

## Article

# Effect of Whole-Body Vibration Training on the Physical Capability, Activities of Daily Living, and Sleep Quality of Older People with Sarcopenia

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**Abstract:** **Aim:** To investigate the effect of whole-body vibration on older people with sarcopenia, and their physical capability, activities of daily living, and sleep quality. **Methods:** This study is quasi-experimental and adopts single-group pretest–posttest design. The study included participants aged older than 65 years who lived in nursing homes and care centers in Taipei, Taiwan. The whole-body vibration training was performed for 3 months, and during each training session, a participant received ten cycles of 60-sec vibration with 30-sec breaks between the cycles. The physical capability, activities of daily living, and sleep quality of the participants were examined to understand the pretest and posttest results of whole-body vibration training. Concerning the statistical methods adopted, nonparametric method-based tests were employed. **Results:** In addition to sleep quality ( $z = 7.367, p > 0.05$ ), significant differences were observed between before and after whole-body vibration training intervention for one-foot balance ( $z = -2.447, p < 0.05$ ), shoulder and arm flexibility ( $z = -3.159, p < 0.05$ ), walking speed ( $z = -2.692, p < 0.05$ ), right-hand grip ( $z = -3.388, p < 0.05$ ), left-hand grip ( $z = -3.264, p < 0.05$ ), five sit–stand repetitions ( $z = -2.936, p < 0.05$ ), skeletal muscle mass index ( $z = -3.621, p < 0.05$ ), and activities of daily living ( $z = 1.163, p < 0.05$ ). **Conclusions:** According to this study, with the 12-week whole-body vibration training in older people with sarcopenia, their physical capability and activities of daily living have improved, though sleeping quality is not statistically significant.

**Keywords:** activities of daily living; physical capability; quasi-experimental research; sarcopenia; physical capability; sleep quality

## 1. Introduction

According to the World Health Organization, a country is an aging society when its number of people aged 65 years or older accounts for more than 7% of the country's population. When this number accounts for more than 14% (or 20%) of the population of the country, the country is an aged society (or a superaged society) [1].

In the aging process, older people's physical functions gradually deteriorate. Additionally, they often experience comorbidity conditions and physical impairment, so their muscles fall into disuse and their muscle mass rapidly decreases [2]. Rosenberg [3] first proposed the term sarcopenia to describe the age-related reduction of muscle mass. Previous studies have shown that sarcopenia can easily result in limited mobility and disability and impair people's quality of life [4]. In the United States, 13%–24% of adults aged  $\geq 65$  years and 50% of those aged  $> 80$  years experienced sarcopenia [5]. In Taiwan, the prevalence of sarcopenia in older people aged  $> 65$  years was 13% [6]. Furthermore,

the mortality rate of older people with sarcopenia was 2–6 times that of those without sarcopenia [7]. The United States estimated that medical costs for sarcopenia to be US\$11.8–26.2 billion per year [8]. Therefore, if sarcopenia could be prevented, substantial medical resources would be saved per year.

Community-dwelling older people typically manage their daily activities independently. The Ministry of Health and Welfare in Taiwan conducted a survey among middle-aged and older people to understand their physical and mental conditions and showed that 62.9% of people aged 65 years and older in Taiwan exercised regularly [9]. A domestic study reported that only 36% of older people living in care facilities exercised regularly (more men than women did among these people) [10]. Furthermore, fewer older people in care facilities exercised regularly than did those in the general community because their physical functions were limited. Wu and Du [11] explored the health status of 156 residents in nursing homes and reported that 44.2% of the residents were entirely dependent. People who require institutional care are typically less independent and require assistance in fulfilling their living functions. Physical and mental problems caused by chronic diseases often accompany aging, resulting in an inability of older people to take care of themselves [12]. Among older people, approximately 15.8% have problems related to physical or mental disabilities. Older people who cannot look after themselves must rely on long-term care provided by nursing homes or care centers. Therefore, older people living in care facilities require more assistance than do those living among the community.

In recent years, interventions to improve muscle function in older people have employed whole-body vibration training, which can improve the muscular strength and power of the lower limbs and achieve results similar to those of resistance training. Vibration-induced stimulation can produce neural adaptation, which may enhance muscular–physiological function. Regarding the principle of vibration training, vibration-induced stimulation can be targeted at a muscle spindle (a muscular receptor) through neural transmission to activate said spindle, thereby generating a strong excitation signal and reducing inhibition of the Golgi tendon organ. The neural signal is sent to motor neuron  $\alpha$  in the spinal cord through type Ia sensory nerve fiber and subsequently sent to skeletal muscle fiber, thereby causing reflex contraction of a muscle [13]. Activation of the muscle spindle (muscular receptor) includes recruitment of motor units and rate coding [14,15]. If single muscle contractions can recruit several motor units and induce rapid-rate coding, high muscular strength can be generated [16]. Studies have indicated that vibration training can significantly promote recruitment of fast-twitch muscle fibers and delay aging-induced muscular dystrophy, thereby enhancing muscular strength and power in older people [17,18].

