Purpose: The first purpose of this study is to investigate the relationship between Post-Stroke Respiratory Sarcopenia (PSRS) and Cognitive Impairment (CI) through Breathing Exercise (BE) as a respiratory rehabilitation after stroke (ST). The second purpose is to introduce a pilot study design set to investigate and compare the acute effects of each BE to develop a BE protocol for further studies.

Methods: Pubmed, Scopus, Web of Science and Google Scholar search engines were used to identify the definition and mechanism of ST, CI and respiratory sarcopenia (RS), and to find cases of application of BE in such conditions.

Results: Review; BEs that improve ST, RS, and CI symptoms are Box Breathing (Tactical Breathing), Fast-Breathing, Slow-paced Breathing, Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise. However, the effect is still unclear as post-stroke patients undergo multiple medical treatments other than BE. Pilot Study Prospective results; Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise, Slow-paced Breathing, Box Breathing (Tactical Breathing) and Fast-Breathing will be performed by 40 healthy college students through a randomized controlled trial for 4 weeks. Respiratory functions, exercise intensity, active oxygen level, blood lactate level, cerebral oxygen saturation and cognitive function will be measured pre- and post-intervention along with acute and 2 week mid-intervention. BEs are expected to improve respiratory function, cognitive performance and energy levels while reducing HR, BP, and stress. However, individual response to BE may vary according to health, physical fitness and lifestyle. All BE will be conducted in an evenly controlled and supervised environment for accurate data collection.

Conclusions: Further study will be done to develop an appropriate BE protocol for PSRS patients per this review. Follow-up studies may also use this review as a reference for the application of BEs in PSRS patients with CI.

Key words: Stroke (ST), Respiratory sarcopenia (RS), Cognitive Impairment (CI), Breathing exercise (BE), Post-stroke respiratory sarcopenia (PSRS)

Introduction

Stroke (ST), colloquially known as a brain attack, transpires when there is an interruption in blood supply to the brain [1]. The principal mechanism triggering the onset of a ST is either an occluded or ruptured artery [2]. An ischemic ST arises when the artery experiences blockage owing to various factors affecting the blood vessels linked to the brain. Conversely, a hemorrhagic ST is induced by elevated intracranial pressure and neurological damage resultant from an arterial rupture within the cerebrum.

Cognitive impairment (CI), a condition characterized by difficulties in memory retention, acquisition of new knowledge, focus, or decision-making that impacts daily life, is widespread among the elderly and individuals who have encountered diverse health challenges [3]. The etiology of CI encompasses a range of factors including aging, vascular issues, and stroke [4-6]. Such afflictions contribute to an increased mortality rate and a compromised quality of life for patients [7,8]. Consequently, individuals grappling with CI necessitate heightened attention and care.

Respiratory Sarcopenia (RS) is a condition typified by the atrophy of muscle fibers and concomitant functional loss within the respiratory muscles, consistent with systemic skeletal muscle deterioration. This mul-
tifactorial phenomenon results in both a diminution of respiratory muscle strength and a reduction in muscle mass [9]. The anatomical composition of respiratory muscles is vividly delineated in (Fig. 1) [10]. It is pivotal to distinguish RS from respiratory dysfunction; the latter arises from limitations in the ventilatory apparatus or the presence of obstructive pulmonary diseases [11]. Additionally, patients suffering from whole-body sarcopenia manifest declines in diaphragmatic muscle thickness in conjunction with decrements in respiratory functionality [12]. In line with these observations, RS contributes to impairments in respiratory functions, culminating in diminished oxygen transport and availability to cerebral neurons, thus rendering them susceptible [13]. This is of paramount importance, given that the brain accounts for approximately 20% of the body’s total oxygen consumption [14]. Further accentuating the urgency for increased attention, the formal categorization of sarcopenia as a muscular disease, as endorsed by its ICD-10-CM diagnostic code, underscores its significance [15].

