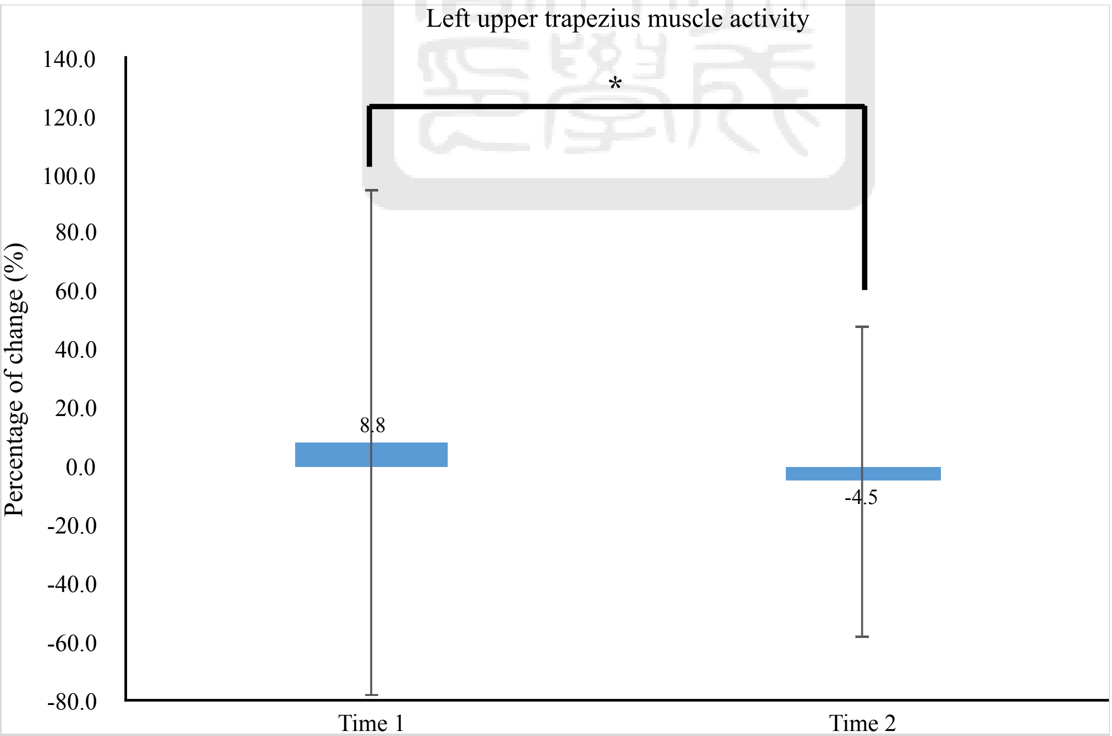

Figure 17. Comparison of the muscle activity for the left upper trapezius between two time points *:Significant difference (p<.05)

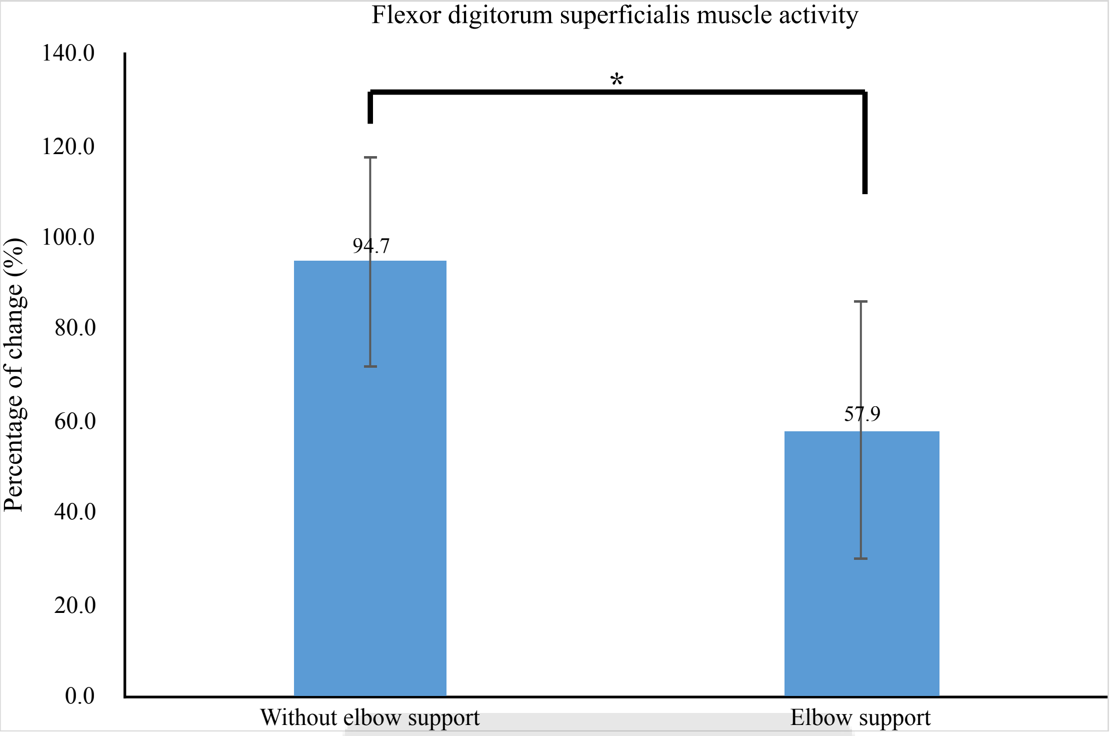

Figure 18. Comparison of the muscle activity for the flexor digitorum superficialis between two conditions *:Significant difference (p<.05)

