INTRODUCTION

Chronic low back pain (CLBP) is known as a global health problem resulting in activity limitation, socioeconomic problems, absenteeism and increasing disability. According to the Global Burden of Disease Study, LBP is among the top ten causes of disability, counting the value of years lived with disability (YLDs) 64.9 million. The lifetime prevalence of LBP is 60-70%, with an annual incidence of 15-45% in industrial countries and the highest prevalence found in working age (35-59 years).\(^1,4\) Precise data all over Indonesia is unknown, but various prevalence in several regions range from approximately 18.9-37%.\(^5,7\) Most LBP have good prognostic, except 10-20% turn to a chronic condition, thus increasing disability and reducing quality of life. The complexity of CLBP problems is characterized by underlying multifactorial biopsychosocial factors influencing the transition from acute to chronic course, forming a serial vicious cycle.\(^8-11\) In this cycle, persistent pain leads to behavioral change and central sensitization, resulting in inactivity and deconditioning, giving consequences in psychological and social life that continuously affect each other and concomitantly increase problems in all aspects involved.\(^11\) Psychological factors in terms of fear-avoidance behavior or major depressive disorder aggravated the condition.\(^12,13\) Pain causes motor control change and maladaptive response that subsequently leads to deconditioning, marked by atrophy, decreasing strength and endurance of muscles in the lower back area.\(^14-17\) Given the low-resolution rate of CLBP, the treatment approach has been shifted to more functional goals, which are decreasing disabilities and improving the patient’s quality of life. Considering the complexity of CLBP, multimodal and multidiscipline strategy by far is the most effective approach.\(^11-15,18\)

Vagus nerve stimulation is an electrical stimulation technique to the tenth cranial nerve afferents that has broad projections and the ability to produce effects on the brainstem, subcortex and cortex as well as the autonomic nervous system (ANS). Several studies have shown that VNS has effects on nociceptive modulation and pain perception and has been investigated for chronic pain management through pain descending modulation and endogenous opioid release mechanism.\(^19-23\) Noninvasive form of VNS, which is delivered by transcutaneous stimulation on the auricular branch of the vagus nerve (ABVN), has been shown to have advantages on anti-inflammatory effects and chronic pain comorbidities (depression, anxiety, psychological...
factors), thus supports therapeutic potency of tVNS in CLBP.24-27

Back extensor muscles have an important role in maintaining all-day postural control, and poor low back muscle endurance has been associated with the potency of developing low back pain, prediction for LBP episodes in the follow-up year, and transition to chronic low back pain.28-30 The Biering Sorensen test (BST) has been proven to be a valid and reliable measurement for back extensor muscle endurance and is the most reported fatigue test in the literature.31 This static test is effective in fatiguing back extensor muscles, easy application and cost-effective measurement.30,32 Patients with LBP showed lower performance significantly compared to healthy subjects in BST examination, and pain scale improvements in chronic low back pain showed a significant correlation with improvements in BST time.33,34 Studies that evaluate the effects of tVNS on back muscle endurance of chronic low back pain have not been obtained. This study aims to determine the effect of adding tVNS therapy to exercise as mainstay therapy for chronic low back pain on the back muscle endurance of chronic low back pain patients.

METHODS
Study design and procedures
This was a randomized controlled group study. Participants were consecutively selected in order of their appearance according to inclusion criteria up to a number of participants. Based on sample calculation, 22 enrolled participants were randomly assigned to the experimental group and control. The study was approved by the Ethical Committee of Dr. Soetomo General Academic Hospital in Surabaya, number 0411/KEPK/IV/2022. Two physicians collected the demographic data, basic anthropometric measurements, history of mechanical CLBP, and clinical symptoms prior to randomization.

Eligibility
Inclusion criteria
Participants aged 18-55 years old with mechanical chronic low back pain (defined as LBP more than 12 weeks without organic signs and red flags including history of violent trauma, malignancy, night pain, systemic steroid use, drug abuse, immunocompromised, unintentional weight loss, infection signs, structural deformity, muciturition problem, fecal incontinence with saddle anesthesia, progressive motor weakness or gait disturbance, marked morning stiffness, peripheral joint involvement or rheumatologic disease or family history, inflammatory disorder, moderate pain with numerical pain rating scale between 4 and 7, and independent ambulation. All participants were informed about the study procedures, risks, and benefits of the investigation and signed informed consent before participating in the trial.