This intervention study was the first to investigate the effect of whole-body vibration on older people with sarcopenia, and their physical capability, activities of daily living, and sleep quality. As an innovative and crucial research, the findings of this study can serve as a reference for medical staff in care facilities to provide care to older people with sarcopenia.

## 2. Methods

Millsap and Maydeu-Olivares [19] contended that research designs with nonrandom group assignments or without a control group are considered quasi-experimental. This might limit the inferences of research results. However, the strength of quasi-experimental studies lies in their practicality and feasibility in clinical areas [20]. The study is a quasi-experimental and adopts single-group pretest–posttest design. We investigated the effect of whole-body vibration training on the basic characteristics, physical capability, activities of daily living (ADL), and sleep quality of older people with sarcopenia in care facilities. The data was collected during 11 May 2016 to 1 August 2016.

### 2.1. Study Participants

The collected data applied in this study is from the Taipei nursing care centers. The diagnosis criteria for sarcopenia are as follows: (i) hand-grip strength of <26 kg for men and <18 kg for women; (ii) walking speed of <0.8 m per s; (iii) skeletal muscle mass index of <10.75 kg/m<sup>2</sup> for men

and  $<6.75 \text{ kg/m}^2$  for women [21]. The SMMI was calculated as follows: total skeletal muscle mass (kg)/weight (kg)  $\times 100$ . In this study, the SMMI was obtained using a body composition analyzer. Compared with traditional bioelectrical impedance analysis instruments, which can evaluate only the weight of subcutaneous fat, the IOS353 can more accurately measure muscle mass by also considering the weight of visceral fat. Moreover, this instrument has computed tomography accuracy correlation of 0.902 and dual energy X-ray absorptiometry accuracy of 0.97. To apply this device for assessment, we recruited 17 older participants with sarcopenia.

The recruitment criteria were as follows: adults aged  $\geq 60$  years who were conscious and could speak or write Mandarin or Taiwanese and whose Mini-Mental State Examination scores were greater than or equal to 21. Following an explanation of our research purposes, the data of residents who met the recruitment criteria were collected after they had agreed to participate in this study and had signed a consent form. In this study, the criteria of exclusion included any of the following: acute injury, hip joint injury, bone fracture, having received surgery, heart disease, coronary artery disease or an artificial cardiac pacemaker, mental disorder or cognitive impairment, Mini-Mental State Examination Scores of  $<21$ , and severe vision or problems of hearing.

## 2.2. Intervention Protocol

In this study, a quasi-experimental design was adopted and an intervention treatment was provided to older people with sarcopenia. This study had three stages.

### 2.2.1. The First Stage

In the pretest, physical capability was measured, daily life function was assessed, and the Pittsburgh sleep quality index (PSQI) was administered.

### 2.2.2. The Second Stage

Older people who met the recruitment criteria received a 3-month whole-body vibration training (three sessions per week). Chen et al. [22] suggested criteria for an Asian working group for sarcopenia and proposed a related intervention specific to Asian populations with the condition. Therefore, the present research was conducted based on their proposed intervention.

Participants were required to grip a handle with a sitting posture on a vibration stimulation platform. The vibration frequency was 20 Hz for weeks 1–4, 24 Hz for weeks 5–8, and 28 Hz for weeks 9–12. Participants received three sessions of training per week. In each session, a participant received ten 60-s vibration cycles and took a 30-s break between the cycles.

### 2.2.3. The Third Stage

In the posttest, physical capability was measured, daily life function was assessed, and the PSQI was administered.

During the pretest, posttest, and vibration training, older people were monitored to prevent accident occurrence. Each older adult was assisted by two research assistants with nursing backgrounds during the research processes. During the measurement processes, each participant was monitored; when a participant exhibited a balance problem, fell, or appeared tired, the activity was terminated for the participant and the participant was requested to rest; his or her blood pressure was then measured.

## 2.3. Instruments

### 2.3.1. Demographics

Demographic information included age, gender, education level, medical history, fall history, history of fractures, and frailty assessment. The frailty status of each participant was evaluated based on the Study of Osteoporotic Fractures (SOF) indicators [23]. The SOF indicators comprise only three items, including weight loss  $>5\%$  of entire body weight in a year; inability to rise five times from a

chair unassisted, and a self-reported lack of energy. Participants whose conditions matched more than two of the SOF indicators were classified as frail, those matching only one indicator were considered prefrail, and those who met none of the indicators were considered nonfrail.

### 2.3.2. Physical Capability

Edvardsson et al. [24] indicated that physical capability were crucial for objective measurement and health assessment and reflected an intervention treatment's effectiveness. Therefore, a physical capability can serve as a crucial indicator for assessing a treatment plan's effectiveness. Cesari et al. [25] indicated that biomarkers included physical capability indicators (e.g., muscle strength measurement, balance, and flexibility), physiological indicators (e.g., blood pressure and bone mineral density), and image-related indicators (e.g., computed tomography, bioelectrical impedance analysis, and dual energy X-ray absorptiometry).

