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*Research Article*

# 3-Minute Burpee Test for Patients with Mild Dementia Disorder May Improve Cognitive Function and Physical Composition

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## ABSTRACT

Currently, the number of dementia patients is increasing at a rate of one every three seconds, and it is estimated to reach 16.2 million by 2050, requiring urgent countermeasures. The increase in the number of dementia patients is a serious and important issue not only in Japan but also worldwide, as it reduces quality of life on an individual level, burdens caregivers, impacts society, and puts pressure on social security costs. Studies have shown that regular exercise programs can improve health by slowing or preventing age-related functional decline. The physical health benefits of older adults who regularly participate in endurance, balance, and resistance training programs are well established. Because exercise program interventions combining aerobic and strength training have a variety of health benefits for older adults and may also improve cognitive function, we investigated the effects of a 3-minute burpee test (3MBT) on cognitive function and body composition.

After 3 months of weekly 3MBT, the evaluation of medial temporal atrophy improved in all subjects in terms of severity of VOI atrophy ($p<0.01$), degree of GM atrophy ($p<0.05$), degree of VOI atrophy ($p<0.05$), degree of VOI/GM atrophy ($p<0.05$), and the number of 3MBT cycles increased ($p<0.05$).

Although this study lacks conclusive evidence as an effective intervention for patients with MCI due to the small population and the fact that it is not an RCT, it is a new finding that 3MBT, which requires no special equipment, place, or time, increased skeletal muscle mass and improved cognitive function.

**Keywords:** Mild cognitive impairment; VSRAD; 3MBT

## 1. Introduction

In 2015, there were 47 million people with dementia (Alzheimer's) worldwide, and it is estimated that the number of people with dementia will increase by one person every three seconds, reaching 106.2 million by 2050[1]. This number increases further if mild cognitive impairment (MCI) is included, in which the patient and family members complain of dementia but do not have any major difficulties in daily life and do not meet the diagnostic criteria for dementia.

The clinical definition of MCI is that the patient or family member complains of memory impairment, one or more cognitive deficits are objectively observed, activities of daily living are normal, and the patient does not suffer from dementia. According to Japan's Ministry of Health, Labour and Welfare, there are approximately 4 million MCI patients among the elderly over 65 years old. The total number of patients with dementia and those with MCI is approximately 8.62 million, or about 1/4 of the total number of elderly people. It is also known that 50% of those diagnosed with MCI will progress to dementia within 4 years, and more than 80% within 6 years.

Dementia, which was the fourth leading cause of care needs in 2004 (10.7%), will be the second leading cause in 2015 (15.3%) and the leading cause in 2022 (16.6%)[2]. Since the proportion of elderly people will further increase due to population decline, urgent measures against dementia are needed. The increase in the number of dementia patients is a serious and important issue not only in Japan but also worldwide, due to the decline in QOL on an individual level, the burden on caregivers, the impact on society, and the pressure on social security costs.

Alzheimer's disease (AD) is a major causative disease of dementia; typical risk factors for AD include obesity, diabetes, depression, lack of exercise, smoking, and educational level. Among these risk factors, lack of exercise has been reported to have the greatest impact on the development of AD[3]. Reducing these risk factors is expected to significantly reduce the prevalence of dementia due to AD.

To determine the effects of interventions on cognitive function, we surveyed approximately 7,000 articles on dementia prevention from 1984 to 2009 and examined the effects of nutritional interventions, medical factors and medications, and social, economic, and behavioral factors in terms of intervention type and method. The results showed that nutritional factors such as vitamin B, folic acid, and ω-3 unsaturated fatty acids, medical factors such as antihypertensive drugs and cholinesterase inhibitors, and drugs were not effective in preventing dementia; only exercise, a social, economic, and behavioral factor, was effective[4].

Exercise improves brain function by stimulating the production of brain-derived neurotrophic factor (BDNF), leading to plastic changes in hippocampal regions and slowing the progression of cognitive decline[5].

Using region-of-interest analysis of magnetic resonance images of 165 non-demented elderly subjects, the results show that, controlling for age, gender, and years of education, higher fitness levels lead to larger left and right hippocampi, and larger hippocampi and higher fitness levels lead to better spatial memory performance. In other words, the results clearly indicate that higher aerobic fitness levels increase hippocampal volume and improve memory function in older adults[6]. Hippocampal capacity declines by 1-2% annually in healthy older adults, and this decline increases the risk of dementia. Aerobic exercise has been shown to offset the decline in hippocampal capacity in the elderly and maintain and improve memory function.