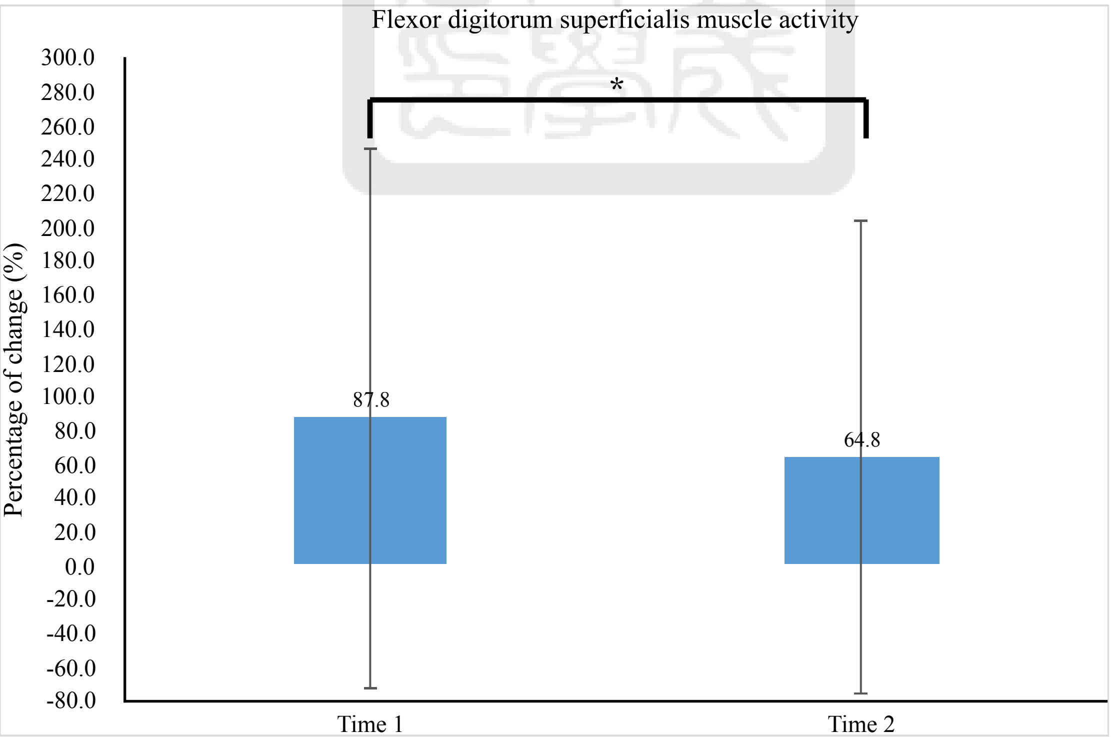

Figure 19. Comparison of the muscle activity for the flexor digitorum superficialis at different time points *:Significant difference (p<.05)

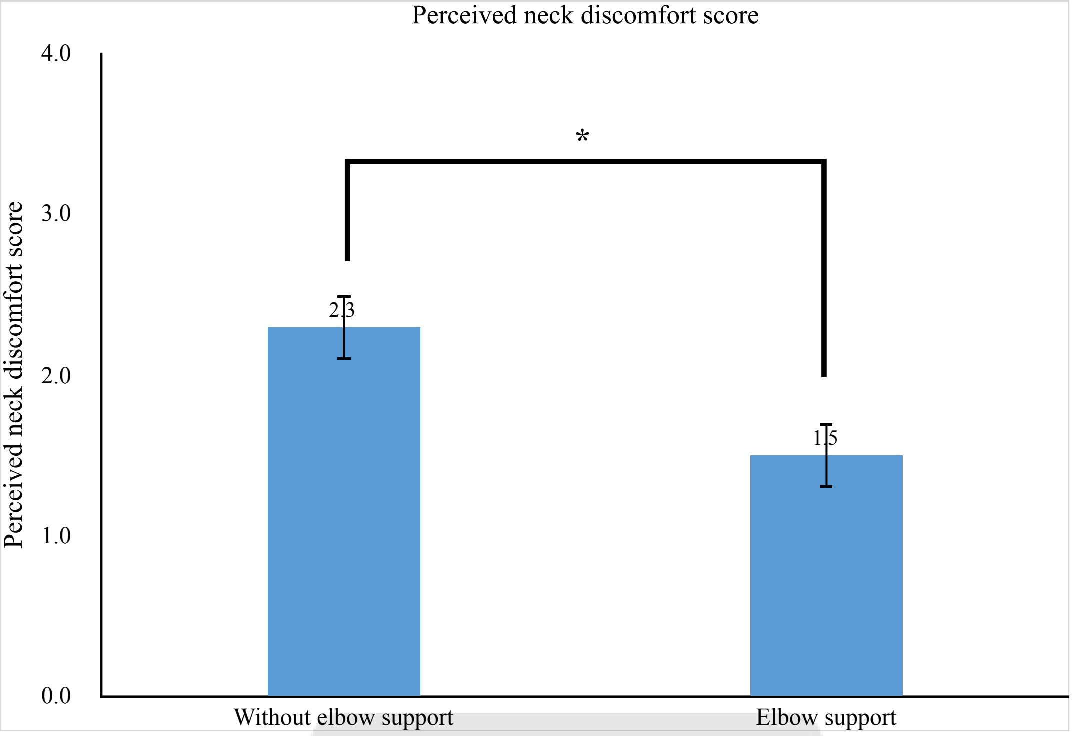

Figure 20. Comparison of the perceived neck discomfort at different conditions
*:Significant difference (p<.05)

