The Effect of Swiss Ball Stabilisation Exercise on Deep and Superficial Cervical Muscle and Pain in Patients with Chronic Neck Pain

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Abstract
This study investigated the effect of Swiss Ball stabilisation exercise on deep and superficial cervical muscle and pain with chronic neck pain. Thirty subjects with chronic neck pain were randomly divided into the Swiss Ball Stabilisation Exercise Group (n=10, SBEG), Craniocervical Flexion Exercise Group (n=10, CFEG), and Conservative Therapy Group (n=10, CTG). All patients performed 40-50 minutes a day, thrice a week for 8 weeks. The CSA (Cross-Sectional Area) of neck muscles, longuscolli, longuscapitis, Anterior scalene and Upper trapezius, was measured using functional MRI and VAS and NDI obtained from the subjects was analyzed. After 8-weeks intervention, two groups showed the significant improvement in CSA of deep and superficial muscles; CSA change of SBEG was the most significant among groups compared with CFEG and CTG (P<.001). Swiss Ball stabilisation exercise is likely to widen the CSA of deep and superficial muscles in patients with chronic neck pain, and can be an efficacious therapeutic method that can decrease numerical value of VAS and NDI.

Keywords: Chronic Neck Pain, Cross-Sectional Area (CSA), Swiss Ball Stabilisation Exercise

1. Introduction

Neck pain is a health problem closely connected with significant physical disorders in the general population1,2, and can be defined as a disabling symptom characterized by periods of alleviation and exacerbation3. Although various physical, psychological, and socio-demographic aspects have been considered as factors of neck pain4, the ultimate cause of neck pain is not found by clinical or diagnostic technique5,6.

Generally, the resolutions of chronic neck pain have been studied through exercise programs of neck muscles7,8. Neck pain disorder has been studied to seek the various solutions in the previous researches; the therapeutic exercise using Cranio-cervical Flexion strengthening exercise9 and the endurance and strength training of neck muscle through elastic rubber band10 that suggest the effect of strength exercise program of neck muscle have been recognized as beneficial methods in the way of relieving the neck pain with specific exercise intervention. That is, such exercise interventions8,10 have focused on demonstrating the interrelationship between exercise program of alleviation of neck pain and elevation of cervical vertebrae functional performance.

Nonetheless, finding the key solution over the alleviation of neck pain disorder is still likely to be a challenging task for researchers since analyzing the aspect of changes in superficial and deep neck muscles may require researchers and physical therapists to employ cutting-edge medical equipment in order to investigate pivotal roles in postural
balance control of the cervical vertebrae and muscular stability of neck muscles. In this respect, it is needless to say that the utilisation of functional MRI offering CSA (Cross-Sectional Area) of cervical muscles can be a viable experimental method in terms of investigating the effect of exercise programs for chronic neck pain.

In addition, Swiss Ball stabilisation exercise has positive effects on the betterment of lumbar pain and the improvement of bone density\textsuperscript{11}; it is a considerably meaningful attempt in that Swiss Ball stabilisation exercise can be practically applied to the patients with chronic neck pain, and such a exercise can stimulate the proprioceptive sense of patients, alleviating the level of neck pain.

Accordingly, with the utilisation of functional MRI, we explored that how the CSA (Cross-Sectional Area) of deep and superficial neck muscles were changed after 8-weeks Swiss Ball stabilisation exercise, and, at the same time, hypothesised that favorably altered CSA of neck muscles will be able to be an efficacious criteria to individuals with chronic neck pain in diagnosing the alleviation or aggravation degree of neck pain symptom.

2. Materials and Methods

2.1 Subject

In this study, thirty participants diagnosed with chronic neck pain by the department of neurosurgery of Y Hospital in South Korea were participated. The participants were randomly divided into three groups, Swiss Ball Exercise Group (SBEG), Craniocervical Flexion Exercise Group (CFEG), and Conservative Therapy Group (CTG). Before administrating interventions of this study, the subjects were given the procedures and the purpose of this study, and gave written informed consent. Patients with previous cervical spine fractures, malignant neoplasms, vascular diseases, other pathological symptoms, and undergone surgery in the past 3 months were excluded from the study (Table 1).

2.2 Exercise Interventions

The exercise programs were conducted thrice a week times for 8 week. Before and after implementing exercise interventions, warm-up and cool-down were respectively carried out for 5 minute. The total exercise time was gradually increased, and the subject's performed 30 minutes during 1–4 week and 40 minutes during 5–8 week, respectively.