Physical capability used in this study were physical function indicators, including one-foot balance, shoulder and arm flexibility, walking speed, grip strength, and five sit-stand repetitions. Chang et al.'s [18] evidence has established physical capability as an indicator of interventional treatment to people with sarcopenia. However, no intervention studies on applying whole-body vibration training to older people with sarcopenia in care facilities have been conducted. This intervention study was the first to investigate the application of whole-body vibration training to older people with sarcopenia in care facilities. The findings of this study can serve as a reference for medical staff in care facilities to provide care to older people with sarcopenia.

### 2.3.3. One-Foot Balance

The elderly adults were asked to stand on one foot while bending the knee of the other leg by approximately 90°. Next, the amount of time (measured in seconds) that the elderly adults maintained their balance was measured. The intraclass correlation coefficient (ICC) and content validity were 0.98 and 0.83, respectively [26].

### 2.3.4. Shoulder and Arm Flexibility

The elderly adults were asked to lift one of their arms above their shoulders and then move it downwards behind their back. Next, they were asked to move the other arm upwards from their waist behind their back. The distance between the two middle fingers was then measured. The same procedure was repeated by alternating the arms and the better score out of the two tests was selected as the elderly adults' upper limb flexibility. The intraclass correlation coefficient and content validity of this test were 0.83 and 0.82, respectively [27].

### 2.3.5. Walking Speed

For the test, the elderly adults were asked to sit in a chair, stand up and walk for eight feet at the sound of the signal, bypass the flagpole, and return to their seat and sit down. The amount of time that the elderly adults needed to complete the tasks were measured, which was used to evaluate their agility and ability to maintain their balance while moving. The intraclass correlation coefficient and content validity of this test were 0.98 and 0.85, respectively [27].

### 2.3.6. Grip Strength

To test the maximal force of the upper limb muscles, the participants performed static contractions by using a JAMAR hydraulic grip strength device (model J00105; Lafayette, USA); each participant used both hands in turn to grip the gripper twice, and the maximum value was recorded as the grip strength value [28]. The intraclass correlation coefficients (ICC) was 0.81 and the content validity of this test was 0.81 and 0.78 for the male and female elderly adults, respectively [27].

### 2.3.7. Five sit–Stand Repetitions

The elderly adults were asked to have their arms crossed in front of their chest and stand up from a sitting position five straight times; the amount of time (measured in seconds) that the elderly adults needed to complete the task was measured. This test allowed an evaluation of the elderly adults' lower limb muscle performance. In a functional fitness-related study, the intraclass correlation coefficient and content validity of 0.95 and 0.83, respectively [27].

### 2.4. Activities of Daily Living (ADL)

In this study, the Barthel index [29] was adopted to assess the ADL of older people in care facilities. The 10 basic ADL, including feeding, transfer, grooming, toilet use, bathing, mobility, climbing and descending stairs, dressing, bowel control, and bladder control, can be used to assess Barthel index. The perfect score on this scale was 100; a high score indicated that an older adult was more capable of ADLs. Cronbach's  $\alpha$  for the internal consistency of this scale was 0.88–0.99 [30]. The institutional population scale and the Barthel index of ADL possessed high predictive validity ( $\rho \geq 0.83$ ) and high effective reactivity [31], respectively.

#### 2.4.1. Sleep Quality

The PSQI consisted of 4 open-ended questions and 19 self-assessment questions; scores on seven components can be calculated. Buysse et al. [32] proposed the seven components were subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. A 4-point Likert scale was adopted for scoring (1 = not during the past month and 4 = three times per week). The total score was in the range 0–21. A PSQI score of 5 was the cut-off point. A total score (on the seven components) of greater than 5 indicated poor sleep quality; a total score of less than or equal to 5 indicated excellent sleep quality. The diagnosis sensitivity and specificity of the PSQI were 89.6% and 86.5%, respectively. Cronbach's  $\alpha$  for the internal consistency of the PSQI was 0.83. The 2-week test–retest reliability coefficient was 0.85–0.90 and the validity measured was 0.85 [33].

#### 2.4.2. Body Mass Index

The WHO body mass index (BMI) classifications of overweight and obesity are intended for international use, calculated as weight in kilograms divided by height in meter square ( $\text{kg}/\text{m}^2$ ). For Asian populations, BMI categories are as follows: BMI < 18.5  $\text{kg}/\text{m}^2$  underweight; 18.5 < BMI < 23  $\text{kg}/\text{m}^2$  increasing but acceptable health risk; 23 < BMI < 27.5  $\text{kg}/\text{m}^2$  increased health risk; BMI < 27.5  $\text{kg}/\text{m}^2$  high health risk [34].

#### 2.4.3. Sample Size

In this study, the participants were older people living in a nursing home in Taipei. The total number of residents in the nursing home was 223. The G-Power 3.1 software program was used to calculate the sample size. The  $\alpha$  level, power, and effect size were set as 0.05, 0.80, and 0.4, respectively, which indicated a minimum sample size of 26.

#### 2.4.4. Ethical Considerations

This study passed the review and ethical approval by the Behavioral and Social Sciences Research Ethics Office of National Taiwan University (IRB-Reference Code: 201402ES013) in Taiwan.

