CHAPTER V

DISCUSSION

Interest in the area of cerebral palsy (CP) and neuromuscular electrical stimulation (NMES) continues to grow because it has potential as a passive, non-invasive, which is claimed to result in gains in strength and motor function. Although there were studies reported that NMES have potential to increase muscle and improve motor function in CP population, unfortunately, those reports variation in the physical abilities of the participants and lack of statistical power to provide conclusive evidences for or against this modality. As a result, this approach remains controversial and its clinical utility remains a topic for debating.

Based on the weak points mentioned above, the present study intent to assess the efficacy of NMES targeted on quadriceps muscle in particpants with only spastic diplegia in a trial using control design with follow-up, and the results of this present study supported the efficacy of NMES to increase muscle strength and ROM and to reduce muscle spasticity in this population. Consequently, since homogenous subjects were regarded, the results in this study may not be able to generalize to other type of CP or disorders. In this study, the quadriceps strength, quadriceps lag, angles of hip, knee and ankle joints during standing, quadriceps muscle spasticity and hamstrings muscle spasticity were selected as the dependent variables. The effects of quadriceps NMES on each variable were discussed below.

Effects of quadriceps NMES on quadriceps strength

The quadriceps strength gain found only in the NMES group indicated that the individuals with spastic diplegia who demonstrated crouch posture can increase isolate quadriceps muscle strength through a short term quadriceps NMES strength training program. Moreover, quadriceps strength drop found after withdrawn the NMES. This reflects that the strength gain was induced by NMES absolutely.

The NMES was applied to the right quadriceps muscle in a child with spastic diplegia for 6 weeks in previously (10), and found that after training right quadriceps strength was increased whereas the untreated left quadriceps remained unchanged. Unfortunately, it's difficult to support the positive effect of the NMES because there was only one subject in their study. Therefore, another randomized placebo-controlled trial study design was conducted, and the NMES was compared to the TES and non-intervention on the quadriceps muscle strength (13). Sixty children with diplegia, quadriplegia, dystonia, ataxia and non-classifiable CP participated to the study. Although rigorous study design and numbers of participants were concerned, the researchers failed to find significant result in quadriceps strength gain. In addition, an exceedingly high inter-participant variability may explain these non-significant results (13).

Since the power analysis was relatively high (92%), this study supports the positive effect of the NMES in individuals with spastic diplegia, specifically, who were classified at GMFCS level III. Hence, the NMES training may be an alternative strength training technique for individuals who have a difficulty in performing the selective resisted exercise. Individual with CP are unable to fully activate their voluntary muscles due to weakness and poor selective motor control. Thus, specific strengthening program was required and the NMES was shown to solve this issue.

Strength gains have been attributed to both neural adaptation and muscle hypertrophy (10, 21). Among untrained populations, neural adaptation to the resistance training program may occur in a short-term period (6-20 weeks) while muscle hypertrophy may occur in a long-term period. Importantly, only hypertrophy can be providing the permanent effect (21, 29-30). The positive change that was found only at the end of week 7^{th} in this study indicated that the strength could be gained in this period and proved that no permanent strength gains yet. Hence, continual stimulation may be necessary to maintain the strength gain, especially in untrained population.

In general, the number of subjects' gender was regarded in strength training program because there were evidences to show that male is stronger than female (9, 22, 29, 57). However, no evidence was found to support this issue in individuals with CP. Based on previous studies (8-10, 13), the improvements in various strengthening programs have ranged from 19.6% to over 100% in both typical and atypical population. In this study, the mean strength gain was 25.65% in the NMES group. Although the number of subjects' gender was not controlled in this study (Male: Female, control 8:0, NMES 2:6), the most change was found in female (72%). Hence, the gender issue may not apply to the individual with dipelgia.

Effects of quadriceps NMES on quadriceps lag

In this study, quadriceps lag showed significantly decreased approximately 4.7 degrees at the end of training in the NMES group. This improvement might be from the improvement of the quadriceps strength. The participants who commonly walk with the crouch gait may not have the ability to extend their knees at the inner range of motion and muscle groups such as quadriceps may become functionally long, due to biomechanical malalignments causing a stretch weakness at the inner range of motion (41). Therefore, the greater the quadriceps strength is, the less the lag angle is. The assessment of the active range of motion versus passive range of motion of the knee joint can give insight into true muscle strength (41-42), therefore, this study selected quadriceps lag as an outcome measure of muscle strengthening in individuals with CP and the positive result was found after training in the NMES group. However, the mean of quadriceps lag in the NMES group that showed significantly decreased approximately 4.7 degrees at the end of training might be needed to use a more sophisticated measuring instrument (42). Likewise, although the quadriceps lag decreased after the NMES training, it did not maintain after withdraw the NMES. Therefore, continual stimulation may be important to maintain the improvement in lag angle.

Effects of quadriceps NMES on hip, knee and ankle joints angles during standing

Although quadriceps strength showed significantly increased and quadriceps lag showed significantly decreased after training, these positive changes did not contribute to improve the angles of hip, knee and ankle joints during standing. There were several explanations for this result. Firstly, a small increase in average strength gain (25.65%) in the NMES group may be insufficient to reduce the knee crouch during standing. Damiano and co-workers (8-9) found that the mean gains in quadriceps strength at 90°, 60° and 30° of knee flexion were 47%, 84% and 140% respectively through a heavy resistance exercise and resulted in significant improvement knee extension during walking. Secondly, although the quadriceps is the dominant muscle group at the knee, other lower extremity muscle groups such as hip extensors and ankle plantar-flexors might also affect lower extremity function and played an important role to erect the posture for supporting the whole body against the gravity (9, 19, 41). Therefore, the target on only one muscle group may be insufficient to improve the crouch posture during standing. In an attempt to decrease the amount of knee crouch during gait in conventional resistance training. Unger and co-workers (34) found that there was a reduction in crouch as compared to an increase in crouching in the control group after 8 weeks of strength training program in ambulant adolescents with spastic CP, however, multiple muscle groups were trained in their study. Finally, both improvements in quadriceps strength and quadriceps lag were assessed in sitting position which was not required all muscle groups and related lower extremity joints to act together. But the angles of hip, knee and ankle joints were assessed in standing which had more gravity involved and stand position was required several muscle groups and joints to act together. Therefore, this study was not found any improvement for all angles.