We have delineated Post-Stroke Respiratory Sarcopenia (PSRS) as a decline in the strength and mass of the respiratory muscles in individuals who have endured a stroke. Previous study suggests that short time after going through stroke, a decrease in the number of motor unit occurs. This is a consequence of the trans-synaptic inhibition of the spinal alpha motor neurons of the particular muscle [16]. Such mechanism explains sarcopenia in skeletal muscles. However, this type of muscle mass and function loss not only occurs in skeletal muscles, but also occurs with high relationship with respiratory muscles [17]. Furthermore, stroke induces hemiplegia, which causes a decrease in the capability of motor activity in the affected part of the body which leads to decreased physical activity [18,19]. As presented, RS can be triggered by a multitude of health-related adversities. Notably, stroke-induced RS is of critical concern to patients due to the potential proliferation of multifarious side effects, including CI. RS leads to impairments in respiratory functions which leads to decreases in cerebral oxygen inflow and cerebral oxygen saturation. This leads to dysfunction of the prefrontal cortex and eventually affecting especially the executive function, memory, and concentration of individuals [20-22]. However, there exists a paucity of research focusing on stroke-induced RS, thereby accentuating the imperative for a comprehensive examination in this domain.

Breathing exercise (BE), constituted of a series of systematized breathing techniques, is extensively practiced across various fields. It has been documented to ameliorate cardiorespiratory and ventilatory functions, overall quality of life, and cognitive faculties [23-25]. Research indicates that regular physical activity can notably augment the quality of life for individuals across all intensity levels—high, moderate, and even mild [26]. ST survivors are susceptible to physical debilitation [27], which can impede their ability to engage in physical activities and exercises. Hence, the selection of an appropriate exercise intensity is a crucial consider-

Fig. 1. Anatomical configuration of respiratory muscles. This figure delineates the anatomical structure of the muscles involved in the inspiratory and expiratory phases of respiration. The inspiratory musculature encompasses the Sternomastoid, Scalenes, External Intercostals, and the Diaphragm. Conversely, the expiratory musculature comprises the Internal Intercostals, External and Internal Obliques, and the Rectus and Transversus abdominis.
ation for stroke patients. BE, performed in a stationary posture, offers an accessible mode of exercise for stroke patients compared to other forms of physical activities.

Consequently, the primary objective is to undertake research on BEs as a form of respiratory rehabilitation, which could potentially catalyze cognitive enhancement in individuals afflicted with PSRS based on the interrelationship between ST, RS, and CI, which we scrutinized above. The secondary objective of this study is to present a preliminary study design configured to explore and juxtapose the acute ramifications of different BE modalities. This will serve as the foundation for the formulation of a novel BE protocol, positioned to enlighten and direct subsequent investigations.

**METHODS**


**RESULTS**

**1. Breathing Exercise (BE) for Stroke (ST)**

BE for ST was composed of Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise, Slow-paced Breathing Exercise and Fast-Breathing Exercise. Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise for ST patients showed significant improvements in respiratory functions such as FVC, FEV1, FVC/FEV1 ratio; 30:15 ratios, Immediate heart rate response to standing; E/I ratio, Heart rate variation with respiration; SBP, Systolic blood pressure; DBP, Diastolic blood pressure.