2.2.1 Swiss Ball Stabilisation Exercise

Swiss Ball Stabilisation Exercise program includes eight types of movements that can help to improve the muscular function of neck muscles and relieve the level of neck pain\textsuperscript{9}. Swiss ball (Theraband, USA) with green color (55-65cm) was applied to male subjects, and female subjects used red ball (45-55cm) for the exercise intervention; the exercise program were organized as follows: neck multi direction, trunk rotation, bridging pulling the jaw down, quadruped position pulling the jaw down, opposite arm/leg pulling the jaw down, bridging with head pulling the jaw down, abdominal crunches pulling the jaw down, and squat pulling the jaw down. The exercise intensity of Swiss Ball stabilisation program was comprised of two sets session with six repetitions during 1–4 week, and three sets session of the program was carried out with ten repetitions during 5–8 week.

2.2.2 Craniocervical Flexion Exercise

Craniocervical Flexor Exercise was consisted of stretching the neck and shoulder joints that accompany various musculoskeletal movements, and includes the flexion of hip and knee joints. While the patients lied down on the floor, towels were placed between the patients' head and floor in order to prevent unexpected collision. During the craniocervical flexor contraction, bending motions by sternocleidomastoid (SCM) and Anterior Scalenus (AS) contraction were restricted. In order to effectively

\begin{table}[h]
\centering
\caption{Physical characteristics}
\begin{tabular}{|c|c|c|c|c|}
\hline
 & Gender & Age (yrs.) & Weight(kg) & BMI(kg/m\textsuperscript{2}) & Pain Duration(month) \\
\hline
SBE(n=10) & M:3, F:7 & 42.10±7.82 & 62.62±7.19 & 23.62±1.42 & 14.63±7.32 \\
CFEG(n=10) & M:3, F:7 & 40.72±6.39 & 62.34±7.46 & 22.45±1.61 & 16.75±7.42 \\
CTG(n=10) & M:3, F:7 & 44.46±5.87 & 67.21±7.49 & 25.12±2.13 & 15.66±8.08 \\
\hline
\end{tabular}
\end{table}

Swiss ball exercise group (SBEG, n=10), Craniocervical flexion exercise group (CFEG, n=10), Conservative Therapy group (CTG, n=10)
stimulate muscular contractions from the longuscolli and longuscapitis, subjects pulled down their jaw, which is able to create a nodding movement. Additionally, to maximise exercise performance of participants, stabiliser pressure bio-feedback unit (Chattanooga TN Inc., USA) was utilized, gradually increasing pressure of the equipment by 2mmHg from 20 mmHg to 30 mmHg. In the first, second, third and fourth step, 10 repetitions per 10-second, 15 repetitions per 10-second, 15 repetitions per 15-second, and 15 repetitions per 20-seconds exercise regimes were administered, respectively; each set was repeated three times, and one minute rest was given between the each set. Neck and shoulder exercise program were organized as follows: neck flexion, extension side bending, side flexion, scapular retraction, thoracic stretching.10 repetitions per 10-seconds twice during 8 weeks.

2.2.3 Conservative Therapy Group
Conservative Therapy Group (CTG) was requested to lie down on the bed comfortably, and we applied electric heating pack with temperature of 50~55°C to the cervical vertebrae. When the subjects complained of pain, we immediately applied a Transcutaneous Electrical Nerve Stimulator (TENS, ITO, Japan) with low frequency and high intensity output to the subjects for 15 minutes. After then, we used Ultra Sound (ITO, Japan) with pulsation frequency of 1.0MHz and treatment intensity of 1–2W/cm² for 40 minutes by 5 minutes intervals.

3. Experimental Measurements

3.1 Functional MRI
1.5T MRI (Magnetic Resonance Imaging, Philips Electronic Inc., Netherlands) was used to measure the CSA (Cross-Sectional Area) of the longuscolli, longuscapitis, and multifidus; the experimental procedure using 1.5T MRI was implemented while the subjects have their knee bent at 45° with straight supine position. The foam wedge was placed behind the knee, which helps the subjects to maintain comfortable position. Rotation or lateral flexion of the cervical spine and excessive cervical lordosis were restricted during the measurement, and they were instructed to keep their forward. Moreover, the left and right side of the longuscolli, longuscapitis, and multifidus were divided into segmented MRI images with thickness of 5mm and intervals of 10mm from the upper and lower plates of cervical 5-6(C 5-6), using T2 MRI images that can provide the accurate observation of the muscular conditions13.