#### 2.4.5. Data Analysis

The data collected were coded, and the Chinese version of Statistical Product and Service Solutions for Windows version 20.0 was employed for data analysis. The Kolmogorov–Smirnov test was performed to examine whether, in the pretest, the demographic characteristics of older people with

sarcopenia in care facilities conformed to normal distribution. The results showed that the research samples did not conform to the normal distribution ( $p < 0.05$ ). Therefore, we adopted nonparametric method, the Wilcoxon test and percentage (mean and standard deviation).

### 3. Results

#### 3.1. Participants

The number of participants who met the inclusion criteria in this research were totaled 31. However, only 17 participants remained during the test as others were either discharged from the institution or withdrew from the study. Therefore, in the measurement variables calculated (via software G-POWER, model 3.1.9), the Power and alpha level were set at 0.95 and 0.05, respectively. According to the results, all of the effects were at 0.4 or above, indicating that all of the measurement variables featured favorable effects.

#### 3.2. Primary Outcome

Effect of Whole-Body Vibration Training on the Physical capability, ADL, and Sleep Quality of Older people.

##### 3.2.1. Physical Capability

**One-foot balance.** This study was performed to analyze the effect of whole-body vibration training on the one-foot balance of the participants by Wilcoxon test. A significant difference in one-foot balance was observed between before ( $M = 3.31$ ,  $SD = 7.19$ ) and after ( $M = 7.37$ ,  $SD = 12.32$ ) whole-body vibration training intervention ( $z = -2.447$ ,  $p < 0.05$ ). According to the results, whole-body vibration training increased the one-foot balance of the participants (Table 1).

**Table 1.** Pretest and posttest results regarding participants' physical capability, ADL, and sleep quality ( $n = 17$ ).

| Variable                          | Pretest<br>MEAN $\pm$ SD | Posttest<br>MEAN $\pm$ SD | z      | p Value  |
|-----------------------------------|--------------------------|---------------------------|--------|----------|
| Physical capability               |                          |                           |        |          |
| One-foot balance                  | 3.31 $\pm$ 7.19          | 7.37 $\pm$ 12.32          | −2.447 | 0.014 ** |
| Shoulder–arm flexibility          | −37.50 $\pm$ 16.34       | −28.56 $\pm$ 13.95        | −3.159 | 0.002 ** |
| walking speed                     | 36.41 $\pm$ 24.58        | 22.00 $\pm$ 17.36         | −2.692 | 0.009 ** |
| Grip strength (right hand)        | 11.19 $\pm$ 7.36         | 14.46 $\pm$ 7.48          | −3.388 | 0.001 ** |
| Grip strength (left hand)         | 12.67 $\pm$ 6.56         | 14.79 $\pm$ 7.04          | −3.264 | 0.001 ** |
| Five sit–stand repetitions        | 47.43 $\pm$ 22.98        | 30.58 $\pm$ 15.32         | −2.936 | 0.003 ** |
| ADL                               |                          |                           |        |          |
| Highly dependent: 21–60 point     | 36.67 $\pm$ 9.01         | 48.57 $\pm$ 13.13         | 1.163  | 0.006 ** |
| Moderately dependent: 61–90 point | 77.7 $\pm$ 7.58          | 73.33 $\pm$ 2.88          |        |          |
| Slightly dependent: 91–99 point   | 95 $\pm$ 0               | 95 $\pm$ 0                |        |          |
| Completely independent: 100 point | 100 $\pm$ 0              | 100 $\pm$ 0               |        |          |
| Sleep quality                     |                          |                           |        |          |
| Satisfactory sleep quality        | 3.00 $\pm$ 1.41          | 3.75 $\pm$ 2.50           | 7.367  | 0.500    |
| Unsatisfactory sleep quality      | 11.20 $\pm$ 3.34         | 10.15 $\pm$ 2.99          |        |          |

Note: Wilcoxon test: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

**Shoulder-arm flexibility.** This study was conducted to analyze the effect of whole-body vibration training on the shoulder-arm flexibility of the participants by Wilcoxon test. A significant difference in shoulder-arm flexibility was observed between before ( $M = -37.50$ ,  $SD = 16.34$ ) and after ( $M = -28.56$ ,  $SD = 13.95$ ) the whole-body vibration training ( $z = -3.159$ ,  $p < 0.05$ ). According to the results, whole-body vibration training increased the shoulder-arm flexibility of the participants (Table 1).

**Walking speed.** This study was performed to analyze the effect of whole-body vibration training on the walking speed of the participants by Wilcoxon test. A significant difference in walking speed



was observed between before ( $M = 36.41$ ,  $SD = 24.58$ ) and after ( $M = 22.00$ ,  $SD = 17.36$ ) whole-body vibration training ( $z = -2.692$ ,  $p < 0.05$ ). According to the results, whole-body vibration training increased the walking speed of the participants (Table 1).

**Right-hand grip strength.** This research analyzed the effect of whole-body vibration training on the right-hand grip strength of the participants by Wilcoxon test. A significant difference in right-hand grip strength was observed between before ( $M = 11.79$ ,  $SD = 7.36$ ) and after ( $M = 14.46$ ,  $SD = 7.48$ ) whole-body vibration training ( $z = -3.388$ ,  $p < 0.05$ ). According to the results, whole-body vibration training increased the right-hand grip strength of the participants (Table 1).