**Table 1. Effects of Breathing Exercise (BE) in Stroke (ST) patients**

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>BE Type</th>
<th>Participant characteristics</th>
<th>Measured variables</th>
<th>Measurement period</th>
<th>Protocol</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seo KC et al. [28]</td>
<td>2013</td>
<td>Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise</td>
<td>n = 30 (M: 17; F: 13) Age (years): 61.5 ± 2.8 Chronic stroke patients</td>
<td>FVC, FEV1, FEV1/FVC, PEF, TV, VC, IRV, ERV, IC</td>
<td>Pre- &amp; Post-Intervention</td>
<td>5 times/week Total 4 weeks 15 minutes/session</td>
<td>Significant improvements in FVC/FEV1, TV, IC</td>
</tr>
<tr>
<td>Seo K et al. [29]</td>
<td>2017</td>
<td>Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise</td>
<td>n = 30 (M: 15; F: 15) Age (years): 63.6 ± 3.7 Stroke Patients</td>
<td>Electromyographic measurement, UT, LD, RA, EAO, IAO</td>
<td>Pre- &amp; Post-Intervention</td>
<td>5 times/week Total 4 weeks 15 minutes/session</td>
<td>Significant improvements in activation of UT, LD, RA, IAO</td>
</tr>
<tr>
<td>Yoon JM et al. [30]</td>
<td>2022</td>
<td>Diaphragmatic Breathing+Pursed-lip Breathing Exercise</td>
<td>n = 32 Older stroke patients</td>
<td>FVC, FEV1, FEV1/FVC, PEF, Chest expansion, 6-minute walk test</td>
<td>Pre- &amp; Post-Intervention</td>
<td>Total 4 weeks</td>
<td>Significant improvements in chest expansion 6-minute walk test FVC, FEV1, PEF</td>
</tr>
<tr>
<td>Larson M et al. [31]</td>
<td>2020</td>
<td>Slow-paced Breathing</td>
<td>n = 12 (M: 9; F: 3) Age (years): 52 ± 13 Stroke patients</td>
<td>BP, HR, BRS, BRSup, BRSdown, HRV</td>
<td>Pre-, during- &amp; Post-Intervention</td>
<td>Acute 15 minutes</td>
<td>Increase in BRS, BRSup, HRV decrease in SBP, HR</td>
</tr>
<tr>
<td>Mourya M et al. [32]</td>
<td>2009</td>
<td>Fast-Breathing</td>
<td>n = 60 Age (years): 20-60 Stage 1 Hypertension</td>
<td>Autonomic function test, S/L ratio, 30:15 ratios, valsalva ratio, E/T ratio, hand grip test, cold pressor response</td>
<td>Pre- &amp; Post-Intervention</td>
<td>15 minutes/session 2 Sessions/day daily Total of 3 months</td>
<td>Significant decrease in SBP, DBP</td>
</tr>
</tbody>
</table>

FVC, Forced vital capacity; FEV1, Forced expiratory volume in 1 second; PEF, Peak expiratory flow; TV, Tidal volume; VC, Vital capacity; IRV, Inspiratory reserve volume; E/R, Expiratory reserve volume; IC, Inspiratory capacity; UT, Upper trapezius; LD, Latissmus dorsi; RA, Rectus abdominis; EAO, External abdominal oblique; IAO, Internal abdominal oblique; BP, Blood pressure; HR, Heart rate; BRS, Baroreflex sensitivity; HRV, Heart rate variability; S/L ratio, Standing to lying ratio; 30:15 ratios, Immediate heart rate response to standing; E/T ratio, Heart rate variation with respiration; SBP, Systolic blood pressure; DBP, Diastolic blood pressure.
Box breathing and slow-paced Breathing Exercise (BE) showed significant improvements in SBP and DBP. These effects of BEs are crucial for ST patients’ outcomes. Precise information is visually delineated in Table 1.

**Table 2. Breathing Exercise (BE) for Respiratory Sarcopenia (RS)**

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>BE Type</th>
<th>Participant characteristics</th>
<th>Measured variables</th>
<th>Measurement period</th>
<th>Protocol</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed S et al.</td>
<td>2021</td>
<td>Box breathing (Tactical breathing)</td>
<td>n = 30 (M: 15, F: 15) Age (years): 18-25 Healthy college students</td>
<td>FVC, FEV1, FEV1/FVC, FEF 25-75, PEF, FVC</td>
<td>Pre- &amp; Post-Intervention</td>
<td>2 sessions/day Total of 30 days 20 times/session</td>
<td>Significant improvements in FVC, FEV1, FVC</td>
</tr>
<tr>
<td>Seo KC et al.</td>
<td>2013</td>
<td>Inspiratory Diaphragmatic Breathing + Expiratory Pursed-lip Breathing Exercise</td>
<td>n = 30 (M: 17, F: 13) Age (years): 61.5 ± 2.8 Chronic stroke patients</td>
<td>FVC, FEV1, FEV1/FVC, PEF, TV, VC, IRV, ERV, IC</td>
<td>Pre- &amp; Post-Intervention</td>
<td>5 times/week Total of 4 weeks 15 minutes/session</td>
<td>Significant improvements in FVC, FEV1, TV, IC</td>
</tr>
<tr>
<td>Yong MS et al.</td>
<td>2017</td>
<td>Diaphragmatic breathing exercise</td>
<td>n = 31 Age (years): 21.8 ± 1.6 Healthy participants</td>
<td>FVC, SVC</td>
<td>Pre- &amp; Post-Intervention</td>
<td>Acute</td>
<td>Significant improvements in FVC, SVC</td>
</tr>
<tr>
<td>Seo K et al.</td>
<td>2017</td>
<td>Inspiratory Diaphragmatic Breathing + Expiratory Pursed-lip Breathing Exercise</td>
<td>n = 30 (M: 15, F: 15) Age (years): 63.6 ± 3.7 Stroke patients</td>
<td>Electromyographic measurement, UT, LD, RA, EAO, IAO</td>
<td>Pre- &amp; Post-Intervention</td>
<td>5 times/week Total of 4 weeks 15 minutes/session</td>
<td>Significant improvements in activation of UT, LD, RA, IAO</td>
</tr>
</tbody>
</table>