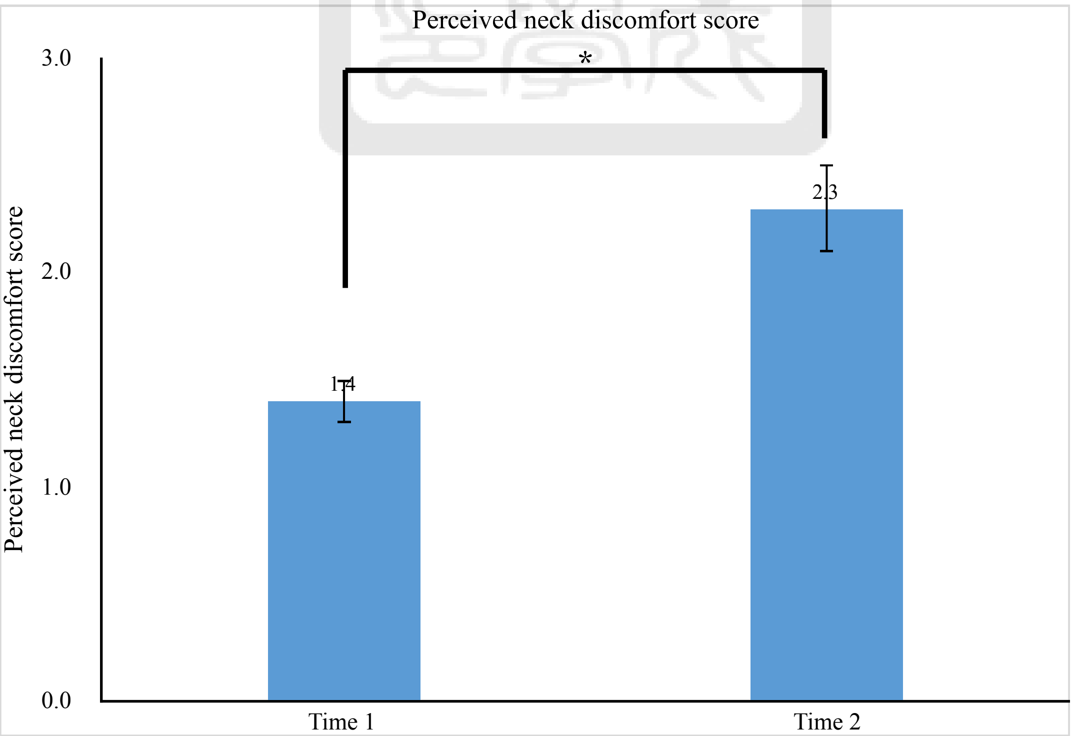

Figure 21. Comparison of the perceived neck discomfort at different time points
*:Significant difference (p<.05)

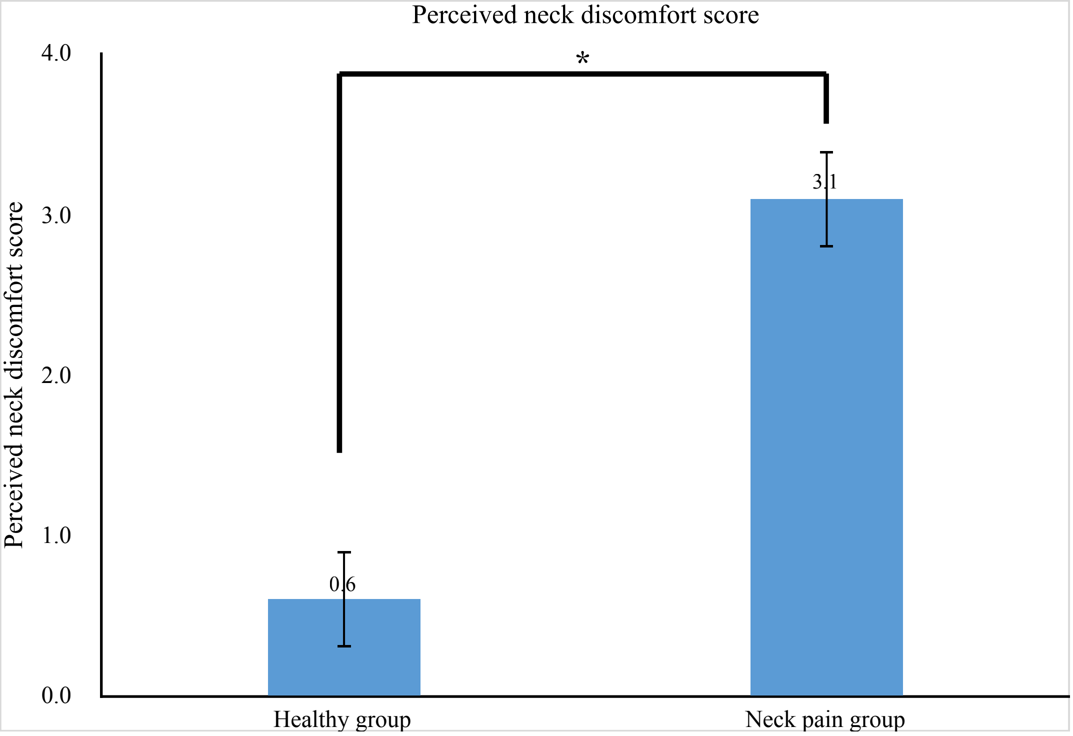

Figure 22. Comparison of the perceived neck discomfort for different groups
*:Significant difference (p<.05)

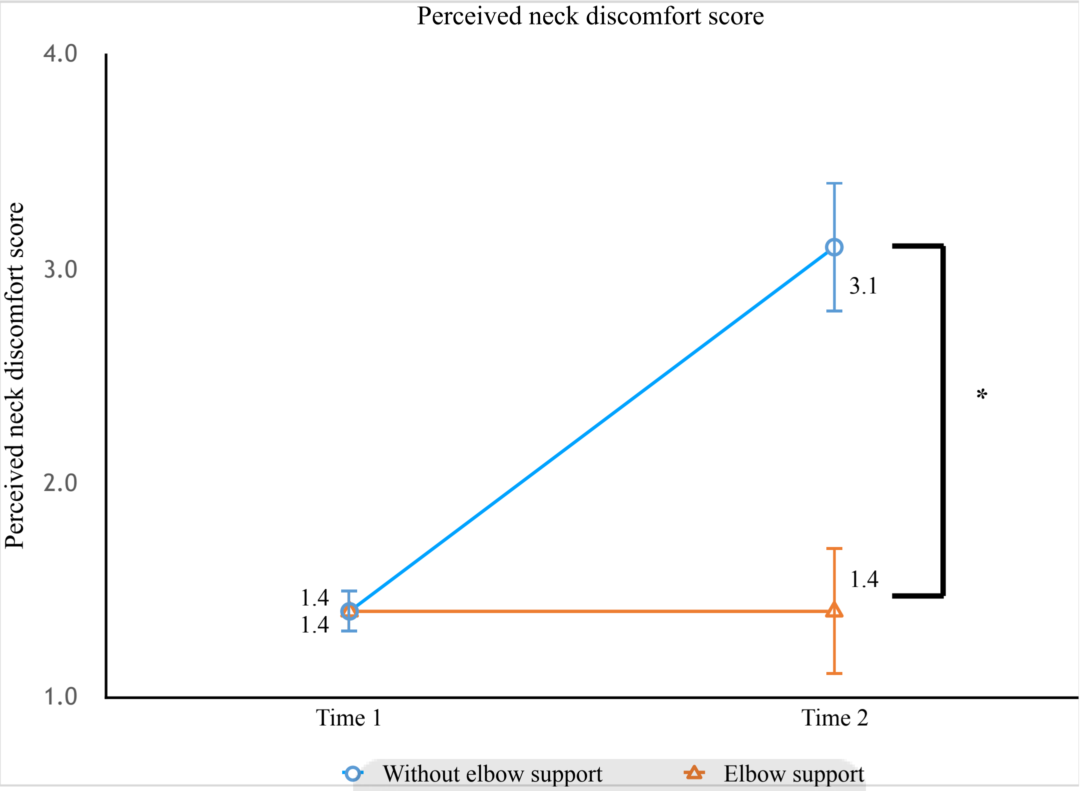

Figure 23. Perceived neck discomfort score : a significant support x time interaction was found The perceived neck discomfort significantly increased when typing under no elbow support condition. “*” indicates that significant differences between the two conditions in Time 2 ($p<0.05$)