**Left-hand grip strength.** This investigation was performed to analyze the effect of whole-body vibration training on the left-hand grip strength of the participants by Wilcoxon test. A significant difference in left-hand grip strength was observed between before ( $M = 12.67$ ,  $SD = 6.56$ ) and after ( $M = 14.79$ ,  $SD = 7.04$ ) whole-body vibration training ( $z = -3.264$ ,  $p < 0.05$ ). According to the results, whole-body vibration training increased the left-hand grip strength of the participants (Table 1).

**Five sit–stand repetitions.** We conducted this research to analyze the effect of whole-body vibration training on five sit–stand repetitions performed by the participants by Wilcoxon test. Comparison between before ( $M = 47.43$ ,  $SD = 22.98$ ) and after ( $M = 30.58$ ,  $SD = 15.32$ ) whole-body vibration training showed that the participants spent significantly less amount of time in performing five sit–stand repetitions ( $z = -2.936$ ,  $p < 0.05$ ) after the training session. According to the results, whole-body vibration training enhanced the five sit–stand repetition performance of the participants (Table 1).

### 3.2.2. ADL

The respective ADL levels of the participants before and after whole-body vibration training were as follows: highly dependent,  $M = 36.67$ ,  $SD = 9.01$  and  $M = 48.57$ ,  $SD = 13.13$ ; moderately dependent,  $M = 77$ ,  $SD = 7.58$  and  $M = 73.33$ ,  $SD = 2.88$ ; slightly dependent,  $M = 95$ ,  $SD = 0$  and  $M = 95$ ,  $SD = 0$ ; completely independent  $M = 100$ ,  $SD = 0$  and  $M = 100$ ,  $SD = 0$ . According to the results, a significant difference in ADL was observed between before and after whole-body vibration training by Wilcoxon test ( $z = 1.163$ ,  $p < 0.05$ ), indicating that whole-body vibration training might improve the ADL of the participants (Table 1).

### 3.2.3. Sleep Quality

In this study, the respective sleep quality results of the participants before and after whole-body vibration training were as follows: satisfactory sleep quality,  $M = 3.00$ ,  $SD = 1.41$  and  $M = 3.75$ ,  $SD = 2.50$ ; unsatisfactory sleep quality,  $M = 11.20$ ,  $SD = 3.34$  and  $M = 10.15$ ,  $SD = 2.99$ . In this study, the effect of whole-body vibration training on participants together with the PSQI was analyzed using a nonparametric Wilcoxon test. The results showed no significant difference in sleep quality between before and after whole-body vibration training ( $z = 7.367$ ,  $p > 0.05$ ) (Table 1).

## 3.3. Secondary Outcome

### Demographic Information, Physical capability, ADL, and Sleep Quality of Older people with Sarcopenia

In this study, we collected data from 17 older people who met the sarcopenia criteria. The descriptive statistics for the demographic information of the participants are as follows: the minimum and maximum age of the participants was 66 and 95 years, respectively; 70.6% of the participants were men; the education level of most participants (64.7%) was higher than the elementary-school level, indicating that most participants were educated; most participants (76.5%) experienced diabetes; 52.9% of the participants had a history of falls; the results of the Study of Osteoporotic Fractures index showed that most participants (88.2%) were prefrail; the SMMI of male and female were 9.87 and 6.53, respectively (Table 2).

**Table 2.** Demographic information, physical capability, activities of daily living (ADL), and sleep quality of research participants (n = 17).

