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# Differences in Balance Function Between Cancer Survivors and Healthy Subjects: A Pilot Study

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**Abstract**

Older adults who have survived cancer experience significantly more falls compared with healthy adults. Adult cancer survivors may also have a lower balance function than healthy adults. We examined muscle strength and balance function among 19 cancer survivors and 14 healthy subjects. The mean age of the cancer survivors was 51.5 ± 11.2 years; 6 men and 13 women. Cancer diagnoses included breast cancer, retroperitoneal sarcoma, acute leukemia, lung cancer, colorectal cancer, thyroid cancer, Ewing's sarcoma, and tongue cancer. The mean age of healthy subjects was 47.4 ± 14 years; 3 men, 11 women. Muscle strength was assessed using hand grip and knee extensor strength tests. Balance function was evaluated using the Timed Up and Go (TUG) test, and body sway was tested using a force platform. No significant differences were found with respect to right and left grip strength or right and left knee extension strength between the 2 groups. A significantly higher TUG time was observed in cancer survivors than in healthy subjects ($P < .05$). With eyes open, the area of the center of pressure was significantly larger in cancer survivors than in healthy subjects ($P < .05$). Similarly, the length per area was significantly lower both with eyes open and closed for cancer survivors than for healthy subjects ($P < .05$). TUG was significantly correlated with muscle strength in both groups ($P < .05$). However, no body sway parameters were related to muscle strength in either group. Cancer survivors had lower balance function that might not have been related to muscle strength. Cancer survivors should be evaluated for balance function as there is a potential for impairment. The findings of this study will be relevant for planning the prevention of falls for cancer survivors.

**Keywords**

cancer, oncology, rehabilitation, physical function, physiotherapy

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## Introduction

Breast cancer patients have a decline in balance function and postural instability 1 to 3 months after chemotherapy.[1] Falls are associated with risk factors unique to people with cancer, including peripheral neuropathy, steroid myopathy, cachexia, and deconditioning.[2,3] A recent study demonstrated less postural steadiness of cancer patients compared with age-matched controls.[4] Breast cancer patients have balance impairments and neuromuscular dysfunction from symptoms of chemotherapy-induced peripheral neuropathy.[5] Furthermore, breast cancer patients who have received chemotherapy show significantly increased postural instability compared with matched controls.[6] Previous case reports showed that cancer survivors have a decline in potential balance function after treatment is stopped and there is a need for further research in this population.[7] Another study showed that

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**Table 1.** Demographics and Clinical Characteristics in Cancer Survivors and Healthy Subjects[a].

| Characteristics | Cancer Survivors (n = 19) | Healthy Subjects (n = 14) | *P* |
|---|---|---|---|
| Age, years | 51.5 ± 11.2 | 47.4 ± 14 | .354 |
| Men, n (%) | 6 (31.6) | 3 (21.4) | .518 |
| Women, n (%) | 13 (68.4) | 11 (78.6) | |
| Height, cm | 160.1 ± 6.9 | 160.6 ± 9.7 | .856 |
| Body weight, kg | 62.4 ± 12 | 54.3 ± 17.5 | .121 |
| BMI, kg/m$^2$ | 24.3 ± 4.2 | 20.6 ± 4 | .018 |
| Diagnosis, n | | | |
| Breast cancer | 9 | | |
| Retroperitoneal sarcoma | 1 | | |
| Acute leukemia | 3 | | |
| Lung cancer | 1 | | |
| Colorectal cancer | 2 | | |
| Thyroid cancer | 1 | | |
| Ewing's sarcoma | 1 | | |
| Tongue cancer | 1 | | |
| Duration of disease (days) | | | |
| Mean ± SD | 2116 ± 1566 | | |
| Median (range) | 1517 (390-5900) | | |

Abbreviation: BMI, body mass index.
[a]Values are presented as mean ± SD unless stated otherwise. Statistical analysis at baseline was performed using an independent Student's *t* test and Pearson's $\chi^2$ test where appropriate.

breast cancer survivors have decreased muscle strength compared with healthy subjects.[8] Decreased levels of lower limb strength are associated with poor balance function in the elderly.[9,10] Therefore, it is hypothesized that the decline in balance function among cancer survivors is related to muscle strength. However, to date, there has been no research to investigate the relationship. The purpose of this study is to investigate the differences in balance function among cancer survivors and healthy subjects. Furthermore, we aimed to identify the potential loss of balance function and assess the relationship between balance function and muscle strength in these 2 groups.

