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Relationship between Respiratory Muscle Strength and Static Balance in Older People Requiring Support and Care

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Abstract

Purpose: This study aimed to clarify the relationship between respiratory muscle strength and balance in older people requiring support or nursing care. **Methods:** Thirty-seven older subjects aged 65 years or older who were certified as requiring nursing care or support were included in the study. Maximal inspiratory pressure (PIMAX), maximal expiratory pressure (PEMAX), and one-leg standing time were measured. Additionally, the Functional Reach Test (FRT) was performed. Pearson correlation coefficient and multiple regression analyses were performed. **Results:** One-leg standing time was positively correlated with PEMAX, and was particularly correlated with PIMAX, while FRT score was not correlated with respiratory muscle strength. Multiple regression analysis with one-leg standing time as the dependent variable and PIMAX and PEMAX as independent variables showed that only PIMAX was significantly correlated with one-leg standing time. **Conclusion:** Focusing on expiratory and inspiratory muscle strength is important for improving one-leg standing ability and thus preventing falls in older people.

Keywords

Respiratory Muscle Strength, PIMAX, PEMAX, One-Leg Standing, Older Person

1. Introduction

Falls are one of the most problematic factors leading to the requirement for

nursing care in older people in Japan. Falls are one of the most frequent accidents, with one third of older people experiencing a fall, leading to serious illness in 20% to 30% of those experiencing falls and an increased risk of death. In addition, fractures resulting from falls cause functional disability, increased dependence in daily activities, decreased quality of life, and increased medical costs owing to prolonged hospitalization [1]. In Japan, where the population is aging at a high rate, preventing falls and reducing the number of people requiring nursing care from increasing are both urgent issues. Risk factors for falls include muscle weakness, poor balance, decreased stride length, and a history of falls, but further research is required to provide useful fall prevention strategies [1] [2] [3].

In recent years, the importance of respiratory muscle strength has become well known. Respiratory muscle strength is often evaluated by maximal inspiratory pressure (PIMAX) and maximal expiratory pressure (PEMAX). Respiratory muscle strength is positively correlated with grip strength and walking speed, which are indicators of total body muscle mass [4] [5]. Previous reports have shown that respiratory muscle strength and the strength of other skeletal muscles decline with age in older people, and that there is a marked decline in this strength in frail or pre-frail older people [6] [7]. Inspiratory muscle training contributes to an increase in muscle thickness of the diaphragm, which is important for balance [8] [9]. Balance functions, such as reactive control and dynamic gait, are improved after 8 weeks of inspiratory muscle training [10]. However, some reports have shown that inspiratory muscle training alone is not associated with functional improvements in the 6-minute walk test or maximum walking speed [11] [12]. Additionally, the relationship between balance function and respiratory muscle strength for fall prevention is unclear. Although one-leg balance in older people declines with age and frailty [13], there have been no reports on the relationship between respiratory muscle strength and one-leg balance [14] [15]. There have only been reports on the relationship between lower limb muscle strength and grip strength [16]. Although the Functional Reach Test (FRT) is widely used [16], it appears to be insufficient as an index to evaluate the risk of falling because it is an assessment that is highly affected by lower limb flexibility and muscle strength [17].

In this study, we investigated the relationship between respiratory muscle strength and balance by examining respiratory muscle strength, one-leg standing time, and FRT scores in frail older subjects who require nursing care.

2. Participants and Methods

2.1. Participants

Thirty-seven older people (age, 81.7 ± 6.0 years; height, 154.7 ± 9.6 cm; weight, 56.2 ± 11.1 kg, 15 men, 22 women) aged 65 years or older who were certified under the long-term care insurance system as requiring nursing care or support were included in the study [18]. The certification level classifications are shown in **Table 1**. The subjects were community-dwelling individuals who attended at

Table 1. Certification level classification of long-term care insurance for the subjects.

	Male	Female
Support		
Level 1	4	7
Level 2	1	7
Care		
Level 1	7	6
Level 2	3	2
Level 3	-	-
Level 4	-	-
Level 5	-	-

least one day-care rehabilitation program each week under the long-term care insurance system. Older people with considerably impaired cognitive function were excluded. Each participant signed the Declaration of Helsinki. This study was approved by the Ethics Committee of the Kanazawa Orthopedic Sports Medicine Clinic (Kanazawa-OSMC-2023-003).

2.2. Measurements

The respiratory muscle strength parameters used in this study were PIMAX and PEMAX. The Autospiro AS-507 (Minato, Osaka, Japan) was used as the measurement device. The subjects assumed a natural sitting posture and a nose clip was used to prevent breath leakage. The one-leg standing test was performed. In this test, the subjects stood facing straight ahead, and the measurement started at the moment when one of the subject's legs left the floor. In the FRT, subjects stood next to a wall with their upper limbs outstretched at a 90-degree angle to the body. The subject then was instructed to lean forward and reach forward as far as possible. An assistant then recorded the point where the fingertip reached the point of maximum forward reach as 0. Care was taken not to rotate the trunk or retract the pelvis too far.

2.3. Statistical Analysis

Pearson correlation coefficient and multiple regression analyses were used to examine respiratory muscle strength, one-leg standing time, and the FRT score. In the multiple regression analysis, PIMAX and PEMAX were independent variables with one-leg standing time as the dependent variable. A p value < 0.05 was considered statistically significant. IBM SPSS was used for analyses (Version 21.0; IBM Corp., Tokyo, Japan).