Exclusion criteria
Excluded were patients with organic LBP (trauma/fracture, tumor, infection, severe degenerative spine, rheumatological condition), radicular pain, analgesic consumption other than acetaminophen or NSAID, or new analgesics in 2 weeks before recruitment, underwent modalities therapy in 1 week, any injury or skin problems at auricula or face, utility of metal implant including pacemaker, pregnancy, history of seizure or epilepsy, moderate to severe depression (HDRS score ≥ 17), history of vasovagal syncope, skin allergy to metal, drugs and alcohol abuse, communication problem, obesity grade 2 according to Asia Pacific criteria, and diabetes mellitus type 2. Drop-out criteria if participants missed the stimulation schedule or exercised twice and experienced allergy or adverse events.

Stimulation procedure
Participants in the experimental group received tVNS administered by the researcher. tVNS treatment lasts 20 minutes each day, and exercise sessions last 30 minutes per day. tVNS was applied to the left ear at the cymba concha and concha area using ear clip electrodes connected to Enraf-Nonius Myomed 632 device. Conductive gel is applied to the metal part of the electrodes to distribute conduction and prevent pain. Stimulation set to 25 Hz and pulse width 500 microseconds in biphasic rectangular symmetric waveform. The intensity adjusted to every participant’s sensory threshold by questioning the tingling sensation without pain. Stimulation was delivered 20 minutes, five times per week for 2 weeks, accompanied by monitoring of vital signs (blood pressure, heart rate, respiratory rate, and peripheral oxygen saturation) before, every 5 minutes during, and after 30 minutes stimulation ended. Participants were asked to report any complaints of increasing pain or discomfort sensation. After stimulation was finished, the researcher checked the area of treatment for any signs of irritation and evaluated the participant’s symptoms.

Exercise treatment
All participants in both groups participated in exercise therapy under the supervision of an experienced physiotherapist who was blinded. Exercise treatment consists of kinesthetic awareness of spinal posture, pelvic tilt exercise, diaphragmatic breathing, core strengthening exercise using abdominal drawing in, cat and camel exercise, and trunk flexibility training, administered twice a week, 30 minutes per session for two weeks.

Outcome
The outcome is a physical performance of back extensor muscle endurance using the Biering Sorensen Test (BST), evaluated before and after two weeks of therapy. Biering Sorensen Test measures the time needed to maintain the upper body above the iliac crest in the horizontal prone position while the lower body is secured at table examination using 3 long straps. Straps were pulled as tight as possible to stabilize the hip, knee and ankle to the table. Before starting position, participants were allowed to rest the upper half of their body on a chair. Time measurement using a stopwatch starts when the participant raises the trunk with the hand crossed over the chest and finishes when a participant can no longer hold the position, reporting pain or fatigue.

Statistical analysis
This study used IBM SPSS Statistics 23.0 and Microsoft Excel for Mac version 16.68 for statistical analysis and calculation. Paired t test analysis was used to compare BST score pre-test and post-test within the group, and an independent t test was used
to compare scores between groups. P value <0.05 is considered significant. Cohen’s d calculation was used to measure the effect size of therapy.

RESULTS

Baseline characteristics of participants in all variables (age, sex, body weight, body height, body mass index, pretest score for numerical pain rating scale (NPRS), Hamilton depression rating scale (HDRS), and BST pre-intervention are presented in Table 1. Data show us no difference found between the control group and experimental group in baseline variables.

The result of the Biering Sorensen Test of the control group before and after the intervention is presented in Table 2. Descriptively, there was a slightly increasing mean score of the control group from the pretest (58.18 ± 50.75) to the post-test (66.82 ± 38.56). The paired t test showed p=0.200, meaning no significant difference was found within the group. The effect size calculated by Cohen's d=0.414 showed a small effect.

Biering Sorensen test of the experimental group before and after intervention tVNS and exercise therapy is shown in Table 3. Descriptively, there was an increasing mean score of the BST experimental group from the pretest (40.30 ± 31.20) to the posttest (66.49 ± 45.87). Paired t test showed p=0.012, meaning a significant difference was found between the pretest and posttest of the experimental group, with effect size calculated by Cohen's d=0.918 showing a large effect.

As shown in Table 3, the mean delta time of the BST experimental group was 26.19 ± 28.51 seconds, while the control group was 18.45 ± 11.92. Independent t test showed p-value = 0.119, which means that there was no significant difference in BST time between groups.