## Methods

### *Study Design*

This study was a prospective, observational investigation of balance and muscle strength among cancer survivors and healthy subjects.

### *Participants and Methods*

Cancer survivors and healthy subjects were recruited in the Relay for Life Niigata in Japan in August 2017, using a poster describing the study aim regarding balance function and muscle strength assessment, which explained that cancer survivors and healthy subjects were needed for the research. Cancer survivors and healthy subjects aged 18 years or older with Eastern Cooperative Oncology Group Performance Status Score 0 or 1 were enrolled.[11] The cancer survivors had to be able to walk and carry out work without any problems, thereby having an Eastern Cooperative Oncology Group Performance Status Score of 0 or 1. Additionally, cancer survivors who could not complete muscle strength tests and balance function assessments were excluded. Consequently, 19 cancer survivors and 14 healthy subjects were included (Table 1). Cancer survivors and healthy subjects participated in one assessment session in our study. The mean ages were not significantly different: 51.5 years (±SD 11.2) for cancer survivors and 47.4 years (±SD 14) for healthy subjects. Six of 19 cancer survivors were men (31.6%) as were 3 of 14 healthy subjects (21.4%). No significant difference was observed in the men-women ratio or mean height or body weight between the 2 groups. However, body mass index was significantly higher in the cancer survivors ($P < .05$). Cancer survivor diagnoses included breast cancer, retroperitoneal sarcoma, acute leukemia, lung cancer, colorectal cancer, thyroid cancer, Ewing's sarcoma, and tongue cancer.

The Niigata University of Health and Welfare Institutional Committee on Human Research approved the study, and written informed consent was obtained from all participants.

### Timed Up and Go Test (TUG)

TUG is a reliable and valid test for quantifying functional mobility that may also be useful in monitoring clinical changes over time.[12] Furthermore, TUG also has been used to measure balance function.[13,14] TUG was performed in our study by asking the participants to sit comfortably in a chair and timing, with a stopwatch, how long it took them to stand up and walk 3 m, turn around, walk back, and sit down again.[12] The time to complete the test was recorded. Participants were asked to perform 2 TUG trials at each testing session, and the fastest of the 2 measurements in seconds was used for analysis.

### Body Sway Testing

Body sway was measured using a gravicorder force platform (GS-10, Anima Inc, Tokyo, Japan). Subjects stood for 30 seconds while looking at a round mark (3 cm in diameter) placed 2 meters in front of their eyes. Researchers ensured that the subjects looked at the mark during all measurements. The velocity of the locus of the gravity-center sway (postural sway) was recorded. The center of pressure (CoP), as the index of postural stability, was measured once using the gravicorder force platform under a 20-Hz sampling rate. Tasks were performed under 2 conditions: eyes open and eyes closed. The total length of CoP (cm), the area of CoP ($cm^2$), and length per area ($cm/cm^2$) were calculated.

### Muscle Strength

*Hand Grip Strength.* Hand grip strength (kg) was evaluated using a standard adjustable-handle dynamometer (TKK5101; Takei Scientific Instruments, Niigata, Japan) positioned at the second grip position for all subjects. The dynamometer was adjusted to each participant's hand size. During the assessment, participants were requested to stand upright with feet shoulder-width apart and look forward, with their elbows fully extended. The dynamometer was held by the testing hand with the grip meter indicator facing outward, and away from any part of the body. Participants were instructed to squeeze the grip with full force, continuously for at least 2 seconds.[15,16] Hand grip strength, measured bilaterally, was used as an index of upper limb strength.

*Knee-Extensor Muscle Strength.* Knee-extensor muscle strength (kg) was measured as an index of lower limb strength using a hand-held dynamometer (μ-TAS MT1; Anima, Tokyo, Japan). For all measurements, a stabilizing belt was used to aid the tester in applying resistance. Knee extension force was tested with subjects sitting with the knee flexed at approximately 60°. The dynamometer was applied to the anterior surface of the tibia, proximal to the malleoli. The maximum force developed during 10 seconds of static effort was recorded.

