Dynamic balance in obese subjects: before and after telerehabilitation weight-bearing exercise for better balance

Astika Cahya Noviana¹, Meisy Andriana¹,², I Putu Alit Pawana¹,
Damayanti Tinduh¹, Hermina Novida², Soenarnatalina Melaniani³

ABSTRACT

Background: People with obesity tend to have balance disturbance and a higher fall risk than those with normal BMI. The Weight-bearing Exercise for Better Balance (WEBB) is an exercise program that could improve balance in the elderly population, but no study implementing the WEBB program on obese subjects. This study aims to analyze the effects of the telerehabilitation WEBB program on dynamic balance in obese subjects, measured by Maximized Reach Distance (%MAXD) and a composite score of the Modified Star Excursion Balance Test (mSEBT).

Methods: Ten male participants aged 18-30 were recruited. Participants underwent the WEBB program 3 times a week for 8 weeks in their own homes under the supervision of the researchers. The intensity of the exercise was increased every 2 weeks. For the analysis, %MAXD and composite score mSEBT were used to assess the dynamic balance before and after the WEBB program.

Results: There was a significant increase (p < 0.05) in %MAXD of both sides and all directions. The mSEBT composite score of both sides also significantly increased (p < 0.05). All the statistical results showed large effect sizes.

Conclusion: The WEBB program through telerehabilitation is proven to significantly improve dynamic balance, as indicated by an increase in %MAXD and mSEBT composite scores in obese subjects.

Keywords: balance, exercise, obesity, telerehabilitation

INTRODUCTION

Obesity and central obesity have become a global public health problem. In 2016, approximately 650 million of the 1.9 billion adults worldwide were obese.¹ Obesity and central obesity themselves are health risk factors strongly associated with various diseases, such as hypercholesterolemia, cardiovascular disease, diabetes mellitus, and hypertension, as well as increased risks of hospitalization and the appearance of severe symptoms if the patient is infected with COVID-19.²⁻⁵ The condition caused by the pathophysiology in people with obesity affects numerous body systems.

The often-overlooked effects of obesity include balance disorders, increased risk of falling and decreased muscle strength in obese individuals.⁶⁻⁷ The previous study stated that a strong relationship exists between obesity and work accidents due to falls or limb injuries; obese individuals have a 25%-68% higher risk of injury at work than their co-workers who have normal body mass index (BMI).⁸

There are various tests to assess balance, one of which is the widely used Modified Star Excursion Balance Test (mSEBT). This test is inexpensive, produces rapid assessment, and has good reliability. Many researchers have performed this test to analyze the effectiveness of balance training programs.⁹⁻¹⁰

The Weight-bearing Exercise for Better Balance (WEBB) program was developed for people with balance disorders and lower limb muscle weakness. It aims to train muscle coordination by carrying out training related to functional activities, so it will help the patient do their daily activities.¹¹

Telerehabilitation is a rehabilitation service involving information and communication technology.¹² It is useful to apply in the COVID-19 pandemic era to reduce contact between healthcare providers and patients. The application of telerehabilitation also gives many advantages compared to center-based rehabilitation, such as reducing healthcare costs, increasing exercise session frequency, and increasing patient adherence to the rehabilitation session.¹³⁻¹⁴

No study has applied the telerehabilitation WEBB program to obese subjects. The present pilot study was conducted to determine the effectiveness of the telerehabilitation WEBB program in improving dynamic balance in obese subjects.

METHODS

Participants

This study was an experimental study with...
a one-group pretest-posttest design. This study included participants who met the criteria, including male undergraduate students of the Faculty of Medicine Universitas Airlangga, aged 18-30 years old, who had a Body Mass Index (BMI) of 30 kg/m² or more and agreed to participate. The participants with chronic illness, neuromusculoskeletal and vascular disease on the lower extremities, and hearing or visual disturbances that may interfere with audio-visual communication would be excluded from this study. The participants were considered to drop out of this study if they could not do the exercise for 3 consecutive days, did not want to carry on with the program, experience complications such as angina or syncope while taking the exercise, got sick, or died. A total of 10 obese participants met the inclusion criteria for this study.

The Research Ethics Committee of Dr. Soetomo General Academic Hospital approved this study (Ref No. 0488/LOE/301.4.2/VI/2021). Prior to the study, written informed consent was obtained from all participants.