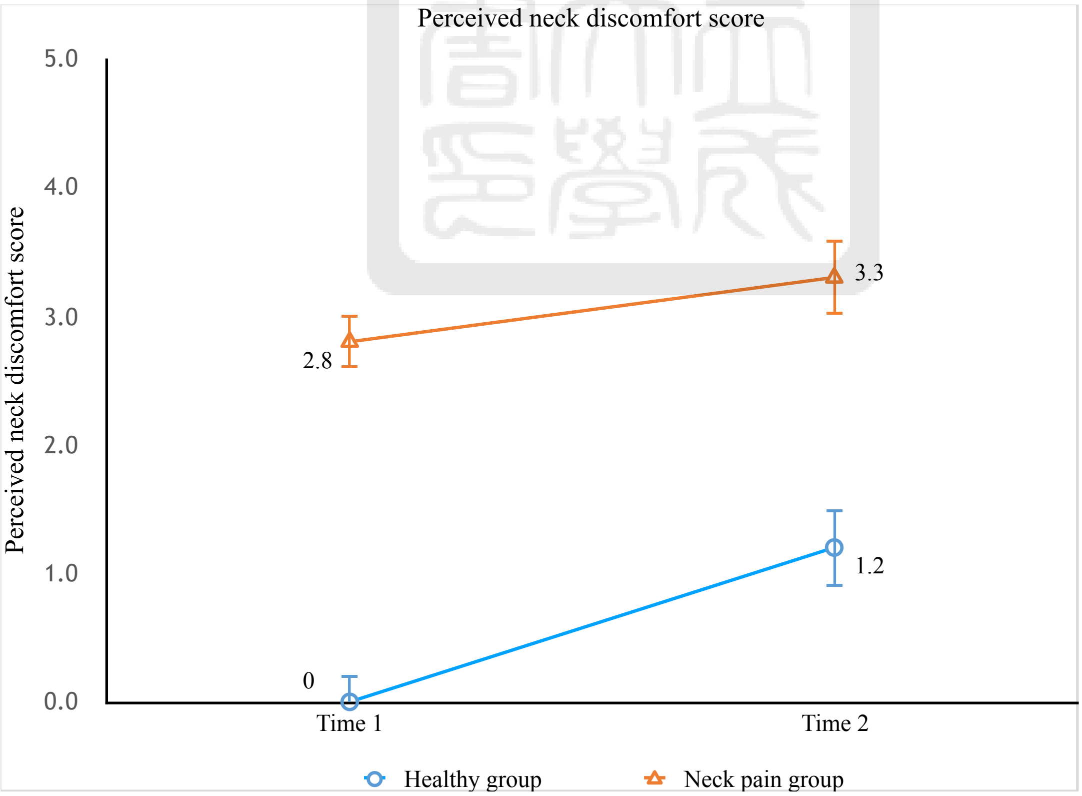

Figure 24. Perceived neck discomfort score: a significant time x group interaction was found. The healthy group increased more neck discomfort than the neck pain group after five-minute typing task

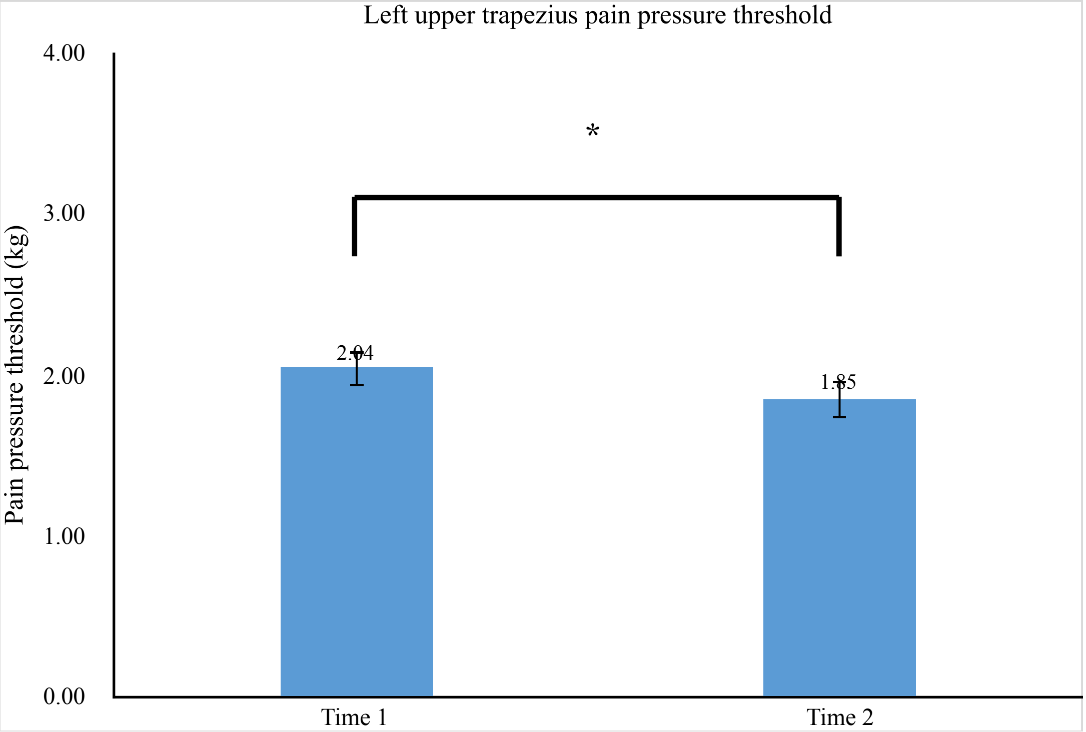

Figure 25. Comparison of the pain pressure threshold for the left upper trapezius at different time points *:Significant difference (p<.05)

