Differences in Muscle Strength, Balance Function, Quality of Life, and Fatigue Levels between Cancer Survivors and Healthy Subjects: a cross-sectional study.

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Abstract
Objectives We aimed to investigate the differences as well as the relationship between muscle strength, balance function, quality of life (QOL), and fatigue in cancer survivors and healthy subjects.
Design A cross-sectional observational study.
Setting The Relay For Life Niigata in Japan
Participants Forty-one cancer survivors and 33 healthy subjects were included.
Methods Muscle strength was evaluated via handgrip and knee extensor strength. Balance function was evaluated using the Timed Up and Go (TUG) test, and body sway was tested using a force platform. QOL was assessed using the Medical Outcome Study 36-item Short-Form Health Survey. Fatigue was measured using the brief fatigue inventory.
Results Cancer survivors exhibited significantly decreased muscle strength, higher TUG, lower QOL, and higher fatigue than healthy subjects (P < 0.05). There were no significant differences between the two groups for any parameters of the body sway tests. There was a relationship between body sway test and QOL (P < 0.05) among cancer survivors. Additionally, some subscales for fatigue and QOL (P < 0.05) were related among cancer survivors; these relationships were stronger than those observed among healthy subjects.
Conclusion Cancer survivors have the same balance function as healthy subjects despite a decrease in muscle strength. Cancer survivors initially tend to have decreased muscle strength, and thereafter worse balance function.
Introduction
Accidental falls are more common among older adults with cancer than the general population, and they are associated with risk factors unique to individuals with cancer. Studies that have assessed falls in cancer patients report yearly rates that are up to two times higher than those among persons of similar ages without cancer. The risk factors associated with falls among cancer survivors include poor physical function, poor cognitive function, and impaired balance function. For older cancer survivors, falls are a significant problem and balance control is a determinant of perceived physical function and well-being. Older cancer survivors reporting a poor quality of life (QOL) in the
physical health domain may have higher risks of falling \(^5\).

One study of adult cancer survivors with peripheral neuropathy, showed that these patients had more problems with balance, a higher symptom burden, and higher levels of perceived stress \(^6\). Another previous study reported that cancer survivors exhibit decreased postural stability when compared with age-matched controls \(^7\). Cancer survivors who have undergone chemotherapy often present with decreased postural stability \(^8\). Chemotherapy-induced peripheral neuropathy may affect postural control \(^8\). Adult survivors of childhood cancer who underwent chemotherapy have been reported to experience late effects of decreased postural control which manifest as poor vision and reduced adaptation skills \(^9\). It has also been reported that cancer survivors have reduced balance function when compared to healthy subjects \(^10\). However, despite the importance of investigating balance function among cancer survivors, few studies to date have investigated this in detail.

Our previous study showed that cancer survivors have a lower QOL when compared to healthy subjects and that there was a significant relationship between muscle strength and QOL in cancer survivors \(^11\). Cancer survivors with peripheral neuropathy had decreased balance function and worse QOL scores particularly in the domain of physical functionality \(^6\). Thus, balance function may be related to QOL among cancer survivors.

The aim of this study was to investigate the differences as well as the relationship between muscle strength, balance function, QOL, and fatigue in cancer survivors and healthy subjects.

**Methods**

**Study Design**

This was a prospective, observational study of muscle strength, balance function, QOL, and fatigue in cancer survivors and healthy subjects.

**Participants and Methods**

We recruited cancer survivors and healthy subjects who participated in the Relay For Life Niigata in Japan in August 2017 and September 2018; subjects were included if they were aged 18 years or older with an Eastern Cooperative Oncology Group Performance Status Score of 0 or 1 \(^12\). In this
study, a cancer survivor was defined as per the National Cancer Institute’s definition as follows: “An individual is considered a cancer survivor from the time of diagnosis, through the balance of his/her life. Family members, friends, and caregivers are also impacted by the survivorship experience and are therefore included in this definition”\textsuperscript{13}. Additionally, cancer survivors with comorbidities who could not complete muscle strength tests and/or balance function assessments were excluded.