To test the hypothesis that aerobic fitness training increases cognitive vitality in healthy but sedentary older adults, an analysis of 18 intervention studies published between 1966 and 2001 found that a combination of aerobic exercise and strength training was effective in improving cognitive function[7].

Similar reports are still available, with 8 of 11 studies reporting that aerobic exercise intervention improved cardiopulmonary function (improvement in the maximal oxygen uptake test, the best measure of cardiopulmonary function) by about 14% in the intervention group, and that this improvement was consistent with improvement in cognitive function[8].

Research has shown that regular exercise programs can delay or prevent age-related functional decline and improve the health of this age group. The physical health benefits of older adults who regularly participate in endurance, balance, and resistance training programs are well established. These health benefits include improvements in muscle mass, arterial compliance, energy metabolism, cardiovascular fitness, muscle strength, and overall functional capacity[9]. Physical activity is also thought to improve cognitive function[7].

These findings suggest that exercise program interventions that combine aerobic exercise and strength training have a variety of health benefits for older adults.

The combined aerobic and strength training exercise program used in this study was the 3-minute burpee test (3MBT). 3MBT has been reported to be associated with maximal oxygen uptake, lean body mass in women and muscle strength (counter movement jump high, isometric mid-thigh pull, isometric bench press), muscle power (counter movement-jump height, isometric mid-thigh pull, and isometric bench press) have been reported to be related[10-14].

3MBT is very cost-effective and effective in improving cognitive function because it does not require special equipment, space, or time to apply high loads to muscle groups and metabolism throughout the body.

## 2. Materials & Methods/Tables/Graphs

Oral interviews, including questions about memory impairment, were conducted one-on-one with the patient and family members along with a professional investigator, and a diagnosis was made using the Mini-Mental State Examination (MMSE) and the Clinical Dementia Rating Scale (CDR).

The test is rated on a 30-point scale, with a score of 23 indicating suspicion of dementia and a score of 20 or less indicating near dementia, with a diagnostic sensitivity of 83% and specificity of 93%. Since the diagnosis of dementia may not be made if the examinee is familiar with the MMSE test, the Clinical Dementia Rating Scale (CDR) test was also administered; a score of 0 on the CDR is normal, 0.5 indicates suspicion of dementia, and a higher score indicates a higher degree of dementia. In this study, among those diagnosed with MCI by physicians based on these tests, 23 subjects (6 men and 17 women) who agreed to cooperate in the study and received permission from their physicians to exercise, were examined using magnetic resonance imaging (MRI) and segmental bioelectrical impedance analysis (S-BIS) to determine the effect of 3MBT intervention The effect of the 3MBT intervention was examined.

The subjects performed 3MBT once a week for 3 months after adequate warm-up. The time of the exercise was left up to the subject, but he was instructed not to perform it consecutively (e.g., Sunday and the following Monday) and to perform it on a different day if he had muscle soreness.

To ensure safety, program implementation was conducted under the online supervision of a family member, roommate, or researcher. During the intervention period, participants were instructed to maintain their previous exercise habits and physical activity levels and not to make any major dietary changes.

### 2.1 3MBT (3-Minute Burpee Test)

The 3MBT was not a competition for the speed of repetition, and particular attention was paid to correct posture. As in previous studies, failure to perform any one of the series of movements correctly was considered a failure and was not counted. In particular, plank postures in which the hips were either too high or too low and postures in which the hands were not clapped over the head were also considered failures[15].

Prior to administering the test, subjects performed a 10-minute warm-up consisting of jogging, jumping jacks, mountain climbers, and stretching. These exercises were performed to increase muscle temperature in the pectoral, deltoid, quadriceps, hamstrings, and trunk muscles used in the burpees.

After 5 minutes of rest from the end of the warm-up, the 3MBT was started.

VSRAD （Voxel-based specific regional analysis system for Alzheimer's disease).

VSRAD is an image statistical analysis method for computerized analysis of brain volumes obtained by MRI in voxel units, and is a system for analyzing and converting morphological image information of medial temporal atrophy unique to early Alzheimer's disease into diagnostic support information.

Using VSRAD, the degree of hippocampal and parahippocampal atrophy can be easily evaluated numerically using the voxel-based morphometry (VBM) method.

VOI (volume of interest) refers to the hippocampus and its surrounding area, which is responsible for memory and cognition. By comparing the atrophy of VOI with that of the entire brain, it is possible to confirm the degree of progression of brain atrophy related to memory and cognition.

VOI atrophy is a numerical value that compares the atrophy of the VOI with that of the brain as a whole, and a value of 1 or higher indicates that the person is in a state of more than age-related atrophy and is at high risk of developing dementia.