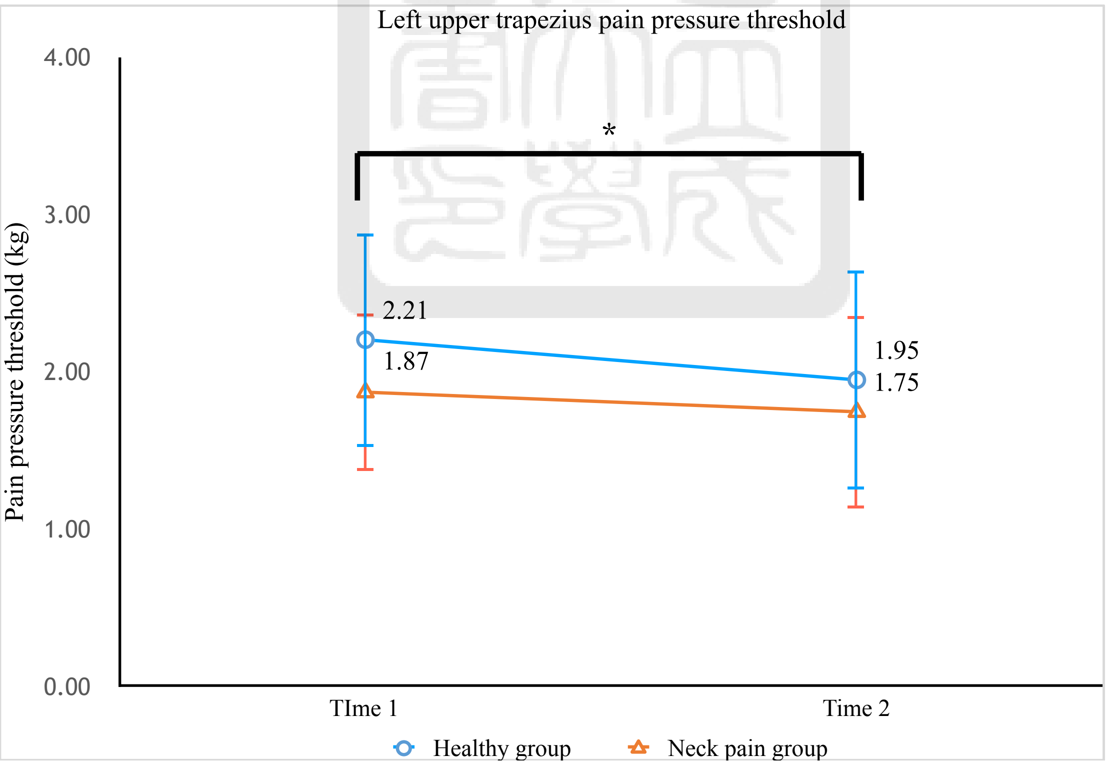

Figure 26. The pain pressure threshold of the left upper trapezius: a significant time x group interaction was found

The pain pressure threshold of the left upper trapezius decreased more in the healthy group than the neck pain group.

“*” indicates that significant differences between the two groups (p<0.05)

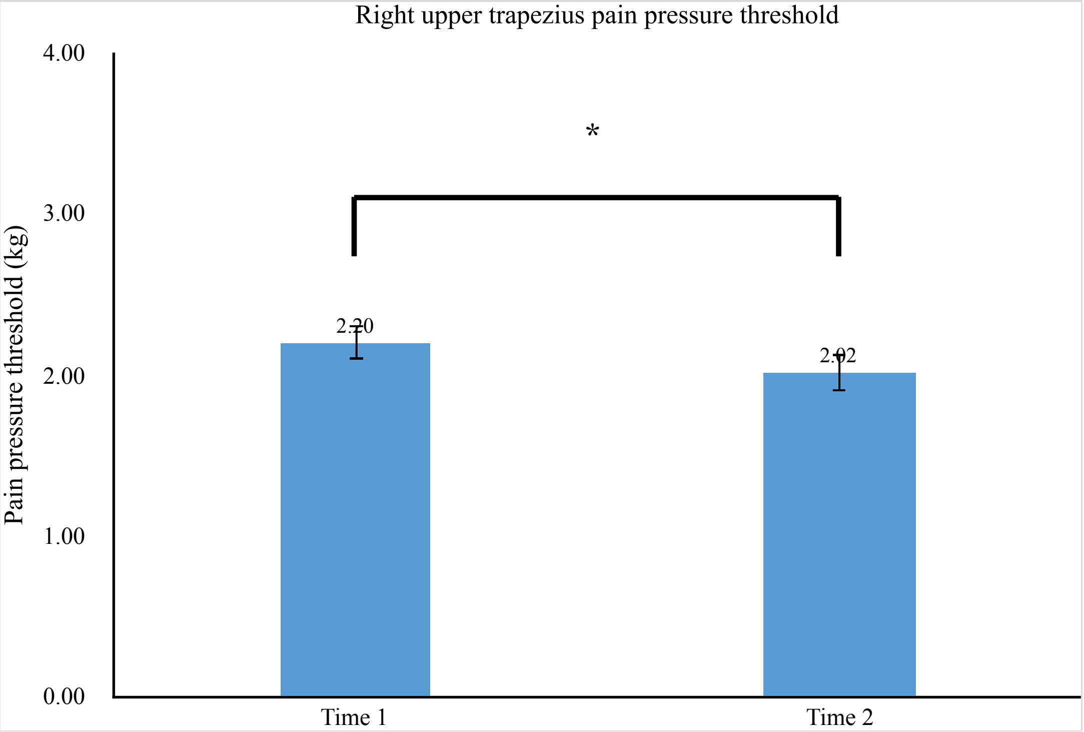

Figure 27. Comparison of the pain pressure threshold for the right upper trapezius at different time points *:Significant difference (p<.05)