Subjects were defined as healthy if they had no comorbidities and were not on prescription medications. Consequently, 41 cancer survivors and 33 healthy subjects were included (Table 1), all of whom participated in one assessment session in this study. The Niigata University of Health and Welfare Institutional Committee on Human Research (Approval No. 18065-180820) approved the study, and written informed consent was obtained from all of the subjects.

Handgrip strength
Handgrip strength (kilogram of force, kgf) was measured as an index for upper limb strength using a digital dynamometer (TKK5101; TAKEI Scientific Instruments Co. Ltd., Niigata, Japan) that measures between 5.0 and 100.0 kgf with a precision of 0.1 kg. The dynamometer was adjusted to each participant’s hand size. During the assessment, participants were requested to stand upright with their feet shoulder-width apart and to 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 performed two trials for each hand alternatively, always starting with their dominant hand. Participants were instructed to squeeze the grip with full force continuously for at least 2 seconds\textsuperscript{14,15}. The maximum handgrip strength for each hand was recorded as “Handgrip strength” and was measured bilaterally. This measurement was normalized to body weight (BW) and expressed as a proportion of the subjects’ BW.

Knee-Extensor Muscle Strength
Knee-extensor muscle strength (kg) was measured as an index for 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 their knee flexed at approximately 60°. The dynamometer was applied to the anterior surface of
the tibia, proximal to the malleoli. The maximum force exerted during 10 seconds of static effort was recorded. This measurement was normalized to BW and presented as a proportion of the subjects’ BW.

Balance function
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\textsuperscript{16}. Furthermore, TUG also has been used to measure balance function\textsuperscript{17,18}. In our study, participants were asked to sit comfortably in a chair and time with a stopwatch the duration it took them to stand up, walk 3 meters (m), turn around, walk back, and sit down again\textsuperscript{16}. The time taken to complete the test was recorded. Participants were asked to perform TUG twice during each testing session, and the fastest of the two measurements was used for analysis.

Body Sway Testing
Body sway was measured using a gravicorder force platform (GS–10, Anima Inc, Tokyo, Japan) to investigate postural stability among the cancer survivors and healthy subjects. Subjects stood for 30 seconds while looking at a round mark [3 centimeters (cm) in diameter] placed 2 m away 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 for postural stability, was measured once using the gravicorder force platform under a 20-Hz sampling rate. Tasks were performed under two conditions: “eyes open” and “eyes closed.” The total length of the CoP (cm), length per time (cm/sec), length per area (cm/cm\textsuperscript{2}), environmental area of the CoP (cm\textsuperscript{2}), rectangular area of the CoP (cm\textsuperscript{2}), and root mean square (RMS) of the CoP (cm\textsuperscript{2}) were calculated.

Health-related QOL
General health-related QOL was assessed using the Medical Outcome Study 36-item Short-Form Health Survey (SF–36). This self-administered questionnaire has been widely used and validated for
the general adult population in Japan\textsuperscript{19-21}, and particularly among cancer survivors\textsuperscript{22}. Internal consistency obtained by Cronbach’s alpha exceeded 0.70 for all sub scales in cancer survivors\textsuperscript{23}. The SF-36 assesses physical and mental health components across the following eight domains: physical functioning, physical role function, bodily pain, general health, vitality, social functioning, emotional role functioning, and mental health. The SF-36 measures multidimensional properties of health-related QOL on a scale from 0-100, with higher scores indicating a better QOL.

**Brief Fatigue Inventory (BFI)**

The BFI was originally developed to assess cancer-related fatigue\textsuperscript{24}. It is a brief questionnaire consisting of nine items; it uses a numerical rating scale from 0-10. The first three items ask patients about their level of fatigue on three occasions: right now; at its usual level within the past 24 hours; and at its worst level within the past 24 hours (using extreme values of 0 for “no fatigue” and 10 for “fatigue as bad as you can imagine”). The next six items ask patients to describe how much fatigue has interfered with different aspects of their life within the past 24 hours. The aspects assessed are general activity, mood, walking ability, normal working ability (both work outside the home and daily chores), relationships with other people, and enjoyment of life. This interference scale ranges from 0 for “does not interfere” to 10 for “completely interferes.” The validity and reliability of the original BFI was established in 1999, for which the Cronbach’s coefficient alpha value was 0.96\textsuperscript{24}. Thereafter, the validity of the Japanese version of the BFI was established in 2003\textsuperscript{25}.