Although the results of VSRAD cannot be used to diagnose Alzheimer's disease, this study used the Z-score, which provides a numerical evaluation of the degree of atrophy in the hippocampus and parahippocampal gyrus, for evaluation.

The evaluation items were Severity of VOI atrophy, Extent of GM atrophy, Extent of VOI atrophy, and Ratio of VOI to whole brain atrophy (Ratio of VOI / GM atrophy), The VSRAD was defined as the ratio of the maximum value in VOI (Max in VOI) to the percentage of whole brain atrophy (Extent of WM atrophy).

### 2.2 Segmental multi-frequency bioelectrical impedance spectroscopy (S-BIS)

S-BIS is a method of predicting body composition based on differences in electrical conductivity due to biological characteristics of tissues. Lean tissue can be distinguished from adipose tissue by its high water content and high conductivity, while adipose tissue has low conductivity. By passing different frequencies from low to high into the body, total water content (TW) is estimated from the high frequency, which is considered to be the frequency that can pass through the cell membrane, and extracellular fluid (ECW) is estimated from the low frequency, which cannot pass through the cell membrane.

Interval impedance values at each site were measured using S-BIS (ML-30, Sekisui Medical, Tokyo, Japan), which provides electrical resistance values at 140 frequencies located on a logarithmic distribution in the range of 2.5 - 350 kHz. Electrodes were disposable electrodes for ECG (Red Dot2330, 3M). Measurements were taken after 1 minute of standing after MRI measurements. This was done to avoid the influence of fluid changes due to body position. Measurements were taken in the fasting state. In the Arm-to-arm model, the current-applying electrodes were placed on the dorsal surfaces of the right and left metacarpals, and the detection electrodes were placed on the line connecting the right and left ulnar stem strike points and the flexor digitorum brevis stem strike point. The leg-to-leg model current-applying electrodes were placed on the dorsal metatarsal surfaces, and the detection electrodes were placed on the line connecting the endocarpal and exocarpal points of the foot. The obtained resistance values of the ECW component (RECW) and TW component (RTW) were calculated by fitting the Cole-Cole model.

The resistance of the ICW component (RICW) was calculated as 1 / [(1/RTW) - (1/ RECW)]. The ICW and ECW of the upper and lower extremities were calculated using the following estimating equations: intrinsic resistivity of the ECW (ρECW = 47 Ωcm) and intrinsic resistivity of the ECW (ρICW = 273.9Ωcm).

$ICW = \rho ICW \times L2 / RECW$

$ECW = \rho ECW \times L2 / RICW$.

For the upper extremity, the distance between electrodes attached to the backs of the right and left metacarpals was measured with both arms extended. For the lower extremities, the distance from the right greater trochanter to the electrode attached to the point connecting the medial and lateral sides of the right foot was measured in the supine position and doubled.

Muscle mass was assessed using the skeletal muscle index (SMI). Skeletal muscle mass (Kg) was divided by the square of height (m). Limb muscle mass is measured by CT, MRI, dual energy X-ray absorptiometry (DXA), and bioelectrical impedance analysis (BIA). However, since each company measures muscle mass according to its own standards, this method cannot be used to measure skeletal muscle mass, but is useful for determining increases or decreases in muscle mass over time. Various studies have also proposed formulas for estimating SMI to facilitate the diagnosis of sarcopenia.

Men:SMI(kg/m2)=0.326×BMI-0.047×abdominal circumference (cm)-0.011×age (years)+5.135

Female:SMI(kg/m2)=0.156×BMI-0.044×Grip strength (kg)-0.010×Abdominal circumference (cm)+2.747

This formula is estimated from BMI (Body Mass Index: weight (kg)/height2 (m)), abdominal circumference, grip strength, and age.

### 2.3 Statistical analysis

All data are expressed as mean ± SD and Student's t-test was used.

IBM SPSS startistics 28 was used for all statistical analyses, with a significance level of less than ($p<0.05$).

## 3. Results & Discussion

In all subjects, assessment of medial temporal atrophy showed improvement in severity of VOI atrophy ($p<0.01$), degree of GM atrophy ($p<0.05$), degree of VOI atrophy ($p<0.05$) and degree of VOI/GM atrophy ($p<0.05$), and increased number of 3MBT cycles. There was no statistically significant difference in the percentage of areas of maximal VOI atrophy and total brain atrophy. In all subjects, changes in body composition increased significantly ($p<0.05$) only in SMI, with no significant changes in body weight, body fat mass, body fat percentage, abdominal circumference, or skeletal muscle mass. When compared by gender, women showed changes in SMI, and the number of cycles of 3MBT increased in both genders (**Table 1**).