Hand grip strength and knee-extensor muscle strength were normalized to body weight and these muscle strength measurements were expressed as a percent of body weight.

### Statistical Analysis

All quantitative variables are expressed as mean ± SD unless stated otherwise. Demographic and clinical characteristics were compared using Student's $t$ test for continuous measures and Pearson's $\chi^2$ test for ordinal variables. The Student's $t$ test was used to compare hand grip and knee-extensor muscle strength based on body weight, TUG time, and body sway parameters. Statistical analysis was performed using SPSS 19.0J (SPSS Japan Inc, Tokyo, Japan) with $P$ values <.05 considered statistically significant.

## Results

Table 2 shows the mean values for muscle strength and balance function for all subjects. Both hand grip strength and left knee strength were significantly decreased in cancer survivors compared with healthy subjects ($P < .05$). No significant differences were found with respect to right knee-extension strength between the 2 groups. TUG time was significantly higher in cancer survivors ($P < .05$). With eyes open, the area of the CoP was significantly larger in cancer survivors than in healthy subjects ($P < .05$). Similarly, the length per area was significantly lower both with eyes open and closed for cancer survivors compared with healthy subjects ($P < 0.05$). However, there were no significant differences in CoP length or CoP area between the 2 groups with eyes closed.

Table 3 shows the relationship between muscle strength and balance function for cancer survivors and healthy subjects. Left hand grip strength and left knee extension strength were significantly negatively correlated with TUG results in cancer survivors ($P < .05$). Similarly, right hand grip strength and right knee extension strength were negatively correlated with TUG in healthy subjects ($P < .05$). However, there was no significant relationship between muscle strength and body sway parameters for eyes open or closed.

## Discussion

Previous studies have shown that breast cancer survivors had significantly decreased lower limb strength compared with healthy subjects,[17] although survivors of Hodgkin's lymphoma had no differences in muscle strength compared with healthy subjects.[18] In the current study, cancer survivors had significantly decreased muscle strength compared with healthy subjects.

**Table 2.** Differences in Muscle Strength and Balance Function Among Cancer Survivors and Healthy Subjects[a].

| Variables | Cancer Survivors (n = 19) | | Healthy Subjects (n = 14) | | *P* |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Right hand grip (kgf/BW) | 0.42 | 0.12 | 0.56 | 0.09 | .001 |
| Left hand grip (kgf/BW) | 0.41 | 0.11 | 0.54 | 0.06 | .000 |
| Right knee ext (kgf/BW) | 0.38 | 0.11 | 0.45 | 0.12 | .098 |
| Left knee ext (kgf/BW) | 0.36 | 0.09 | 0.44 | 0.09 | .020 |
| Timed Up and Go test (s) | 6.1 | 0.8 | 5.0 | 0.7 | .000 |
| Eyes open | | | | | |
| Length of CoP (cm) | 43.8 | 18.3 | 38.8 | 8.6 | .349 |
| Area of CoP ($cm^2$)[b] | 3.0 | 2.0 | 1.7 | 0.9 | .018 |
| Length/area ($cm/cm^2$)[b] | 17.7 | 7.9 | 26.9 | 10.6 | .007 |
| Eyes closed | | | | | |
| Length of CoP (cm) | 58.5 | 25.2 | 53.2 | 16.6 | .501 |
| Area of CoP ($cm^2$)[b] | 2.7 | 1.2 | 2.1 | 1.2 | .141 |
| Length/area ($cm/cm^2$)[b] | 22.8 | 6.8 | 29.8 | 9.9 | .033 |

Abbreviations: BW, body weight; CoP, center of pressure; ext, extension.
[a]Values are presented as mean ± SD unless. Statistical testing was performed using Student's *t* test.
[b]Area means environmental area of CoP.