| Variables                               | Min   | Max   | IQR         | n  | %    |
|---|-------|-------|-------------|----|------|
| <b>Demographical Information</b>        |       |       |             |    |      |
| <b>Age</b>                              | 66    | 95    |             |    |      |
| PR25                                    |       |       | 77          | 1  | 5.9  |
| PR50                                    |       |       | 80          | 1  | 5.9  |
| PR75                                    |       |       | 87          | 2  | 11.8 |
| <b>Gender</b>                           |       |       |             |    |      |
| Male                                    |       |       |             | 12 | 70.6 |
| Female                                  |       |       |             | 5  | 29.4 |
| <b>Education level</b>                  |       |       |             |    |      |
| Illiterate                              |       |       |             | 5  | 29.4 |
| Literate                                |       |       |             | 1  | 5.9  |
| Elementary school                       |       |       |             | 3  | 17.6 |
| Junior high school                      |       |       |             | 1  | 5.9  |
| Junior college                          |       |       |             | 2  | 11.8 |
| University or above                     |       |       |             | 5  | 29.4 |
| <b>Health status (multiple choices)</b> |       |       |             |    |      |
| Diabetes                                |       |       |             | 13 | 76.5 |
| Hypertension                            |       |       |             | 3  | 17.6 |
| Received surgery recently               |       |       |             | 1  | 5.9  |
| <b>Fall history</b>                     |       |       |             |    |      |
| Yes                                     |       |       |             | 9  | 52.9 |
| No                                      |       |       |             | 8  | 47.1 |
| <b>Fracture history</b>                 |       |       |             |    |      |
| Yes                                     |       |       |             | 1  | 5.9  |
| No                                      |       |       |             | 16 | 94.1 |
| <b>Frailty assessment (SOF index)</b>   |       |       |             |    |      |
| Normal                                  |       |       |             | 2  | 11.8 |
| Prefrail                                |       |       |             | 15 | 88.2 |
| Frail                                   |       |       |             | -  | -    |
| <b>Skeletal muscle mass index</b>       |       |       |             |    |      |
| Male                                    | 6.69  | 10.60 |             |    |      |
| PR25                                    |       |       | 9.70(8.3)   | 1  | 8.3  |
| PR50                                    |       |       | 10.07(8.3)  | 1  | 8.3  |
| PR75                                    |       |       | 10.54(8.3)  | 1  | 8.3  |
| Female                                  | 6.58  | 7.48  |             |    |      |
| PR25                                    |       |       | 6.68(20.0)  | 1  | 20.0 |
| PR50                                    |       |       | 6.70(20.0)  | 1  | 20.0 |
| PR75                                    |       |       | 7.09(20.0)  | 1  | 20.0 |
| <b>Physical capability</b>              |       |       |             |    |      |
| One-foot balance (s)                    | 0.0   | 30.0  |             |    |      |
| PR25                                    |       |       | 0.0(41.2)   | 7  | 41.2 |
| PR50                                    |       |       | 2.0(23.5)   | 4  | 23.5 |
| PR75                                    |       |       | 5.0(5.9)    | 1  | 5.9  |
| Shoulder–arm flexibility (cm)           | −70.0 | −20.0 |             |    |      |
| PR25                                    |       |       | −53.0(6.3)  | 1  | 6.3  |
| PR50                                    |       |       | −30.0(18.8) | 3  | 18.8 |
| PR75                                    |       |       | −20.0(25.0) | 4  | 25.0 |
| Walking speed(s)                        | 12.9  | 93.0  |             |    |      |
| PR25                                    |       |       | 17.6(8.3)   | 1  | 8.3  |
| PR50                                    |       |       | 27.6(25.0)  | 3  | 25.0 |
| PR75                                    |       |       | 50.0(16.7)  | 2  | 16.7 |



Table 2. Cont.

| Variables                                | Min   | Max   | IQR        | n | %    |
|--|-------|-------|------------|---|------|
| Grip: Right-hand grip strength (kg)      | .0    | 27.5  |            |   |      |
| PR25                                     |       |       | 6.0(5.9)   | 1 | 5.9  |
| PR50                                     |       |       | 10.1(5.9)  | 1 | 5.9  |
| PR75                                     |       |       | 15.0(11.8) | 2 | 11.8 |
| Grip: Left-hand grip strength (kg)       | 2.0   | 25.0  |            |   |      |
| PR25                                     |       |       | 7.7(5.9)   | 1 | 5.9  |
| PR50                                     |       |       | 12.0(5.9)  | 1 | 5.9  |
| PR75                                     |       |       | 18.0(11.8) | 2 | 11.8 |
| Five sit–stand repetitions (s)           | 20.0  | 90.0  |            |   |      |
| PR25                                     |       |       | 27.0(8.3)  | 1 | 8.3  |
| PR50                                     |       |       | 36.0(8.3)  | 1 | 8.3  |
| PR75                                     |       |       | 60.0(8.3)  | 1 | 8.3  |
| Body index mass                          | 14.92 | 28.39 |            |   |      |
| PR25                                     |       |       | 19.2(5.9)  | 1 | 5.9  |
| PR50                                     |       |       | 20.9(5.9)  | 1 | 5.9  |
| PR75                                     |       |       | 23.9(5.9)  | 1 | 5.9  |
| <b>ADL</b>                               |       |       |            |   |      |
| Highly dependent (21–60 points)          | 30    | 60    |            |   |      |
| PR25                                     |       |       | 30(28.6)   | 2 | 28.6 |
| PR50                                     |       |       | 45(14.3)   | 1 | 14.3 |
| PR75                                     |       |       | 60(28.6)   | 2 | 28.6 |
| Moderately dependent (61–90 points)      | 65    | 90    |            |   |      |
| PR25                                     |       |       | 66(25.0)   | 1 | 25.0 |
| PR50                                     |       |       | 72(25.0)   | 1 | 25.0 |
| PR75                                     |       |       | 86(25.0)   | 1 | 25.0 |
| Slightly dependent (91–99 points)        | 95    | 95    | 100(100)   | 1 | 100  |
| Completely independent (100 points)      | 100   | 100   | 100(100)   | 5 | 100  |
| <b>Sleep quality</b>                     |       |       |            |   |      |
| Satisfactory sleep quality (<5 points)   | 2     | 4     |            |   |      |
| PR25                                     |       |       | 2(50.0)    | 1 | 50.0 |
| PR50                                     |       |       | 4(50.0)    | 1 | 50.0 |
| PR75                                     |       |       | -          |   |      |
| Unsatisfactory sleep quality (>5 points) | 6     | 19    |            |   |      |
| PR25                                     |       |       | 8(20.0)    | 3 | 20.0 |
| PR50                                     |       |       | 11(13.3)   | 2 | 13.3 |
| PR75                                     |       |       | 13(6.7)    | 1 | 6.7  |

The analysis results for the physical capability of the 17 participants were as follows: (a) one-foot balance of 3.31 s; (b) shoulder–arm flexibility of −37.50 cm; (c) walking speed of 36.41 s; (d) right-hand grip strength of 11.19 kg; (e) left-hand grip strength of 12.67 kg; (f) five sit–stand repetitions amounting to 47.43 times; (g) body mass index of 21.69 kg/m<sup>2</sup> (Table 2).