FVC, Forced vital capacity; FEV1, Forced expiratory volume in 1 second; FEF 25-75, Forced expiratory flow at 25-75%; PEF, Peak expiratory flow rate; FIVC, Forced inspiratory vital capacity; PEF, Peak expiratory flow rate; TV, Tidal volume; VC, Vital capacity; IRV, Inspiratory reserve volume; ERV, Expiratory reserve volume; IC, Inspiratory capacity; UT, Upper trapezius; LD, Latissimus dorsi; RA, Rectus abdominis; EAO, External abdominal oblique; IAO, Internal abdominal oblique; BP, Blood pressure; HR, Heart rate; SVC, Slow vital capacity.

**Table 3. Breathing Exercise (BE) for Cognitive Impairment (CI)**

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>BE Type</th>
<th>Participant characteristics</th>
<th>Measured variables</th>
<th>Measurement period</th>
<th>Protocol</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laborde S et al.</td>
<td>2021</td>
<td>Slow-paced Breathing</td>
<td>n = 78 (M: 41, F: 37) Age (years): 23.33 Healthy participants with no chronic conditions</td>
<td>Cardiac vagal activity inhibition task (Stroop task) Working memory Capacity (AOSPAN) Cognitive flexibility (Modified card sort test)</td>
<td>Cardiac vagal activity (Pre- &amp; Post-Intervention) Executive function (Post-Intervention)</td>
<td>3 sets 5 minutes/set 1 minute rest between set Acute</td>
<td>Better performance on executive function tasks compared to control group</td>
</tr>
<tr>
<td>Laborde S et al.</td>
<td>2017</td>
<td>Slow-paced Breathing</td>
<td>n = 16 (M: 14, F: 2) Age (years): 17.39 Adolescents with developmental disabilities</td>
<td>Cognitive stress task (Kaufman-assessment battery of children) Heart rate variability recording</td>
<td>Cognitive stress task (Post-intervention) Heart rate variability Recording (Pre- &amp; Post-intervention)</td>
<td>3 sets 5 minutes/set 1 minute rest between set Acute</td>
<td>Better performance on cognitive stress task compared to control group</td>
</tr>
<tr>
<td>Röttger S et al.</td>
<td>2021</td>
<td>Tactical Breathing (Box Breathing)</td>
<td>n = 30 (M: 24, F: 6) Age (years): 24.2 ± 2.3 Healthy adults</td>
<td>Stroop task Subjective strain (MDMQ) Breathing rate Sympathetic activity HR, HRV Electrodermal activity</td>
<td>Subjective strain (Pre- &amp; Post-intervention) Stroop task (Post-intervention) Others (Pre- &amp; Mid- &amp; Post-intervention)</td>
<td>Acute 6 minutes</td>
<td>Less physiological arousal in Tactical Breathing compared to the other group</td>
</tr>
<tr>
<td>Bouchard S et al.</td>
<td>2012</td>
<td>Tactical Breathing (Box Breathing)</td>
<td>n = 41 Age (years): 18-60 Soldiers with basic stress management training &amp; first aid training in combat</td>
<td>HR, Salivary cortisol</td>
<td>HR (Baseline, During an apprehension phase, during the live simulation) Salivary cortisol (Waking up, before and after the live simulation)</td>
<td>30 minutes/session 1 session/day Total of 3 days</td>
<td>Significant stress reduced compared to control group</td>
</tr>
</tbody>
</table>