**Table 3.** Correlation Between Muscle Strength and Balance Function for Cancer Survivors and Healthy Subjects[a].

| | | | Eyes Open Condition | | | Eyes Closed Condition | | |
|---|---|---|---|---|---|---|---|---|
| | | Timed Up and Go Test (Seconds) | Length of CoP (cm) | Environmental Area of CoP | Length/ Environmental Area | Length of CoP (cm) | Environmental Area of CoP | Length/ Environmental Area |
| Right hand grip (kgf/BW) | Cancer survivors | | | | | | | |
| | Healthy subjects | −0.638* | | | | | | |
| Left hand grip (kgf/BW) | Cancer survivors | −0.740** | | | | | | |
| | Healthy subjects | | | | | | | |
| Right knee ext (kgf/BW) | Cancer survivors | | | | | | | |
| | Healthy subjects | −0.616* | | | | | | |
| Left knee ext (kgf/BW) | Cancer survivors | −0.468* | | | | | | |
| | Healthy subjects | | | | | | | |

Abbreviations: CoP, center of pressure; BW, body weight; ext, extension.
[a]Statistical analysis using Pearson correlation coefficient. Only significant correlation coefficients are presented.
*$P < .05$. **$P < .01$.

Nasopharyngeal cancer survivors have been reported to have significantly shorter one-leg-stance times than healthy subjects.[19] Our study showed that cancer survivors have higher TUG times compared with healthy subjects. The TUG test assesses a person's mobility and requires both static and dynamic balance. Therefore, cancer survivors may have a decreased balance function compared with healthy subjects.

In our previous research, patients with hematological cancer had significant increases in CoP length after chemotherapy and transplantation compared with before.[20] We found a significantly larger CoP area for cancer survivors than for healthy subjects. In both the eyes open and closed conditions, cancer survivors have a significantly lower length per area than healthy subjects. These results showed that cancer survivors have impaired body sway function, but it has also been demonstrated that cancer survivors can improve sway velocity in both the eyes open and closed conditions after 13 weeks of combined aerobic and resistance training exercise.[21] Our study suggests that it may be necessary to assess balance function, including TUG time and body sway parameters using a force platform, in order to identify potential loss of balance function in cancer survivors.

Therefore, we investigated the relationship between muscle strength and balance function including TUG and the body sway test. Muscle strength tended to be related to TUG performance. It is interesting that left muscle strength was significantly related to TUG scores in the cancer survivor group, but in healthy subjects, right muscle strength was significantly related to TUG. There are no previous reports of differences in strength and TUG scores on the left and right sides in other populations. Cancer survivors

and healthy subjects may have different characteristics for muscle strength as measured by TUG. No relationship with muscle strength was observed for body sway test parameters in cancer survivors or healthy subjects. A previous study showed that hand grip strength is associated with body sway among older adults.[22] This relationship was not observed in this study due to the very small population.

### *Study Limitations*

The findings of this study should be considered in light of some limitations. First, we demonstrated differences in muscle strength and balance function between only 2 groups. The decrease of balance function in cancer survivors has some confounding factors, such as sex, age, treatment, physical activity, body fat, and somatosensory function on impaired balance function. Second, we did not have detailed clinical information for the cancer survivors; thus, we cannot investigate the differences in muscle strength and balance function by diagnosis and the effect of chemotherapy and radiation. In a future study, we will evaluate balance function in a larger group of cancer survivors and healthy subjects. Despite these limitations, we believe that the findings will be relevant in for planning rehabilitation and fall prevention for cancer survivors.

## Conclusion

Cancer survivors have significantly decreased balance function compared with healthy subjects. TUG results have a relationship with muscle strength, but the body sway test does not. These findings might be helpful for planning future studies of exercise therapies for cancer survivors. Other types of investigation may shed light on some of our puzzling results Evaluation of one-leg standing, functional reach, and the Berg balance scale would be useful to measure balance function in cancer survivors beyond the TUG and body sway tests used in this study.