3.2 Visual Analogue Scale (VAS) and Neck Disability Index (NDI)
Visual Analogue Scale (VAS) and Neck Disability Index (NDI) were evaluated before and after the study. Numerical level of neck pain was rated using a 10-point VAS with a score of 0 (no neck pain during a typical day) to 10 (worst neck pain during a typical day). A decreased ability to manage activities in daily life regarding the level of neck pain was indicated with 50-point NDI (0: no overall neck, 50: the most severe neck pain). The NDI score comprised of ten questionnaires was answered by each patient, which ranges from 0 (no back pain during activities) to 5 (severe pain during activities). ten questionnaires was answered by each patient, which ranges from 0 (no back pain during activities) to 5 (severe pain during activities).

4. Date Analysis
With all data obtained from this study, we calculated Mean (M) and Standard Deviation (SD) using SPSS/PC 18.0 statistic program for Windows. We carried out two-way ANOVA analysis used to demonstrate the differences among values from the experimental groups (SBEG, CFEG, and CG) and measuring period (before/after 8-weeks intervention). In addition, when the statistical significance in the data was shown, post-verification of Duncan analysis was conducted. Statistical significance was adopted at $P < 0.05$ in this study.

5. Results

5.1 Cross-Sectional Area (CSA) Changes in Deep and Superficial Cervical Muscles
CSA Changes of deep and superficial cervical muscles are presented in Table 2. Deep cervical muscle (longuscolli, longuscapitis) and superficial cervical muscle (anterior scalene muscle, upper trapezius) were no significant difference within groups, however, there was noticeable improvement between times (longuscolli : $p<.001$, longuscapitis : $p<.001$, anterior scalene muscle : $p<.001$, anterior scalene muscle : $p<.001$, upper trapezius : $p<.001$, neck flexion : $p<.001$, neck extension : $p<.001$, neck side bending : $p<.001$, neck side flexion : $p<.001$, scapular retraction : $p<.001$, thoracic stretching : $p<.001$, neck flexion : $p<.001$, neck extension : $p<.001$, neck side bending : $p<.001$, neck side flexion : $p<.001$, scapular retraction : $p<.001$, thoracic stretching : $p<.001$).
upper trapezius: $p<.001$); the CSA improvement of the anterior scalene muscle in SBEG was the most remarkable compared with other groups. In the Post-hoc analysis of the each group, SBEG and CFEG increased after exercise intervention in CSA, but CG was not changed. Besides, interaction between Group and Time was shown in significance level.

### 5.2 Disability Index and Pain Index in NDI and VAS

The changes in NDI and VAS are presented in Table 3. NDI decreased with significant difference within group ($p<.01$). In the Result of post-hoc analysis regarding the changes of NDI, distinctly reduced disability appeared in the exercise intervention groups (SBEG, CFEG) in comparison with CG. NDI also significantly decreased between time intervals for measurement. However, interaction was shown between Group and Time in significance level. VAS point significantly decreased within groups ($p<.05$). When analyzing the result of VAS point using post-hoc analysis, decreased VAS appeared in the exercise intervention groups (SBEG, CFEG) compared with CG. VAS was significantly reduced between intervals for measurement as well. Interaction between Group and Time was shown presenting significant difference.

### 6. Discussion

Functional MRI has been considered as an experimental measurement providing the scientific reliability and objectivity in evaluating CSA (Cross-Sectional Area) changes of anatomical structure of neck muscles. Although MRI is not a readily available experimental measurement in the clinical fields because of certain limitations, it has been an optimum experimental method to analyze the activities and changes of deep and superficial cervical muscles. Accordingly, this study hypothesized that subjects with chronic neck pain performing three different exercises interventions, respectively, will show Cross-Sectional Area (CSA) changes of neck muscle in functional MRI measurement, and have positive prognosis on the level of neck pain according to the altered cross-sectional area of neck muscles.