MDMQ, Multidimensional mood questionnaire.

https://www.ksep-es.org
Table 4. Comparison of non-equipment-based breathing exercise and equipment-based breathing exercise

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Use of equipment</th>
<th>Type</th>
<th>Participant characteristics</th>
<th>Measured variables</th>
<th>Measurement period</th>
<th>Protocol</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed A et al.</td>
<td>2021</td>
<td>Non-equipment-based</td>
<td>Box Breathing (Tactical Breathing)</td>
<td>n=30 (M: 15, F: 15) Age (years): 18-25 Healthy college students</td>
<td>FVC, FEV1, FEV1/FVC, FEF25-75, PEF, FVC</td>
<td>Pre- &amp; Post-Intervention</td>
<td>2 sessions/day Total of 30 days 20 times/session</td>
<td>Significant Improvements in FVC, FEV1, FVC</td>
</tr>
<tr>
<td>Laborde S et al.</td>
<td>2021</td>
<td>Non-equipment-based</td>
<td>Slow-paced Breathing</td>
<td>n=78 (M: 41, F: 37) Age (years): 23.33 Healthy participants within chronic conditions</td>
<td>Cardiac vagal activity inhibition task (Stroop task), Working memory Capacity (AOSPAN), Cognitive flexibility (Modified card sort test)</td>
<td>Cardiac vagal activity (Pre- &amp; Post-Intervention), Executive function (Post-Intervention)</td>
<td>3 sets 5 minutes/set 1 minute rest between set</td>
<td>Better performance on executive function tasks compared to control group</td>
</tr>
<tr>
<td>Yoon JM et al.</td>
<td>2022</td>
<td>Non-equipment-based</td>
<td>Diaphragmatic Breathing+Pursed-lip Breathing Exercise</td>
<td>n=3 2 Older stroke patients</td>
<td>FVC, FEV1, FEV1/FVC, PEF, Chest expansion, 6-minute walk test</td>
<td>Pre- &amp; Post-Intervention</td>
<td>Total 4 weeks</td>
<td>Significant improvements in chest expansion, 6Minute walk test FVC, FEV1, PEF</td>
</tr>
<tr>
<td>Mourya Met al.</td>
<td>2009</td>
<td>Non-equipment-based</td>
<td>Fast-Breathing</td>
<td>n=60 Age (years): 20-60 Stage 1 hypertension</td>
<td>Autonomic function test, S/L ratio, 30:15 ratios, Valsalva ratio, E/I ratio, Hand grip test, Cold pressor response</td>
<td>Pre- &amp; Post-Intervention</td>
<td>15 minutes/session 2 sessions/day daily Total of 3 months</td>
<td>Significant decrease in SBP, DBP</td>
</tr>
<tr>
<td>da Silva Guimarães B et al.</td>
<td>2021</td>
<td>Equipment-based</td>
<td>POWERbreathe K-5</td>
<td>n=101 (M: 49, F: 52) Age (years): 18-86 Tracheostomized patients on prolonged weaning</td>
<td>Respiratory muscle strength (MIP, Timed inspiratory effort index), ICU Survival rate, Weaning success</td>
<td>Pre- &amp; Post-Intervention</td>
<td>30 breaths/set 2 sets/session 1 session/day 5 days/week</td>
<td>Improvements in respiratory muscle strength (MIP, Timed inspiratory effort index), ICU survival rate, Weaning success</td>
</tr>
<tr>
<td>Kaeotawee P et al.</td>
<td>2022</td>
<td>Equipment-based</td>
<td>Threshold IMT</td>
<td>n=60 (M: 42, F: 18) Age (years): 8-15 Obese children / Adolescents</td>
<td>FEV1, FEV1/FVC, FEF25-75, PEF, Respiratory muscle strength (MIP, MEP), 6-MWT</td>
<td>Pre- &amp; Post-Intervention</td>
<td>30 breaths/session 2 sessions/day Total of 8 weeks</td>
<td>Improvements in 6-MWT, MIP</td>
</tr>
<tr>
<td>Lee HY et al.</td>
<td>2014</td>
<td>Equipment-based</td>
<td>Feedback device</td>
<td>n=22 Age (years): 6-12 Children with cerebral palsy</td>
<td>Pulmonary function test (FVC, FEV1, PEF, VC, TV, IRV, ERV)</td>
<td>Pre- &amp; Post-Intervention</td>
<td>15 minutes/session 3 days/week Total of 4 weeks</td>
<td>Improvements in FVC, FEV1</td>
</tr>
</tbody>
</table>