The Barthel index was employed to assess the ADL of the participants. The results showed that 53% of the participants were highly dependent and 29% were moderately dependent (Table 2), indicating that most of the participants needed other people's help. Additionally, the PSQI was employed to examine the sleep quality of the participants. As shown in Table 2, 77% of the participants had unsatisfactory sleep quality, indicating that most of the participants did not have excellent sleep quality (Table 2).

#### 4. Discussion

##### 4.1. Demographic Information, Physical Capability, ADL, and Sleep Quality of Older People with Sarcopenia

The results of this study suggested that most older people with sarcopenia living in care facilities are men; these results concur with those of Wu et al. [35] and Chien, Huang, and Wu [36]. Moreover,

diabetes was the most common comorbidity among the participants in the present study, followed by hypertension. Kim et al. [37] investigated 145 people aged 65 years or older with sarcopenia and found that 73% had diabetes and 56% had hypertension. Landi et al. [38] investigated 40 people aged 70 years or older with sarcopenia in nursing homes and discovered that 66% experienced hypertension and 18% experienced diabetes. Another study investigated the muscle mass of 359 older people in the general community with sarcopenia, in which 48.5% experienced hypertension and 13% experienced diabetes [39]. According to the aforementioned studies, most older people with sarcopenia experience chronic diseases, indicating the existence of comorbidities.

More than half of the participants in the present study had experienced a fall; this finding accorded with those of related studies, which have shown that older people with sarcopenia are at high risk of falling. Yamada et al. [40] investigated 414 older people with sarcopenia and revealed that most such people were worried about falls and had experienced a fall. They also discovered that falls were related to sarcopenia [40]. Regarding frailty, the present study showed that 88.2% of participants were in the early stages of frailty. According to Morley et al. [41], sarcopenia reduces muscular strength and slows walking speed, resulting in reduced activity, reduced overall calorie consumption, and increased frailty. In addition, one study indicated that sarcopenia is an expression of frailty; both sarcopenia and frailty are associated with aging of the musculoskeletal system [42].

Regarding body composition and physical fitness, average torso muscle mass (for both men and women) was  $20.58 \pm 2.83$  and walking speed was less than 0.8 m/s. The average value of shoulder–arm flexibility was less than 35 cm, and women were superior to men in this regard. The average time for one-foot standing did not exceed 5 s. The average grip strength of men was lower than 26 kg and that of women was lower than 18 kg. These results were similar to those of related studies. Yamada et al. [40] investigated 414 older people with sarcopenia and revealed that the walking speed of men was  $\leq 1.0$  m/s and that of women was  $\leq 0.8$  m/s, the flexibility of women was superior to that of men, and the average grip strength of men (22 kg) was greater than that of women (15 kg). Lee et al. [43] investigated people aged 65 years or older in Yilan County, Taiwan, and conducted a study on sarcopenia. The average torso muscle mass of men was  $22.6 \pm 3.0$  and that of women was  $16.0 \pm 2.2$ ; in addition, their walking speeds were greater than 1.0 m/s and the average grip strength of men ( $>26$  kg) exceeded that of women ( $>18$  kg) [43]. Another study investigated the body composition and physical fitness of 359 older people with sarcopenia; the walking speed of the participants exceeded 1.0 m/s and the average grip strengths of men and women exceeded 26 and 18 kg, respectively. Compared with the aforementioned studies [44,45], the walking speed, flexibility, and grip strength of the participants—older people living in care facilities—in the present study were inferior to those of older people with sarcopenia in the general community, possibly because the environmental characteristics of nursing homes and care centers differ from those of the general community. Moreover, older people living in care facilities typically do not exercise or engage in physical activity regularly, resulting in deteriorated physical fitness.

The sleep quality of older people with sarcopenia living in care facilities was analyzed. The results revealed that for most participants, sleep quality was unsatisfactory. These results accord with those of related studies, which have indicated that most older people in care facilities experienced unsatisfactory sleep quality. Lin, Su, and Chang [45] explored the sleep quality of 205 older people from four public and private nursing homes in Taipei. Among these people, 69.3% had poor sleep quality (PSQI  $> 5$ ) and 59% were dissatisfied with their sleep quality, indicating that most older people living in care facilities have unsatisfactory sleep quality.