Exercise Intervention
The WEBB program was carried out for 8 weeks, 3 times per week. The exercise took place in each participant’s home; all participants wore sports clothing and shoes during the intervention. Before the exercise, the telerehabilitation safety was measured by the subjects reporting their pulse, Borg Scale Rating of Perceived Exertion (RPE), Visual Analog Scale (VAS), and pre-exercise complaints to the researchers via instant message. The intervention was carried out after the condition of the subject was considered by the researchers as feasible to take the exercise. After the exercise, subjects report their pulse, RPE, VAS, and post-exercise complaints to the researchers via instant message. Telerehabilitation compliance was measured by filling out an exercise diary, sending evidence of training (photos and videos) via instant message, and weekly evaluations every Sunday via video teleconference.

The WEBB program designed in this study contains three types of exercises.11

It was then followed by the coordination exercise, which consisted of two sets of the exercise: 1) standing on a decreased base: one minute of standing with both feet, one minute of standing in tandem stance, and standing on one leg for one minute each; and 2) stepping in different directions: one minute of long stepping on narrow base support, one minute of stepping forward over an object, and two minutes of stepping sideways over an object. The last series of the exercise was the coordination and strength exercise which included: 1) two sets of the sit-to-stand exercise with ten reps for each of the following movements: with hand assistance, without hand assistance, and unilateral squatting; 2) heel raise exercise: bilateral heel raise for three sets of ten reps and unilateral heel raise for two sets of ten reps each leg; and 3) lateral step-up exercise and forward step-up exercise for two sets of ten reps for each movement. The rest period between exercises and sets was 10–15 seconds. The height of the object used for the stepping and set-up exercises increased from 15 cm to 20 cm after four weeks of exercise. The exercise intensity was increased gradually every two weeks: one-minute exercises were increased to 1.5, 2, and 2.5 minutes, and two minutes exercises were changed to 3, 4, and 5 minutes. Meanwhile, the number of sets was also increased from 2 sets to 3, 4, and 5 sets and from 3 sets to 4, 5, and 6 sets.

Data Collection
Hybrid telerehabilitation was applied in this study and conducted from August to December 2021. The confounding variables were daily physical activity and daily food intake, which could not be controlled during the study. The data on the daily physical activity was gained through the International Physical Activity Questionnaire-Short Form (IPAQ-SF), while the data related to daily food intake was obtained from a food record and converted using the Nutrisurvey program to get the data on calories (kcal). The pre- and post-exercise data collections were carried out offline, while the intervention was performed at the participant’s home with online supervision.

In this study, the mSEBT was used to assess dynamic balance. The data was measured before and after the program to determine whether there was a difference between them. The participants were asked to do single-leg stances, with the free limb reaching the anterior (ANT), posterolateral (PL), and posteromedial (PM) directions.35 The measurements were taken 3 times for each direction, and the farthest distance was used for data analysis. All reach distances were normalized as a percentage of stance limb length (LL) as the % Maximized Reach Distance (%MAXD). Each participant’s limb length (LL) was measured from the anterior superior iliac spine to the medial malleolus of each limb. The formula for the measurement is [%MAXD = (reach distance/LL) x100].15,16 Meanwhile, the composite score was the mean of the three reach distances measured for each lower extremity [Comp = ((ANT+PM+PL) / (3xLL)) x 100].16

Statistical Analysis
The Shapiro-Wilk test was used to test the normal data distribution. Meanwhile, the paired t-test was implemented to compare the mSEBT data before and after the WEBB program. The significance level was p < 0.05, and the effect sizes were also presented. A commonly used interpretation is to refer to the effect sizes as small (d = 0.2), medium (d = 0.5), and large (d = 0.8) based on benchmarks suggested by Cohen.17 All statistical tests were performed using SPSS software version 26.

RESULTS
Participant characteristics
A total of 10 male undergraduate university students participated in this study, and there were no participant drop-outs (Table 1). The average age was 20.70 ± 2.11 years, with a BMI of 35.11 ± 4.37 and WHR of 0.94 ± 0.07. The daily physical activity based on the IPAQ-SF questionnaire was 4 inactive, 5 minimally active, and 1 HEPA active participant. The average daily food intake was 6.92 ± 2.52 kcal.