FVC, Forced vital capacity; FEV1, Forced expiratory volume in 1 second; PEF, Peak expiratory flow; TV, Tidal volume; VC, Vital capacity; IRV, Inspiratory reserve volume; ERV, Expiratory reserve volume; MIP, Maximal inspiratory pressure; MEP, Maximal expiratory pressure; ICU, Intensive care unit.
2. Breathing Exercise (BE) for Respiratory Sarcopenia (RS)

BE for RS included Box Breathing (Tactical Breathing) and Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise. Box Breathing (Tactical Breathing) showed significant improvements in respiratory functions which include FVC, FEV1, and FIVC. Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing Exercise showed significant improvements in respiratory functions such as FVC, FVC/FEV1, TV, IC, and SVC. In addition, it showed improvements in respiratory muscle activation of the UT, LD, RA, and IAO. Such results support the mechanism of BE being a respiratory rehabilitation program for RS. The specific information is visually outlined in Table 2.

3. Breathing Exercise (BE) for Cognitive Impairment (CI)

BE for CI included Slow-paced Breathing and Tactical Breathing (Box Breathing). Slow-paced Breathing resulted in better performance on executive function tasks and cognitive stress tasks. Tactical Breathing (Box Breathing) resulted in less physiological arousal and stress reduction. Accurate information is distinctly presented in Table 3.

4. Non-Equipment-based Breathing Exercise VS. Equipment-based Breathing Exercise

We compared non-equipment-based BEs and equipment-based BEs in order to identify the difference in protocols and results of these two different methods. Resultingly, both methods showed beneficial effects on physiological factors such as respiratory function, as well as physical fitness levels. However, whereas non-equipment-based BE demonstrated positive effects on cognitive function, the impact of equipment-based BE on cognitive function remains inadequately supported by existing studies. Therefore, a systemized non-equipment-based BE protocol can be an effective program for PSRS compared to equipment-based BE. Visual information is supported in Table 4.

5. Summary

ST stands as a significant precursor to CI and RS. We have formulated a mechanism wherein RS functions as a mediator for CI in ST patients. Within this framework, we propose the hypothesis that BE hold the potential to enhance cognitive function or ameliorate CI. We are set to embark on a pilot study, and the anticipated acute impacts of the BEs on college students include the following:

1. Inspiratory Diaphragmatic Breathing and Expiratory Pursed-lip Breathing Exercise are projected to bolster respiratory function, alleviate anxiety levels, and augment focus and attention.
2. Implementing the Box Breathing Exercise (Tactical Breathing) is predicted to diminish stress and fortify cognitive function.
3. Fast-Breathing Exercise is anticipated to amplify alertness and boost energy levels, whereas.
4. Slow-paced Breathing Exercise is foreseen to decrease heart rate, blood pressure, and stress levels.