There was a significant improvement in the percentage of atrophic areas within the VOI in men and in the degree of VOI in women (**Table 2**). The relationship between medial temporal atrophy and body composition showed a positive trend for the percentage of total brain atrophy areas and body fat mass ($p<0.1$).

**Table 1:** Body composition and 3MBT changes by gender.

| | age | body weight (kg) | Lean body weight (kg) | body fat (%) | Body fat (kg) | SMI (kg/m2) | 3MBT (cycle) |
|---|---|---|---|---|---|---|---|
| pre male (n=6) | 73.67±3.6 | 59.48±5.3 | 24.63±1.16 | 23.82±5.86 | 14.22±3.7 | 6.90±0.47 | 22.9±5.3 |
| post male (n=6) | | 61.05±5.62 | 25.85±2.43 | 22.63±4.16 | 13.42±4.5 | 7.15±0.34 | 24.9±4.9＊ |
| pre female (n=17) | 74.24±5.1 | 50.98±7.29 | 17.77±2.06 | 33.11±7.65 | 17.54±5.70 | 5.52±0.65 | 14.3±3.9 |
| post female (n=17) | | 52.05±7.5 | 18.12±2.51 | 33.03±7.52 | 17.19±5.86 | 5.68±0.68＊ | 16.3±3.7＊ |

Male: SMI(kg/m2)=0.326×BMI-0.047×Abdominal Surround(cm)-0.011×Age+5.135
Female：SMI(kg/m2)=0.156×BMI-0.044×grip(kg)-0.010×Abdominal Surround(cm)+2.747
Diagnostic criteria for sarcopenia using SMI in Asians (male 7.0kg/m2, female 5.7kg/m2)
＊Comparison of each group (p<0.05)

**Table 2**: Changes in Medial Lateral Atrophy after Intervention.

| | age | Severity of VOI atrophy | Extent of GM atrophy | Extent of VOI atrophy | Raito of VOI / GM atrophy |
|---|---|---|---|---|---|
| pre male (n=6) | 73.67±3.61 | 1.49±0.26 | 3.84±1.43 | 23.13±12.06 | 6.86±4.73 |
| post male (n=6) | | 1.34±0.31 | 3.53±1.20 | 18.30±10.64＊ | 5.32±2.77 |
| pre female (n=17) | 74.24±5.14 | 1.51±0.51 | 3.32±13.4 | 22.60±19.40 | 6.50±3.51 |
| post female (n=17) | | 1.44±0.53＊ | 3.28±1.33 | 21.51±19.14 | 5.54±3.85 |

＊Comparison of each group (p<0.05)

## 4. Summary/Conclusion

This study investigated the effects of 3MBT on cognitive function and body composition over a 3-month period in patients with mild dementia. Results showed an increase in the number of cycles of 3MBT, an increase in skeletal muscle mass, and an improvement in cognitive function; since 3MBT has been shown to be associated with aerobic capacity and muscle strength, an increase in the number of cycles would be expected to indicate an increase in both abilities.

Systematic reviews examining the effects of exercise interventions for older adults with MCI have been recommended, but there is no conclusive evidence[16-17].

Although some individual reports have shown efficacy for patients with MCI, the small population size, the fact that early reports were not RCTs, the fact that they were not evaluated according to the severity of dementia, and the fact that aerobic exercise, intensity, and long-term application were not considered have been pointed out as reasons for the lack of efficacy The reasons for the lack of efficacy are pointed out.

Although this study also lacks conclusive evidence as an effective intervention for patients with MCI due to the small population and the fact that it is not an RCT, it is a new finding that 3MBT, which requires no special equipment, place, or time, increased skeletal muscle mass and improved cognitive function.

In the future, it is expected to reduce the onset of dementia and improve cognitive function. Since the prevalence of dementia increases with age and anyone can develop dementia, it is important to develop an exercise habit and improve physical function in order to prevent the disease.

The higher the intensity of this exercise habit, the greater the health benefits. 3MBT is versatile because it can be performed in a small space. 3MBT is expected to prevent dementia, maintain and improve aerobic capacity and muscle strength, and improve QOL for all people through habitual practice.

## 5. Conflict of Interest/ Funding

This manuscript and similar manuscripts have never been published in any language, except for abstracts and scholarly articles, and there are no conflicts of interest or funding disclosures.

## 6. Ethical Approval

This study was approved by the Research Ethics Committee of Momoyama Gakuin University. Informed consent was obtained from all participants before the study was conducted. Participants participated in the study after paper forms and verbal explanations.

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