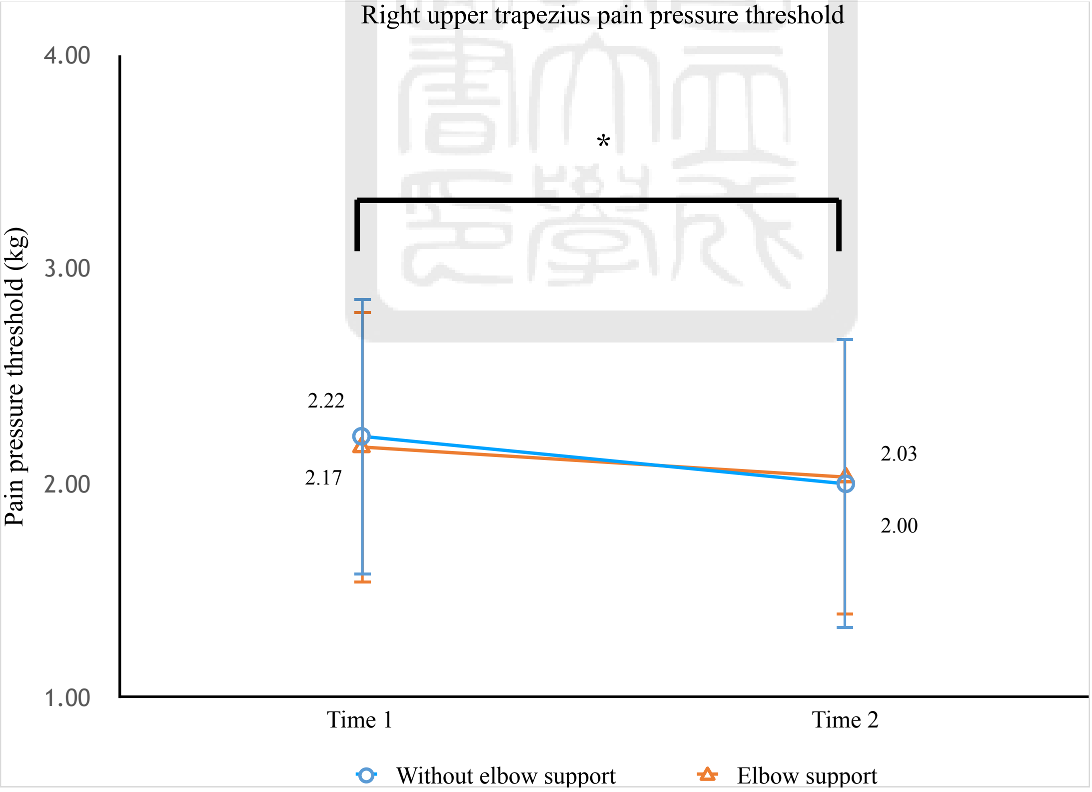

Figure 28. The pain pressure threshold of the right upper trapezius: a significant support x time interaction was found

The pain pressure threshold of the right upper trapezius decreased significantly under no elbow support condition

“*” indicates that significant differences between Time 1 and Time 2 in the two conditions at P-value <0.05)

國立政治大學圖書館

Appendix

Appendix 1

台灣活動量調查- 短版問卷 International Physical Activity Questionnaire (IPAQ)

問卷編號：________
流 水 號：________
受試者姓名：________
訪員姓名：________
訪視日期：________
成　　功：
您的回答將有助於我們了解：國人身體活動的現況。

想請教您的是：有關您在過去七天中花在身體活動的時間，包括工作、做家事、整理庭院／陽台、交通，及您在娛樂、運動等活動中所花的時間。就算您認為自己不愛動，也請您回答每一個問題。

您過去七天的身體活動與過去 3 個月的身體活動比較起來(請打勾)
□1.比較多　□2.比較少　□3.差不多(請繼續)

請回想過去七天中，所有您做過的費力活動。這些活動會讓您的身體感覺費力，呼吸比平常喘很多，但請只考慮那些一次您至少會持續 10 分鐘以上的身體活動。

1、過去七天中，您有多少天有做費力的身體活動？例如跑步、上山爬坡、持續性的快速游泳(不含慢游、玩水、泡水)、上樓梯、有氧舞蹈／運動、快速地騎腳踏車、打球(如網球單打、籃球、足球)、跳繩、重量訓練、搬運重物(大於 17 台斤／10 公斤)、或者是鏟土。
______天
□　沒有做費力的身體活動　　　請跳答問題 3

2、您通常一天花多少時間在費力的身體活動上？
一天_____小時______分鐘
□　不知道/不確定
回想過去七天中，您所有做過中等費力的活動。中等費力的活動表示：這些活動會讓您覺得身體有點費力，呼吸比平常喘些，但請只考慮那些您一次至少持續 10 分鐘以上的身體活動。

3、過去七天中，您有多少天有做中等費力的活動？例如：下山健走、用一般速度游泳、下樓梯、跳舞(不含有氧舞蹈、慢舞、國際標準舞或元極舞)、太極（不含外丹功）、用一般速度騎腳踏車、攜帶有點重的東西走路(例如買菜、背、抱小孩。有點重是指 7.5-15 台斤／4.5-9 公斤：例如二包 A4 的紙、二瓶家庭號鮮奶、一個小玉西瓜、三個帶皮鳳梨、五公斤的米、三個紅磚頭、七瓶玻璃罐的台灣啤酒或米酒、一箱 24 瓶易開罐飲料)、整理庭院／陽台、費力的家務(清洗窗戶、用手擦地、鋪床、手洗衣服、手工洗車)、或是網球雙打、羽毛球、桌球、排球、棒球？請不要將提輕物的走路算進去。

_______天

□ 沒有做中等費力的活動　　　請跳答問題 5

4、您通常一天花多少時間在中等費力的活動上？

一天______小時_______分鐘

□ 不知道/不確定

回想過去七天中，您花在走路上的時間有多久？包括工作、居家、和外出交通時的走路，以及您純粹為了娛樂、運動及休閒而花在走路（不含上下樓梯、爬山）上的時間。

5、過去七天中，您有多少天曾經走路持續 10 分鐘以上？

_______天

□ 沒有走路持續 10 分鐘以上　　　請跳答問題 7

6、您通常一天花在走路上的時間有多久？

一天______小時_______分鐘

□ 不知道/不確定

最後一個問題是：過去七天的工作天中，您坐著的時間有多久？請將工作、居家、做功課及休閒的時間都算進去，包括坐在桌前、打電腦、拜訪朋友、吃飯、閱讀、坐著或斜躺著看電視，但請不要將睡著的時間算進去。

7、過去七天的工作天中，您一天坐著的時間有多久？

一天______小時_______分鐘

本問卷到此結束！謝謝！

Appendix 2

頸部失能量表　**Neck Disability Index（NDI）**

填寫這份問卷能幫助治療師了解因為頸部造成的頭、頸、與上肢的不適症狀， 影響你/妳日常生活活動的情況。在每一題請選擇一個最能形容你/妳今天狀況的答案回答：

問題 1—疼痛程度

□ 此時我並不覺得疼痛。
□ 此時我感覺到很輕微的疼痛。
□ 此時我感覺有輕微的疼痛。
□ 此時我感覺中等程度的疼痛。
□ 此時我感覺嚴重的疼痛。
□此時我感覺非常嚴重的疼痛。