Nonetheless, it is crucial to recognize that individual responses to BE may vary, influenced by factors such as health status, physical fitness, physical capacity, and lifestyle. To ensure the accuracy of data collection, all BE sessions will be conducted in a rigorously controlled and super-

Fig. 2. Implementation of BE in the interplay between ST, RS, and CI. ST culminates in CI, with RS serving as an intermediary factor. The impact of implementing BE (comprising Inspiratory Diaphragmatic Breathing+Expiratory Pursed-lip Breathing, Box Breathing/Tactical Breathing, Slow-paced Breathing, and Fast-Breathing) will be ascertained through the course of our investigation.
DISCUSSIONS

We suggest a pilot study aimed at substantiating the acute and short-term effects of Inspiratory Diaphragmatic Breathing Exercise+Expiratory Pursed-lip Breathing Exercise, Slow-paced Breathing, Box Breathing (Tactical Breathing) and Fast-Breathing Exercise. Our pilot study will be composed of 3 phases. Phase 1 will be finding the acute effect of each breathing exercises. Phase 2 will be finding the effects of practicing each breathing exercises for 2-week. Phase 3 will be finding the effects of practicing each breathing exercises for 4-week. Previous studies showed a minimum of 2-week breathing exercise protocol and a maximum of 4-week breathing exercise protocol. Therefore, the purpose of our pilot study is to find the most efficient and effective breathing exercise protocol. Furthermore, each breathing exercise will be executed 5 days a week, while performing the exercise for 15 minutes per day. Follow-up study will be executed to determine the combination effects of each BE. Insights obtained from this phase will then be used to develop a new type of BE.

Sample size for this study was calculated using G-power, version 3.1. A power analysis with a desired effect size of 0.25 (default), significance level of 0.05, and power of 0.80 determined that a sample size of 36 was required. 40 people will be recruited considering the drop-outs, and the recruited individuals will be randomly distributed into 4 breathing exercise groups. There will be a total of 4 measurement periods throughout the study. This study will be conducted in University of Seoul, Seoul, Republic of Korea on 40 healthy college students. Participants will be recruited through online and offline recruitment advertisements.

Measurement variables will encompass a range of physiological and cognitive parameters. Respiratory functions, comprising Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), Maximal Inspiratory Pressure (MIP), and Maximal Expiratory Pressure (MEP), will be measured utilizing the Bionet Cardio7 (Bionet America, Inc., USA). Exercise intensity includes Rate of Perceived Exertion (RPE) and Heart Rate (HR), which will be measured pre-, mid-, and post-intervention, utilizing the Polar monitoring system (Polar Electro, Finland). Active oxygen levels will be assessed through the BioDoctor BS-502 device (Bionics, Republic of Korea), while blood lactate levels will be ascertained utilizing the Accutrend Plus Analyzer (Roche Diagnostics, Switzerland). Pre- and post-intervention measurements of cerebral oxygen saturation will be measured during the administration of the Neurocognitive test CNS Vital Signs, along with the fNIRS device (OBELAB, Korea). Cognitive function, germane to the CNS Vital Signs, will be evaluated as well. All variables will undergo pre- and post-intervention measurements, while additional measurement of exercise intensity mid-intervention will be conducted. Our pilot study is visually presented in Fig. 3.

Results of this current review have shown the effects of breathing exercises on ST, RS, and CI. However, previous studies have been conducted in participants with various characteristics which makes it difficult to consider a superior BE. Furthermore, there was a lack of studies particularly targeting PSRS patients. Therefore, there is a need of further study on investigating the effects of BE on PSRS patients. PSRS patients are...
high risk groups which makes is crucial to verify the effectiveness and safety of BE before application.

CONCLUSION

CI followed by respiratory muscle mass and function loss in ST patients are critical. In addition, the improvement of respiratory function, cognitive performance, and physiological parameters through BE in various cases has been confirmed. Still there is a need of development of standardized BE protocols for PSRS patients. Therefore, further study will be conducted to establish an appropriate BE protocol for PSRS patients based on this review. The results of our pilot study will be used to develop a new BE protocol which will undergo validation through application to college students in order to affirm its safety and feasibility. After verifying the safeness of the new BE protocol, we will gradually apply it to healthy older adults, ST patients, and PSRS patients. Future follow-up studies may also use this paper as a reference, orienting the application of BE in PSRS patients with CI.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization: JG Lee, MS Ha; Funding acquisition: JG Lee, MS Ha; Methodology: JG Lee, JH Lee; Project administration: MS Ha; Visualization: JG Lee; Writing - original draft: JG Lee; Writing - review & editing: JH Lee, MS Ha.

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