#### *4.2. Effect of Whole-Body Vibration Training on the Physical Capability, ADL, and Sleep Quality of Older People*

In this study, after the participants received a 12-week whole-body vibration training, their one-foot balance, shoulder–arm flexibility, walking speed, grip strength, and performance in five sit–stand repetitions improved significantly. Wei et al. [19] provided whole-body vibration training for older

people with sarcopenia, who continued it for 12 weeks (three sessions per week); after the training, they found the time taken to perform five sit-stand repetitions and the speed for walking 10 m improved significantly. Researches explored the effect of 6-week whole-body vibration training on the functional fitness of 30 older women [46]. The results showed that the experimental group that received the whole-body vibration training exhibited a superior performance in flexibility, 30-sec sit and stand, one-foot standing, and sit-stand coordination compared with the control group. In other words, whole-body vibration training significantly improved the lower-limb muscle strength, alacrity, walking speed, and flexibility of older women. Other study has censored the effectiveness of whole-body vibration training provided to older people and found that whole-body vibration training obviously enhanced the lower-limb muscle strength and balance of the older people [5]. Previous studies have indicated that whole-body vibration training provides vibration-induced mechanical stimulation, which further activates the neuromuscular control system, increases the excitation and recruitment of motor units, and induces activity of synergistic and antagonistic muscles, resulting in rapid muscle contraction and enhanced muscle function and balance [47].

Following the whole-body vibration training intervention, the dependence level and risk of fall of the present study's participants significantly decreased. In other words, whole-body vibration training significantly improved the ADL function and balance of older people with sarcopenia in care facilities. The results accorded with that of related studies. Barbosa et al. [48] explored the effect of whole-body vibration training on the balance, ADL function, and quality of life of older people in care facilities. In their study, 29 older people were randomly assigned to the control group and the experimental group, which received 8-week whole-body vibration training; the ADL (Barthel index) and Berg balance scale were employed to assess the daily life function and balance of the participants. The results showed that the ADL and dependence level of the experiment group significantly improved compared with their pretest scores and the control group; in addition, the risk of falls of the experimental group decreased compared with their pretest scores and the control group.

In this study, after the intervention ended, the PSQI was employed to assess the participants' sleep quality. The results showed that their sleep quality did not significantly change. Currently, no studies on the influence of whole-body vibration training on the sleep quality of older people with sarcopenia have been conducted; however, some studies have explored the relationship between sleep quality and sarcopenia. Most studies have examined the relationship between sleep quality and factors that influenced sarcopenia (e.g., growth hormone, adrenaline, and insulin) [49,50]. No significant difference was observed for the following reasons. In the training plan for the whole-body vibration training program designed in the present study, the vibration frequency was 20 Hz in weeks 1–4, 24 Hz in weeks 5–8, and 28 Hz in weeks 9–12. The participants received three sessions of training per week. In each session, they received ten 60-s vibration cycles and were allowed a 30-s break between each pair of consecutive cycles. However, the intervention lasted only 12 weeks, indicating that sleep quality cannot improve significantly during such a short period. The sleep quality of older people has been reported to improve significantly following 6-month exercise-based interventions [51,52]. Lira et al. [53] conducted a similar study and found that the sleep quality of older people significantly might improve following a 6-month intervention but not following a 3-month intervention, indicating that long-term exercise is required to improve the sleep quality of older people. These results concur with those of Reid, Baron, Lu, Naylor, Wolfe, and Zee [54], who indicated that exercise can improve sleep quality and that the improvement becomes more significant as the period of exercise is lengthened. Therefore, a long intervention period is required to improve the sleep quality of older people significantly. We suggest that future intervention periods for whole-body vibration training should be relatively long and participants should be followed up for longer periods to understand the effects of whole-body vibration training on sleep quality in older people living in care facilities.

### 4.3. Limitations of the Study

This study was the first study that explored the effect of whole-body vibration training on the physical capability, ADL, and sleep quality of older people receiving long-term care in care facilities. Therefore, this study featured innovation and relevance. Nevertheless, this study had several research limitations. First, this study is a quasi-experimental study and adopts single-group pretest–posttest design. This design enabled the research to be conducted in a natural situation and few variables need to be controlled; however, no control group was used to compare different interventions, which was a disadvantage of this design. Meanwhile, because this research was conducted in a quasi-experimental design, the external validity had limited explanatory power to make inferences. Second, since this study measured multiple outcomes, it needed to be aware of the type-I error “prioritise these” in terms were necessary. Third, because of manpower, resource, and time limitations, the sample size was small; however, the test power was sufficient to detect differences between different conditions. Finally, WHO strongly recommends an RCT should be registered. Although this was a quasi-experimental research, it is necessary to be registered for future research.

## 5. Conclusions

This study determined that the 12-week whole-body vibration training might improve the physical capability, ADL, and sleep quality of older people in care facilities. Therefore, whole-body vibration training not only improved the one-foot balance, shoulder–arm flexibility, walking speed, grip strength, five sit–stand repetitions of these older people with sarcopenia but also enhanced their ADL and sleep quality. The result of this study might serve as a reference for nurses to provide care to older people in care facilities and for enhancing their quality of life.

**Author Contributions:** P.-C.L. and S.-F.C. developed the idea direction and the concept of the study. P.-C.L. and S.-F.C. also developed the protocol and prepared the initial manuscript. S.-F.C. revised the study protocol and provided useful insights. Moreover, P.-C.L. conducted the study and created the article draft. S.-F.C. and H.-Y.H. drafted the paper, rechecked the statistical analysis data and table format, and audited the study process. All authors have read and agreed to the published version of the manuscript.

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