3. Results

The correlation analysis showed that one-leg standing time was positively correlated with PIMAX ($r = 0.499$, $p = 0.002$) and PEMAX ($r = 0.359$, $p = 0.029$). Ad-

ditionally, FRT score was positively correlated with PIMAX (r = 0.131, p = 0.427) and negatively correlated with PEMAX (r = −0.039, p = 0.815), but this was not significant. The results of the multiple regression analysis are shown in Table 2. The regression equation was significant (R2 = 0.205, p = 0.008). The p value was significant for PIMAX (p = 0.026), which indicated that PIMAX showed explanatory power for one-leg standing time.

4. Discussion

This study examined the relationship between respiratory muscle strength, one-leg standing, and FRT score in older patients requiring long-term care. PIMAX and PEMAX were positively correlated with one-leg standing time, and especially PIMAX showed a strong positive correlation. However, FRT score showed no significant correlation with respiratory muscle strength. The multiple regression analysis showed that PIMAX was the only variable with explanatory power for one-leg standing time.

The current finding that respiratory muscle strength was positively correlated with balance in older people who require nursing care has important implications. Most reports on health of older people have focused on the relationship of balance with lower limb muscles [14] [15]. However, the assessment of trunk muscle strength is not as easy to perform as that for lower limb muscle strength. Therefore, the relationship of balance with trunk muscles has not been clarified in detail. Respiratory muscle strength in this study was assessed by evaluating the trunk muscles because the diaphragm, abdominal muscles, and intercostal muscles in the trunk are the main active muscles. Respiratory muscle strength declines with age and weakness. Additionally, people with strong respiratory muscle strength are less likely to become frail [19]. Respiratory muscle strength is an extremely important factor in maintaining the lives of older people, and this strength has been the subject of a lot of research in recent years.

A study of PIMAX training twice a day for 8 weeks reported a considerable improvement in balance scores, such as the mini-BEST and timed up and go tests, and similar effects were obtained in other balance training programs [20]. The diaphragm increases in thickness and function with PIMAX training. The diaphragm acts in a feed-forward manner in response to rapid limb movements, stabilizing the spinal column and maintaining balance [21]. Furthermore, the diaphragm works in concert with other deep trunk muscles to increase intra-abdominal pressure, stabilize the lumbar region, and stabilize balance. In this study, the ability to perform the one-leg standing posture was considered to indicate higher

Table 2. Relationships between one-leg standing time and PIMAX and PEMAX.

	β	p value
PIMAX	0.434	0.026*
PEMAX	0.021	0.871

*p < 0.05.

PIMAX and diaphragmatic function because this test involves a rapid postural change. However, in tasks that do not involve abrupt postural changes, such as the FRT, there is no need to increase intra-abdominal pressure. Therefore, a higher FRT score is not considered to indicate a significant difference in PIMAX or diaphragmatic function.

The present study also showed a positive correlation between one-leg standing time and PEMAX. Among the trunk muscles, abdominal muscle mass decreases with age, while back muscle mass does not [22]. The skeletal muscle mass of the quadriceps and abdominal muscles also decline in frail older subjects [23]. The abdominal muscles, which assist in expiration, were likely selectively weakened compared with the back muscles, which assist in inspiration. This view is consistent with the results of a previous study that showed a positive correlation between skeletal muscle mass and PEMAX in older people requiring nursing care [24]. The frail subjects in this study with a significantly shorter one-leg standing time may also have had decreased PEMAX, which requires more abdominal muscle activity. Because the abdominal muscles are activated in PEMAX, the ability to stand on one leg is important in frail older people. Conversely, because the diaphragm activates to increase intra-abdominal pressure in PIMAX, PIMAX may be more strongly related to the ability of older people in better general condition to stand on one leg for longer periods.

A previous study showed that, compared with scores for other physical function tests, such as lower limb muscle strength, the 5-m walk test, and the timed up and go test, one-leg standing time was most affected by and declined the most with aging [25]. In the one-leg standing test, the effect of aging is particularly noticeable in the first 5 seconds of standing on one leg. Older people have less ability to shift and stabilize their center of gravity and greater movement after the center of gravity is stabilized [26]. These findings suggest that the balance function in older people is impaired owing to the difficulty of rapid and instantaneous postural control accompanied by a shift in the center of gravity. With regard to muscle strength, one-leg standing time has been shown to be positively correlated with hip flexor, extensor, and abductor muscle strength [26]. This suggests that muscle strength is more involved in one-leg standing balance than muscle mass. Surprisingly, older patients often stand on one leg for long periods of time, even if their muscle mass is clearly reduced. Therefore, in addition to the importance of muscle mass, the ability to exert muscle strength and the ability to control posture by exerting muscle strength in the trunk, lower limbs, and other parts of the body are important. Respiratory muscle strength, which was the focus of this study, is clearly involved in balance function. Further research is required to promote fall prevention in older people.

5. Limitations

In this study, the assessment of balance was performed using a static balance index, and the relationship of dynamic balance with walking and similar move-

ments was not examined. Previous studies have reported that static balance, such that measured in one-leg standing, does not correlate with dynamic balance, such as that measured in the stand-sit test and the timed up and go test [27]. Therefore, the relationship between dynamic balance and respiratory muscle strength needs to be investigated in the future. In addition, this study was limited to a single group at a single facility, there was no control group, and no comparison with lower limb muscle strength was made. Therefore, future studies need to investigate whether respiratory muscle strength or lower limb muscle strength is more related to balance.

6. Conclusion

One-leg standing time is positively correlated with PIMAX and PEMAX in older people who require support and nursing care. In particular, one-leg standing time is positively correlated with a higher PIMAX. These results suggest that PIMAX is a major factor involved in one-leg standing.

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Conflicts of Interest

The authors declare no conflicts of interest associated with this manuscript.

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