In our study, after 8-weeks intervention to the subjects, Swiss Ball exercise group (SBEG) showed the greatest improvement among three groups in the CSA change of deep and superficial neck muscles, however, there was no significant difference among groups. The significant changes in SBEG is that, when comparing the pre-test data with post-test data, CSA of SBEG was the most noticeable among three groups; CSA of longuscolli and longuscapitis in deep cervical muscles were increased by 25.16% and 23.2%, respectively. In addition, CSA of anterior scalene

| Table 2. CAS changes of deep and superficial cervical muscles |
|-------------------------------------------------------------|
| SBEG(n=10) | CFEG(n=10) | CTG(n=10) | 2-way ANOVA | F | P |
| Deep Cervical Flexor muscle | | | | | |
| Longuscolli (mm$^2$) | Group | 1.355 | .275 |
| Pre-test | 121.94±19.72 | 114.98±98.30 | 122.79±18.20 | Time | 128.386 | .000*** |
| Post-test | 152.15±27.88 | 137.60±23.62 | 121.48±18.06 | Group*Time | 39.270 | .000*** |
| Longuscapitis (mm$^2$) | Group | 1.943 | .163 |
| Pre-test | 125.36±25.81 | 128.37±25.01 | 121.68±21.27 | Time | 129.500 | .000*** |
| Post-test | 154.40±20.65 | 147.41±26.38 | 120.90±20.88 | Group*Time | 40.010 | .000*** |
| Superficial Cervical Flexor muscle | | | | | |
| Anterior scalene muscle(mm$^2$) | Group | .256 | .776 |
| Pre-test | 213.37±91.86 | 239.01±93.40 | 234.07±72.52 | Time | 105.615 | .000*** |
| Post-test | 276.60±87.34 | 268.30±95.71 | 219.80±68.24 | Group*Time | 78.099 | .000*** |
| Upper trapezius (mm$^2$) | Group | .606 | .553 |
| Pre-test | 1917.14±329.31 | 1875.37±502.22 | 1854.20±323.97 | Time | 54.461 | .000*** |
| Post-test | 2152.30±349.89 | 2087.80±503.04 | 1829.61±321.04 | Group*Time | 21.089 | .000*** |

SBEG: Swiss Ball Exercise Group, CFEG: Craniocervical Flexion Exercise Group, CTG: Conservative Therapy Control group $p<.001$
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Table 3. The changes in NDI and VAS

|                | SBEG(n=10) | CFEG(n=10) | CTG(n=10) | 2-way ANOVA | F       | P      | Post-hoc |
|----------------|------------|------------|-----------|-------------|---------|--------|----------|
| NDI(point)     |            |            |           | Group       | 9.345   | .001** |          |
| Pre-test       | 21.00±3.88 | 21.81±4.39 | 21.70±3.92| Time        | 856.922 | .000***| a, b>c   |
| Post-test      | 9.10±1.19  | 10.80±2.65 | 16.30±3.68| Group*Time  | 11.345  | .000***|          |
| VAS(point)     |            |            |           | Group       | 4.211   | .026*  |          |
| Pre-test       | 6.18±.76   | 6.26±.79   | 6.55±.59  | Time        | 291.468 | .000***| a, b>c   |
| Post-test      | 2.35±.33   | 2.94±.34   | 4.01±.67  | Group*Time  | 13.542  | .000***|          |

SBEG: Swiss Ball Exercise Group, CFEG: Craniocervical Flexion Exercise Group, CTG: Conservative Therapy Control group
NDI: Neck Disability Index (0-50 point), VAS: Visual Analogue Scale (0-10 point)

A recent study by reference15, proposed that the level of pain has close interrelationship with muscular function of deep cervical flexor muscles when patients practice certain tasks; patients suffering from neck pain shown deteriorated exercise performance can have better exercise performance through interventions. Our study did not measure functional aspects of cervical vertebrae such as muscular strength, muscular endurance, and flexibility; however, preceding researches reported that applying certain exercise strategies will be able to expand the CSA of cervical vertebral muscles, which can lead to the alleviation of chronic neck pain, ameliorating the function of cervical vertebrae. The findings in our investigation suggest that the CSA changes of neck muscles have a close relation with chronic neck pain and disability of neck muscles. That is, it is thought that the CSA expansion of neck muscles will be able to alleviate the neck pain and disability of neck muscles. Consequently, the results shown in our study demonstrate that continuous Swiss Ball stabilisation exercise during certain period is able to play a pivotal role in improving CAS of deep and superficial neck muscles, and, thus, may effectively stimulate the proprioceptive sense of patients with chronic neck pain, reducing pain and dysfunction of neck muscles. In this regard, the findings of our study prove that the application of exercise, especially, Swiss Ball stabilisation exercise has positive effects on reducing VAS and NDI, and will be likely to be a beneficial exercise approach to patients suffering from chronic neck pain.

7. Acknowledgement

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