Figure 1 shows comparison data of BST pre and post-intervention in box and whisker plots between the two groups. While the pre-intervention data showed a relatively similar distribution of both groups, the post-intervention data presented a relatively similar median value with larger differences and distribution between pre and post-intervention of the experimental group, indicating larger change occurred in the experimental group.

DISCUSSION

To our knowledge, this study is the first to evaluate the effects of tVNS on back muscle endurance of CLBP patients. The current study showed that tVNS is safe, with no complaints nor side effects of participants during the administration of tVNS stimulation. Previous studies mentioned side effects of skin rashes at the stimulation site, headache, sore throat, and vagal reflexes in the form of coughing hoarseness. The rarest is decreasing heart rate and fainting. Side effects stated were generally mild to moderate that decreased with reducing stimulation intensity and disappeared after the stimulation was finished.

Characteristics at baseline are believed to have an influence on the treatment response of LBP patients, namely BMI and depression. Based on Asia Pacific criteria, most of the subjects had grade 1 obesity category with a total of 11 people (50%) of the total subjects, 5 people were overweight subjects (22.72%), while subjects with normal BMI (27.27%) 6 people. Previous studies suggest that subjects with higher BMI showed a

Table 1. Patient characteristics at baseline

<table>
<thead>
<tr>
<th></th>
<th>Control group (n=11)</th>
<th>Experimental group (n=11)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td>0.611</td>
</tr>
<tr>
<td>Male</td>
<td>9 (81.8%)</td>
<td>8 (72.7%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2 (18.2%)</td>
<td>3 (27.3%)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>44.90 ± 10.07</td>
<td>40.72 ± 10.68</td>
<td>0.356</td>
</tr>
<tr>
<td>Body weight (Kilogram)</td>
<td>67.90 ± 14.80</td>
<td>67.09 ± 11.97</td>
<td>0.888</td>
</tr>
<tr>
<td>Body height (Centimeter)</td>
<td>166.63 ± 9.26</td>
<td>164.63 ± 8.64</td>
<td>0.606</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.84 ± 3.63</td>
<td>24.92 ± 3.59</td>
<td>0.961</td>
</tr>
<tr>
<td>NPRS</td>
<td>5.81 ± 1.07</td>
<td>5.45 ± 1.12</td>
<td>0.449</td>
</tr>
<tr>
<td>HDRS</td>
<td>3.36 ± 2.90</td>
<td>4.18 ± 4.06</td>
<td>0.593</td>
</tr>
<tr>
<td>BST Pre</td>
<td>58.18 ± 50.75</td>
<td>40.30 ± 31.20</td>
<td>0.332</td>
</tr>
</tbody>
</table>

The score presented as ‘percentage and 2 mean ± standard deviation. P value based on ‘Chi square test and ‘independent t-test. *Significant if p-value < 0.05. BMI: Body Mass Index; NPRS: Numerical Pain Rating Scale; HDRS: Hamilton Depression Rating Scale.

Table 2. Normality and homogeneity of Biering Sorensen test (BST) in both groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>P-value</th>
<th>Normality</th>
<th>Mean ± SD</th>
<th>P-value</th>
<th>Homogeneity</th>
</tr>
</thead>
<tbody>
<tr>
<td>BST Pre Test</td>
<td>Experimental Control</td>
<td>0.783</td>
<td>Normal</td>
<td>40.30 ± 31.20</td>
<td>0.332</td>
<td>Homogenous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.859</td>
<td>Normal</td>
<td>58.18 ± 50.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BST Post Test</td>
<td>Experimental Control</td>
<td>0.727</td>
<td>Normal</td>
<td>66.49 ± 45.87</td>
<td>0.986</td>
<td>Homogenous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.835</td>
<td>Normal</td>
<td>38.56</td>
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</tr>
</tbody>
</table>

Table 3. Biering Sorensen test (BST) of both groups pre and post-intervention

<table>
<thead>
<tr>
<th>Group</th>
<th>Evaluation</th>
<th>Mean ±SD</th>
<th>p-value</th>
<th>Effect size (Cohen’s d)</th>
<th>Δ BST (seconds)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (n=11)</td>
<td>Pre-test</td>
<td>58.18 ± 50.75</td>
<td>0.200</td>
<td>0.414 (small effect)</td>
<td>0.52 ± 2.82</td>
<td>0.117</td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>66.82 ± 38.56</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental (n=11)</td>
<td>Pre-test</td>
<td>40.30 ± 31.20</td>
<td>0.012*</td>
<td>0.918** (large effect)</td>
<td>2.38 ± 2.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>66.49 ± 45.87</td>
<td></td>
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</tr>
</tbody>
</table>