%MAXD mSEBT
The right side %MAXD anterior (ANT) was increased from 76.58 ± 10.65 to 85.53 ± 8.08, posterolateral (PL) 68.16 ± 9.26 to 88.37 ± 8.87, and posteromedial (PM)
88.14 ± 8.20 to 99.29 ± 8.18. The left side %MAXD ANT was increased from 81.82 ± 7.70 to 85.82 ± 5.21, PL 71.41 ± 15.44 to 88.46 ± 9.99, and PM 86.01 ± 8.83 to 98.74 ± 9.05. Table 2 and Table 3 show that the %MAXD mSEBT on the right (R) and the left (L) had a significant difference before and after undergoing the WEBB program in all reach directions with p < 0.05. The calculations of the mean effect size of Cohen’s d paired t-test %MAXD mSEBT on the right (R) and the left (L) indicate large effect sizes (Cohen’s d ANT R and L 0.8; PL R = 2.2 and L = 2.4; PM R = 1.8 and L = 1.9).

**Composite score mSEBT**

The composite scores mSEBT for the right side was 77.62 ± 7.41 before the WEBB program and 91.06 ± 7.61 after the program. The left-side composite score was 79.75 ± 10.02 before the WEBB program and 91.00 ± 7.53 after the program. Table 4 displays that the mSEBT composite scores for the right (R) and the left (L) had a significant difference before and after undergoing the WEBB program (R and L p < 0.001), while the calculations of the mean effect sizes of Cohen’s d paired t-test %MAXD mSEBT on the right (R) and the left (L) show large effect sizes (Cohen’s d R = 2.0 and L = 2.7).

**DISCUSSION**

People with obesity have a higher risk of balance disorders and falling. It is caused by several pathologies that occur in their body system. The increase in body mass is a mechanical factor that causes lumbar lordosis and a shift of the center of gravity (COG) to the anterior, contributing to balance disorder. Furthermore, the function of the mechanoreceptors in the foot sole is also impaired due to the increased pressure in that area caused by the increase in body mass. People with obesity also experience an increase in the inflammatory response, thus leading to neurological disorders, neuropathy, and impaired proprioception. Such conditions in obese people will elevate their risk of falling by 31%.

The Star Excursion Balance Test (SEBT) effectively detected reach disturbances caused by increased body mass, thus being used as a clinical tool to assess dynamic balance ability. After further studies were conducted on the reliability and validity of SEBT, test-redundancy and learning effects were found in this test, leading to the simplification of the test to the Modified Star Excursion Balance Test or mSEBT. The interclass correlation coefficients (ICC) values for inter-rater reliability were 0.88, 0.87, and 0.88 for the anterior, posteromedial, and posterolateral directions, respectively. The ICC intrarater reliability was 0.88, 0.88, and 0.90 for the anterior, posteromedial, and posterolateral directions, respectively. The WEBB program could be done safely during this study. The participants reported no significant side effects during the intervention. Some of them complained about experiencing rapid breathing and mild muscle pain in their legs after the exercise. After conducting the statistical analysis, the %MAXD results increased significantly in all reach directions. These findings are in line with a previous study in which the %MAXD results are found to improve after the balancing exercise.

Regarding the mSEBT composite score, the scores before the WEBB program were

### Table 1. Basic characteristics of participants

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Min</th>
<th>Max</th>
<th>Mean ± sd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>10</td>
<td>18.00</td>
<td>26.00</td>
<td>20.70 ± 2.11</td>
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<tr>
<td>Weight (kg)</td>
<td>10</td>
<td>83.00</td>
<td>120.00</td>
<td>98.35 ± 13.64</td>
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<td>Height (cm)</td>
<td>10</td>
<td>158.50</td>
<td>178.00</td>
<td>167.35 ± 5.90</td>
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<tr>
<td>BMI</td>
<td>10</td>
<td>30.09</td>
<td>41.04</td>
<td>35.11 ± 4.37</td>
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<tr>
<td>WHR</td>
<td>10</td>
<td>0.85</td>
<td>1.09</td>
<td>0.94 ± 0.07</td>
</tr>
<tr>
<td>Daily physical activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Inactive</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2. Minimally active</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. HEPA active</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily food intake (kcal)</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>10</td>
<td>3.60</td>
<td>11.60</td>
<td>6.92 ± 2.52</td>
</tr>
</tbody>
</table>

### Table 2. Right side %MAXD mSEBT in pre- and post-WEBB

<table>
<thead>
<tr>
<th></th>
<th>ANT</th>
<th>PL</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (%)</td>
<td>76.58</td>
<td>85.53</td>
<td>68.16</td>
</tr>
<tr>
<td>Sd</td>
<td>10.65</td>
<td>8.08</td>
<td>9.26</td>
</tr>
<tr>
<td>p-value</td>
<td>0.036*</td>
<td>&lt;0.001*</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>Effect size</strong></td>
<td>0.8</td>
<td>2.2</td>
<td>1.8</td>
</tr>
</tbody>
</table>