Effects of quadriceps NMES on the spasticity of quadriceps and hamstrings muscle

In this study, the MAS of quadriceps muscle showed significantly decreased at the end of training in the NMES group indicated that NMES applied directly to the spastic agonist muscle had potential to reduce spasticity. There were a few evidences for a reduction in spasticity of the agonist when NMES was applied to the antagonist muscle or to both agonist and antagonist muscles; however, the mechanisms underpinning these effects are still unclear and studies on the effects of NMES on muscle spasticity and motor function have shown varied results (45, 58). NMES has been used most often on the antagonist to the spastic muscle to produce a reciprocal relaxation effect but it has also been used directly on the spastic muscle for the purpose of fatiguing them (46). It has been proposed that stimulation of the antagonist reduces spasticity in the agonist via the group Ia reciprocal inhibitory pathway or via polysynaptic pathways mediated by flexion reflex afferents. In another way, stimulation of the spastic agonist may lead to a reduction in activity via recurrent inhibition of its own α motor neuron. It is also possible that, by stretching the agonist or the antagonist muscles through their available range of movement, mechanical factors are altered, so leading to a reduction in spasticity (10, 45-46). In the present study, NMES training target on quadriceps muscle may lead to a reduction in activity via recurrent inhibition of its own α motor neuron and/or temporarily fatigue since the electrodes were placed directly on spastic muscle group (45-46), therefore, the decreasing in quadriceps spasticity was not seen at the follow up. In addition, this study was found no change in hamstrings spasticity which may be because the MAS of hamstrings muscle was already zero since baseline. Therefore, this result suggested that the NMES protocol can be provided without increasing in muscle spasticity.

CONCLUSION

This study investigated the effects of quadriceps NMES on quadriceps strength, quadriceps lag, angles of hip, knee and ankle joints during standing, quadriceps spasticity and hamstrings spasticity in eighteen participants with spastic diplegia who exhibit crouch posture. The two study groups were assigned conditions by drawing to either control group or NMES group. Only the participants in the NMES group performed bilateral quadriceps strength training using NMES for 10 repetitions/set, 3 sets/day, and 3 days/week for 7 weeks. The quadriceps strength, quadriceps lag, the angles of hip, knee and ankle joints during standing, QMAS and HMAS were compared between test times for each group and between groups for each tested times including before, at the end and 2 weeks after training.

The results indicated that the quadriceps NMES training had potential to increase quadriceps strength, decrease quadriceps lag and reduce quadriceps spasticity. However, improvements in angles of hip, knee and ankle joints during standing were not found. Therefore, this study supported that the NMES technique was useful for individuals with spastic diplegia who have a difficulty in conventional resistance training program for using as an alternatively adjunct therapy in rehabilitation program. This modality can provide an increasing in quadriceps strength, improving in quadriceps lag and reducing in quadriceps spasticity. However, the improvement in parameters as mentioned above did not ensure crouch posture improvement.

CLINICAL APPLICATION

This study recommended that NMES applied on quadriceps muscle 3 days per week, for 7 weeks had potential to increase quadriceps strength, decrease quadriceps lag and reduce quadriceps muscle spasticity in individuals with spastic diplegia. However, this study represents the participants who demonstrated crouch gait and were classified at level II or III of GMFCS which seemed to be quite weak in quadriceps muscle; therefore, target population should be regarded for general application. In this study, quadriceps NMES training was performed in open chain movement and seemed to show improve in quadriceps strength, quadriceps lag and quadriceps spasticity and there were no improvement in crouch posture during standing. If the quadriceps NMES training was performed in closed chain movement (i.e. standing position), it was believed that there would be some results in positive change in extensive crouch management. In addition, the program of NMES training was 10 contractions/ set, 3 sets/ day, 3 days/ week, for 7 weeks. It seemed to provide a small increase in quadriceps strength gain and the strength gain did not sustain after withdrawn the NMES. If the quadriceps NMES training performed more training time (20 weeks) or kept continuing the program, it was believed that there would be some beneficial changes in positive effects for this population.

LIMITATION AND FUTURE STUDY

1. The duration of quadriceps NMES training in this study was short-term period (7 weeks). It may provide only neural adaptation and strength gain may present temporary. Therefore, future study should allow more time for training (more than 20 weeks) to produce hypertrophy and then provide the permanent strength gains.
2. The quadriceps NMES training was performed as open chain exercise in seated posture in this study. It may not provide sufficient load to evoke extensive strength gain and then improve crouch posture. Therefore, future study may perform quadriceps NMES training in closed chain exercise as standing posture that has the body weight and all in muscle groups of the lower extremity involve. In addition, future research might also determine whether closed chain maneuver could be more beneficial than open chain for strengthening muscle and improving motor function.
3. Electrodes were placed over the muscle belly of quadriceps muscle in this study. It may not provide the maximal quadriceps contraction actually. Therefore, future study may place electrodes over the motor point of muscle for achieving the maximal muscle contraction actually with the least current amplitude use.