*Significant if p-value < 0.05. **Large effect size if value > 0.8
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in back extensor muscle endurance. It is also supported by the result of Cohen’s d effect size that showed a large effect in the experimental group, which means that the addition of tVNS increased the effect of exercise therapy on back extensor muscle endurance.41-42

The mechanism that causes significant improvement in the experimental group given additional tVNS therapy is unclear, but it is thought to be obtained from the tVNS mechanism of action in descending inhibition of pain modulation and endogenous opioid production, as psychological improvements, namely depression and mood, and anti-inflammatory effects, as well as effectiveness in reducing fatigue that reduces movement performance, and subsequently reduce kinesthesia.21-26 that individuals with poor back extensor muscle endurance have been shown to have a low fatigue threshold thus decrease fatigue may contribute to improve back extensor endurance, increasing ability of participant to prolong the performance.

Improvement of BST in the experimental group for 2 weeks of intervention showed an early effect on improving back extensor muscle endurance after tVNS addition to exercise therapy, compared to previous studies that showed improvement after exercise therapy for 4 weeks and 6 weeks.40-42 This could also be the reason why no significant improvement was seen in the control group, which is administered exercise only, considering that neuromuscular improvement occurs in more than 2 weeks while muscle function such as new hypertrophy yields from exercise for at least 10 weeks. A systematic review states that the longer the duration of exercise (i.e., 12 compared to 8 weeks), the bigger the benefit obtained supports this opinion.43

There was no significant difference in comparing the BST of the two groups. This non-significant difference in results between the two groups is probably because exercise therapy has provided a relatively small effect to improve outcomes, considering the short term of intervention. Meanwhile, tVNS adjunctive therapy was shown to add to the effects of exercise therapy,

Figure 1. Box and whisker plot diagram of Biering Sorensen Test pre and post-intervention between the two groups. The light grey and dark grey boxes showed pretest and posttest measurements, respectively.

negative correlation with BST, supporting the results.40 Assessment of BST pretest score shows that both groups’ mean scores are less than the normal value (healthy men and women score 198 and 197 seconds respectively), indicating the predictive value of LBP 1 year later associated with LBP risk of one to three times.40 In chronic LBP patients, depression is known for a strong relationship with intensity and duration of pain and disability,8 and low efficacy to exercise therapy.41 Besides that, non-physiological factors (psychological and environmental) have an influence on physical performance results.42 Evaluation of the participant's depression scale with HDRS showed no significant difference between groups.

The results showed a significant increase in the BST time assessment pre and post-intervention of the experimental group that was given additional tVNS in exercise therapy. No VNS studies that evaluate back muscle endurance in CLBP make comparison difficult. Previous studies suggested that improvements in BST may associated with improvements in the pain scale.35-37 One study that administered fentanyl to CLBP subjects showed an increase of BST (28%, p<0.05) in evaluation after 5 minutes of injection compared to placebo, which supported the current study result that improvements occur parallel to pain improvement. In terms of the minimal detectable change value (MDC) of BST in non-specific LBP subjects of 24.1, the experimental group has met this value. This means that the addition of tVNS to exercise therapy for 2 weeks has provided a positive improvement
resulting in the mean score exceeding the threshold, which could be seen as statistically significant in the experimental group. Distribution data shown by box and whisker plots also suggest an increasing trend in experimental group results.

**Study limitation**
The current study had several limitations, for not evaluating tVNS as a single therapy to compare with exercise. Also, re-evaluation is needed in the longer term to find out the benefit of long-term effects.

**CONCLUSION**
As growing evidence supports the effects of tVNS in chronic pain and the importance of functional goal in CLBP treatment, this study supports the potency of tVNS beneficial effects on back muscle endurance of CLBP patients in the relatively short term and confirm its safety. Advantages of short term reducing pain expected to increase adherence to exercise, increase activity and cut vicious cycle of CLBP. However, further investigation in a larger study would needed to confirm this potential effect.

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**CONFLICT OF INTEREST**
All authors state that there is no conflict of interest to declare.

**AUTHOR CONTRIBUTION**
RNK, RAMA, and YDP have the same contribution in writing the report and results of this study, from preparation, data search, data and statistical analysis, interpretation and final report. DT and PS have the same contribution in critical revision from proposal preparation to results presentation and final report. SM has contributed to the confirmation of data and statistical analysis, as well as critical revision since proposal preparation results presentation to the final report.

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**REFERENCES**