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### References

1. Monfort SM, Pan X, Patrick R, et al. Natural history of postural instability in breast cancer patients treated with taxane-based chemotherapy: a pilot study. *Gait Posture*. 2016;48:237-242.
2. Wildes TM, Dua P, Fowler SA, et al. Systematic review of falls in older adults with cancer. *J Geriatr Oncol*. 2015;6:70-83.
3. Sattar S, Alibhai SM, Spoelstra SL, Fazelzad R, Puts MT. Falls in older adults with cancer: a systematic review of prevalence, injurious falls, and impact on cancer treatment. *Support Care Cancer*. 2016;24:4459-4469.
4. Schmitt AC, Repka CP, Heise GD, Challis JH, Smith JD. Comparison of posture and balance in cancer survivors and age-matched controls. *Clin Biomech (Bristol, Avon)*. 2017;50:1-6.
5. Kneis S, Wehrle A, Freyler K, et al. Balance impairments and neuromuscular changes in breast cancer patients with chemotherapy-induced peripheral neuropathy. *Clin Neurophysiol*. 2016;127:1481-1490.
6. Wampler MA, Topp KS, Miaskowski C, Byl NN, Rugo HS, Hamel K. Quantitative and clinical description of postural instability in women with breast cancer treated with taxane chemotherapy. *Arch Phys Med Rehabil*. 2007;88:1002-1008.
7. Hile ES, Fitzgerald GK, Studenski SA. Persistent mobility disability after neurotoxic chemotherapy. *Phys Ther*. 2010;90:1649-1657.
8. Harrington S, Padua D, Battaglini C, et al. Comparison of shoulder flexibility, strength, and function between breast cancer survivors and healthy participants. *J Cancer Surviv*. 2011;5:167-174.
9. Akbari M, Mousavikhatir R. Changes in the muscle strength and functional performance of healthy women with aging. *Med J Islam Repub Iran*. 2012;26:125-131.
10. Schlicht J, Camaione DN, Owen SV. Effect of intense strength training on standing balance, walking speed, and sit-to-stand performance in older adults. *J Gerontol A Biol Sci Med Sci*. 2001;56:M281-M286.
11. Oken MM, Creech RH, Tormey DC, et al. Toxicity and response criteria of the Eastern Cooperative Oncology Group. *Am J Clin Oncol*. 1982;5:649-655.
12. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc*. 1991;39:142-148.
13. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go test. *Phys Ther*. 2000;80:896-903.
14. Lin MR, Hwang HF, Hu MH, Wu HD, Wang YW, Huang FC. Psychometric comparisons of the timed up and go, one-leg stand, functional reach, and Tinetti balance measures in community-dwelling older people. *J Am Geriatr Soc*. 2004;52:1343-1348.
15. Malhotra R, Ang S, Allen JC, et al. Normative values of hand grip strength for elderly Singaporeans aged 60 to 89 years: a cross-sectional study. *J Am Med Dir Assoc*. 2016;17:864.
16. Yu R, Ong S, Cheung O, Leung J, Woo J. Reference values of grip strength, prevalence of low grip strength, and factors

affecting grip strength values in Chinese adults. *J Am Med Dir Assoc*. 2017;18:551.
17. Yee J, Davis GM, Beith JM, et al. Physical activity and fitness in women with metastatic breast cancer. *J Cancer Surviv*. 2014;8:647-656.
18. de Lima FD, Bottaro M, de Oliveira Valeriano R, et al. Cancer-related fatigue and muscle quality in Hodgkin's lymphoma survivors. *Integr Cancer Ther*. 2018;17:299-305.
19. Fong SS, Chung LM, Tsang WW, et al. Balance performance in irradiated survivors of nasopharyngeal cancer with and without Tai Chi Qigong training. *Evid Based Complement Alternat Med*. 2014;2014:719437.
20. Morishita S, Kaida K, Aoki O, et al. Balance function in patients who had undergone allogeneic hematopoietic stem cell transplantation. *Gait Posture*. 2015;42:406-408.
21. Almstedt HC, Grote S, Perez SE, Shoepe TC, Strand SL, Tarleton HP. Training-related improvements in musculoskeletal health and balance: a 13-week pilot study of female cancer survivors. *Eur J Cancer Care (Engl)*. 2017;26(2). doi:10.1111/ecc.12442.
22. Carmeli E, Imam B, Levi R, Merrick J. Hand grip strength is associated with body sway rate among older adults with intellectual disability. *J Policy Pract Intellect Disabil*. 2013;10:321-325.