**Notes:** *significant if p < 0.05. Abbreviations: ANT, anterior; PL, posterolateral; PM, posteromedial.

### Table 3. Left side %MAXD mSEBT in pre- and post-WEBB

<table>
<thead>
<tr>
<th></th>
<th>ANT</th>
<th>PL</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (%)</td>
<td>81.82</td>
<td>85.82</td>
<td>71.41</td>
</tr>
<tr>
<td>Sd</td>
<td>7.70</td>
<td>5.21</td>
<td>15.44</td>
</tr>
<tr>
<td>p-value</td>
<td>0.037*</td>
<td>&lt;0.001*</td>
<td>&lt;0.001*</td>
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<tr>
<td><strong>Effect size</strong></td>
<td>0.8</td>
<td>2.4</td>
<td>1.9</td>
</tr>
</tbody>
</table>

**Notes:** *significant if p < 0.05. Abbreviations: ANT, anterior; PL, posterolateral; PM, posteromedial.

### Table 4. Composite mSEBT scores for pre- and post-WEBB

<table>
<thead>
<tr>
<th></th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre (%)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (%)</td>
<td>77.62</td>
<td>91.06</td>
</tr>
<tr>
<td>Sd</td>
<td>7.41</td>
<td>7.61</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001*</td>
<td></td>
</tr>
<tr>
<td><strong>Effect size</strong></td>
<td>2.0</td>
<td>2.7</td>
</tr>
</tbody>
</table>

**Notes:** *significant if p < 0.05.
improve the modulation of specific reflexes as needed. After 4 weeks of exercise, the brain will adapt, where the motor cortex activity will decrease in proportion to the improvement in postural control. This decrease in motor cortex activity after several weeks of balance training is consistent with skill acquisition or automation. Conversely, this automation increases activities in subcortical regions such as the basal ganglia and cerebellum. The cerebellum is essential in modulating specific muscle activity for certain activities. Furthermore, the cerebellum’s role in acquiring balance skills assumes that balance training will induce some “shifts in movement control” from cortical to subcortical and cerebellar.

Balance training carried out for an extended period (years) will stimulate structural neuroplasticity in the central nervous system and affect the excitability of the corticospinal pathways. After each exercise, cortical reactivity decreases during the execution of postural activities. It can be due to the increased synaptic efficiency of direct corticospinal projections to muscles, including the ones covering the ankle joint, which can be beneficial when performing voluntary contractions.

This study applied the hybrid telerehabilitation method. Applying this method has advantages and disadvantages. The offline initial data collection made evaluating the participants’ initial condition easier before starting the program. The researcher also could give a direct explanation of the exercise and the safety measure protocol during that offline meeting. Meanwhile, the online training program could reduce contact between the researchers and the participants. The telerehabilitation method also gave the participants flexibility to choose their exercise time and adjust it with the participants’ class schedule. It would reduce the drop-out rate and increase compliance with the exercise. The implemented telerehabilitation method also has limitations. Not all exercises were supervised from beginning to end, thus requiring a high level of trust between the researchers and the participants. The results of this study prove that even though the WEBB program was provided through telerehabilitation, it still showed a significant effect on the participants. The same results were found in other studies on WEBB that did not apply the telerehabilitation method. In addition, the findings of this study are in accordance with previous studies, which show that telerehabilitation has a similar effect to traditional or center-based rehabilitation methods.

Another case study reveals that telerehabilitation can increase accessibility to rehabilitation programs while reducing physical contact in the COVID-19 pandemic.

**CONCLUSION**

The WEBB program through telerehabilitation is proven to significantly improve dynamic balance, as indicated by an increase in %MAXD and mSEBT composite scores in obese subjects. This study only involved 10 participants from a specific population without a control group. Further studies are needed to examine participants from a more diverse population and compare the implementation of the WEBB program as a center-based rehabilitation program and a home program, with and without telerehabilitation.

**ETHICAL CONSIDERATIONS**

The Research Ethics Committee of Dr. Soetomo General Academic Hospital approved this study (Ref No. 0488/LOE/301.4.2/V1/2021). Prior to the study, written informed consent was obtained from all participants.

**FUNDING**

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**CONFLICT OF INTEREST**

The author reports no conflicts of interest in this work.

**AUTHOR CONTRIBUTION**

All authors have contributed equally from the conceptual framework, data acquisition, and data analysis until the study results are reported through publication.
ACKNOWLEDGMENTS

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