問題二—自我照顧能力(例如：洗澡，穿衣服)

□ 我在進行一般自我照顧的日常活動時，不會產生額外的不適症狀。
□ 我能完成一般自我照顧的日常活動，但會產生額外的不適症狀。
□ 我必須小心且緩慢，才能完成一般自我照顧的日常活動。
□ 我可以完成大部分自我照顧的活動，但需要一些協助。
□ 我的一般日常活動都需要別人協助才能完成。
□ 我無法完成穿衣，洗澡一般自我照顧的日常活動，需要待在床上。

問題三—抬起或提起重物

□ 我可以提起重物且不產生疼痛。
□ 我可以提起重物但會產生疼痛。
□ 因為頸部造成的頭、頸、與上肢的不適症狀，我無法自地面提起重物， 但 如果這個重物放置在桌面上我能使用它。
□ 因為頸部造成的頭、頸、與上肢的不適症狀，我無法自地面提起重物， 但 如果這個中等重量物體放置在桌面上我能使用它。
□ 我只能提起很輕的物體。
□ 我無法提起或提起任何物體。

問題四—閱讀(例如：報紙、雜誌、書籍…)

□ 我可以如我所願的閱讀，且不會產生不適症狀。
□ 我可以如我所願的閱讀，但會產生輕微的不適症狀。
□ 我可以如我所願的閱讀，但會產生中度的不適症狀。
□ 因為頸部造成的頭、頸、與上肢的不適症狀，使我不能如我所願的閱讀。
□ 因為嚴重的不適症狀，我幾乎不能閱讀。
□ 我完全無法閱讀。

問題五—頭部疼痛

□ 我不覺得頭痛。
□ 我偶爾會有輕微頭痛。
□ 我偶爾會有中等程度的頭痛。
□ 我常常會有中等程度的頭痛。
□ 我常常會有嚴重的頭痛。
□ 我幾乎一直感覺到頭痛。

問題六—注意力

□ 我能毫無困難的完全集中注意力。
□ 我能完全集中注意力但覺得有一點點困難。
□ 我有一點困難去完全的集中注意力。
□ 我很難完全的集中注意力。
□ 我非常困難完全的集中注意力。
□ 我完全無法集中注意力。

問題七—工作

□ 我能完成所有我想要做的工作。
□ 我僅能完成一般日常工作。
□ 我僅能完成大部分一般日常工作。
□ 我無法完成一般日常工作。
□ 我幾乎無法做任何的工作。
□ 我完全無法做任何的工作。

問題八—開車

□ 我開車時，不會產生不適症狀。

□ 我開車一段時間，就會產生輕微不適症狀。

□ 我開車一段時間，就會產生中等程度不適症狀。

□ 因為會產生頸部造成的頭、頸、與上肢的中等程度不適症狀，所以我不能 開太久的車。

□ 因為會產生頸部造成的頭、頸、與上肢的嚴重不適症狀，所以我不太能開車。

□ 我無法開車。

問題九—睡眠

□ 我沒有睡眠的問題。

□ 不適症狀很輕微的干擾了我的睡眠(影響睡眠時間小於1小時)。

□ 不適症狀輕微的干擾了我的睡眠(影響睡眠時間約1-2小時)。

□ 不適症狀中度的干擾了我的睡眠(影響睡眠時間約2-3小時)。

□ 不適症狀嚴重的干擾了我的睡眠(影響睡眠時間約3-5小時)。

□ 不適症狀非常嚴重的干擾了我的睡眠(影響睡眠時間約5-7小時)。

問題十 —休閒娛樂活動

□ 我能參與各種休閒娛樂活動。

□ 我能參與各種休閒娛樂活動但會感覺頸部有些不適症狀。

□ 因為頸部造成的頭、頸、與上肢的不適症狀，我僅能參與大部分的休閒娛樂活動。

□ 因為頸部造成的頭、頸、與上肢的不適症狀，我僅能參與少部分的休閒娛樂活動。

□ 因為頸部造成的頭、頸、與上肢的不適症狀，我難以參與休閒娛樂活動。

□ 我無法參與任何的休閒娛樂活動。

謝謝你完成此問卷

Appendix 3

國立成功大學
人體研究說明及同意書

適用範圍：非醫療法第 8 條所規範之人體研究、問卷、訪談及檢體採集等

(本同意書應由計畫主持人親自向受試者說明詳細內容，並請受試者經過慎重考慮後方得簽名）

您被邀請參與此研究，本說明及同意書提供您有關本研究之相關資訊，研究主持人將會為您說明研究內容並回答您的任何疑問。

計畫名稱：比較手肘支撐對有無頸痛之智慧型手機使用者的肌肉活性與姿勢之效果。

執行單位：國立成功大學物理治療學系

研究經費來源：無

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受試者姓名：
性別：　出生日期：
通訊住址：
聯絡電話：

一、研究簡介：

智慧型手機的高普及率，常伴隨著肌肉骨骼系統疾病的高盛行率。智慧型手機族常見的肌肉骨骼系統疾病位置為：頸部、肩膀、上背、上肢、下背，以頸部的盛行率(17.3% to 89.9%)為最高。而造成智慧型手機使用者頸部肌肉骨骼疾病的危險因子，主要有三項：1.錯誤的使用姿勢 2.使用時間的長短 3.高重複性動作。並且智慧型手機使用者於坐姿打字，最易產生頸部屈曲、降低上斜方肌疼痛閾值。因此如何避免增加肌肉活性且改善使用姿勢，是本研究的重點。

近年，開始討論手肘支撐的效果，發現手肘支撐可以有效降低年輕智慧型手機使用者的肌肉活性以及改善姿勢。但先前的研究都是針對健康的年輕使用族群，對於使用時肌肉活性會更高、姿勢更差的頸部疼痛使用者尚無研究探討。

二、研究目的：

本研究之目的乃在比較有無慢性頸部疼痛的年輕智慧型手機用戶的姿勢和肌肉收縮情形之差異，並比較給予肘部支撐時對於其姿勢及肌肉收縮情形的影響。

三、研究預計執行期間、受試者數目：

執行期間：自 IRB 通過　～ 111 年 12 月 31 日

預計 60 位

四、研究之主要納入與排除條件：

納入條件：年紀 20~40 歲之間，日常生活有在使用智慧型手機的成年人。

慢性頸部疼痛組納入的條件有：(1)疼痛區域為上頷線到第一節胸椎棘突(2)疼痛為反覆發生三個月(3)頸部失能指標量表大於 5 分(4)需有手機打字的技能

排除條件：(1)患有高血壓或心血管疾病(2)懷孕(3)有任和神經學症狀(4)頸部或者肩膀曾經有手術過(5)因其他醫療因素影響到脊椎及上肢(6)有皮膚問題病史(7)有創傷病史

五、研究方法、程序及受試者應配合事項：

本研究含準備時間總約 1.5 小時。簽署同意書後，符合納入標準者即開始前測準備流程。

請受試者填寫基本資料(出生年月、過去病史、教育程度、慣用手等)，並量測身高體重、身體質量、疼痛壓力閾值，有頸部疼痛者則多填寫視覺疼痛量表與頸部失能量表。

於資料填寫完畢後，將於受試者身上貼上反光球以及肌電圖貼片。接著，進入實驗主要測試階段。請受試者依平常休息坐姿、雙腳踩地、雙手靜放於大腿上，紀錄三次十秒鐘的休息姿勢做為基礎資料。接著隨機進行兩次五分鐘的智慧型手機打字任務，一次為無肘部支撐、一次為有肘部支撐，兩次任務之間會休息 3 分鐘確保受試者有足夠的休息。各組於每次的打字任務結束後，會立即進行疼痛壓力閾值的後測。

主要實驗過程約 30 分鐘，實驗其間研究者將利用三度空間立體攝影做受試者的姿勢分析，並利用肌電圖來了解使用手機時肌肉的收縮情形。

六、研究資料之保存期限及運用規劃：

我們會在法律範圍之內，將您的研究資料視為機密(保存至 2024 年 12 月 31 日)。所有關於您的研究資料皆會放置於成功大學姿勢與平衡實驗室內電腦加密的檔案夾中。研究結果即使發表了，您的資料也會以編號呈現，不會透露出任何有關您的個人資料，以達保密效果。

七、研究材料之保存與使用

1.受試者資料之保存與再利用

您的資料將由研究團隊妥善保存至 2024 年 12 月 31 日 屆滿後即銷毀。所有新的研究計畫都要再經由成大醫院人體研究倫理審查委員會審議通過，倫理審查委員會若認定新的研究超出您同意的範圍，將要求我們重新得到您的同意。

八、可預見之風險及造成損害時之補救措施：

您可自行決定是否要參加本計畫，並於過程中可隨時撤銷同意，以退出計畫參與，不需要任何理由，並且不會造成您有任何不愉快的感受。

九、研究預期效益：

針對智慧型手機使用者，研究人員將利用問卷、動作分析系統與肌電圖，來針測您的姿勢與肌肉控制方式。並進一步有無慢性疼痛之智慧型手機用者，在有無手肘支撐的狀況下，使用手機時的肌肉活性與姿勢變化差異。此研究結果可以協助臨床工作者給於有慢性頸部疼痛的年輕智慧型手機使用的姿勢改善建議，達到早期預防、早期治療得目的。

十、損害補償與保險：

(一)如依本研究所訂臨床研究計畫，因而發生不良反應或損害，由國立成功大學負損害補償責任。但本受試者同意書上所記載，而無法預防之可預期不良反應，不予補償。

(二)如依本研究進行因而發生不良反應或損害，國立成功大學願意提供必要的協助。

(三)除前二項補償及醫療照顧外，本研究不提供其他形式之補償。若您不願意接受這樣的風險，請勿參加研究。

(四)您不會因為簽署本同意書，而喪失在法律上的任何權利。

十一、受試者權利及個人資料保護機制：

(一)參加研究之補助

在此次實驗完整結束後，將會獲得一份約 100 元的紀念品和提供兩分鐘的正確姿勢衛教。

(二)保護隱私

研究所得資料可能發表於學術雜誌，但不會公佈您的姓名且對受試者個人資料之隱私絕對保密，同時計畫主持人將謹慎維護您的隱私權。中央衛生主管機關、研究委託者與成大醫院人體研究倫理審查委員會在不危害您的隱私情況下，依法有權檢視您的資料。

(三)研究過程中如有新資訊可能影響您繼續參與研究意願的任何重大發現，都將即時提供給您。

(四)如果你(妳)在研究過程中對研究工作性質產生疑問，對身為患者之權利有意見或懷疑因參與研究而受害時，可與成大醫院之人體研究倫理審查委員會聯絡請求諮詢，其電話號碼為：06-2353535 轉 3635 或 e-mail : em73635@mail.hosp.ncku.edu.tw 或郵寄至 704 台南市北區勝利路 138 號門診大樓人體研究倫理審查委員會。

本同意書一式兩份，主持人/共同主持人研究人員已將同意書副本交給你(妳)，並已完整說明本研究之性質與目的，也已回答您研究等相關問題。

十二、研究可能衍生之商業利益及其應用之約定：

本研究預期不會衍生專利權或其他商業利益。

十三、研究之退出與中止：

您可自由決定是否參加本研究；研究過程中也可隨時撤銷同意，退出研究，不需任何理由，且不會引起任何不愉快。研究主持人或贊助廠商亦可能於必要時中止該研究之進行。

十四、簽名欄：

（一）受試者已詳細瞭解上述研究方法及其所可能產生的危險與利益，有關本試驗計畫的疑問，業經計畫主持人詳細予以解釋。本人同意接受為臨床試驗計畫的自願受試者。

受試者簽名：______________________________

日期：___________ 年__________月_________日

（二）見證人使用時機：

1. 受試者、法定代理人或有同意權之人皆無法閱讀時，應由見證人在場參與所有有關受試者同意書之討論。見證人應閱讀受試者同意書及提供受試者之任何其他書面資料，以見證研究主持人或其指定之人員已經確切地將其內容向受試者、法定代理人或有同意權之人解釋，並確定其充分了解所有資料之內容。
2. 受試者、法定代理人或有同意權之人，仍應於受試者同意書親筆簽名並載明日期。

但得以指印代替簽名。

3. 見證人於完成口述說明，並確定受試者、法定代理人或有同意權之人之同意完全出於其自由意願後，應於受試者同意書簽名並載明日期。
4. 研究相關人員不得為見證人。

見證人簽名：______________________________

日期：____________年__________月__________日

聯絡電話：________________________________

（三）主持人或研究人員已詳細解釋有關本研究計畫中上述研究方法的性質與目的，及可能產生的危險與利益。

主要主持人/共同主持人/研究人員簽名：____________________

日期：____________年__________月__________日