**Statistical analysis**

The results are presented as means ± standard deviations (SDs). We compared demographic and clinical characteristics between cancer survivors and healthy subjects using Student’s t tests for continuous variables and Pearson’s chi-squared tests for ordinal variables. Two-tailed unpaired t-tests (continuous) were used to compare handgrip and knee extensor muscle strength, balance function, and QOL between the two groups. Mann-Whitney U tests were used to compare subscales for fatigue between the two groups. Pearson’s correlation coefficients were used to evaluate the association between muscle strength, balance function, QOL, and time from diagnosis, as well as potential associations between balance function and QOL. Spearman’s rank correlation coefficients were used
to evaluate potential associations between fatigue and QOL. Statistical analysis was performed using SPSS 19.0J (SPSS Japan Inc., Tokyo, Japan). P-values <0.05 were considered statistically significant.

Results
Clinical and demographic characteristics of the enrolled subjects
Overall 74 subjects were enrolled, of which 41 (55.4%) were cancer survivors (Table 1). The mean ages (±SD) of participants in the two groups did not differ significantly. No significant difference was observed in the male-to-female ratio, mean height, BW, or body mass index (BMI) between the two groups. The diagnoses of the cancer survivors are shown Table 1. The time from cancer diagnosis of all cancer survivors was >1 year.

Strength and balance tests
Both hand grip and knee strength were significantly decreased in cancer survivors compared to the healthy subjects (P < 0.05, Table 2). Additionally, TUG time was significantly higher in the cancer survivors (P < 0.05). There were no significant differences in any of the parameters investigated in the body sway tests between cancer survivors and healthy subjects (P > 0.05), regardless of the testing conditions (i.e., eyes open or closed).

Health-related QOL
Physical functioning, physical role function, and general health were significantly lower in cancer survivors than in healthy subjects (P < 0.01, Table 3). No significant differences were observed between the two groups.

BFI
Usual fatigue was significantly higher in cancer survivors than in healthy subject (P < 0.05, Table 3). No significant differences were found in the other eight subscales of BFI between the two groups.

Associations between balance muscle strength, balance function, QOL, and fatigue, and time from cancer diagnosis
Among cancer survivors, in the “eyes open” and “eyes closed” testing conditions, CoP and length per time were significantly correlated to time from cancer diagnosis (P < 0.05). There was no significant correlation between muscle strength, other balance function, QOL, and fatigue, and time from cancer diagnosis (P > 0.05).

Associations between balance function and QOL
When cancer survivors had their eyes open, the length per environmental area, environmental area of
the CoP, rectangular area of the CoP, and RMS of the CoP were significantly correlated to physical functioning (P < 0.05, Table 4). Additionally, the length per environmental area was significantly correlated to physical role function (P < 0.05). However, the other parameters were not significantly associated with the subscales for QOL. When healthy subjects had their eyes open, the environmental area of the CoP and rectangular area of the CoP were significantly correlated to physical functioning (P < 0.05). Similarly, with their eyes closed, the length of the CoP, length per time, and environmental area of the CoP were significantly correlated to physical functioning (P < 0.05). When healthy subjects had their eyes open, the length of the CoP, length per time, environmental area of the CoP, rectangular area of the CoP, and RMS of the CoP were significantly correlated to general health (P < 0.05). For both conditions (i.e. eyes opened and closed), the environmental area of the CoP and rectangular area of the CoP were significantly correlated to emotional role function and physical role function (P < 0.05). When healthy subjects had their eyes open, the environmental area of the CoP was significantly correlated to mental health (P < 0.05).

**Associations between fatigue and QOL**

Among cancer survivors, fatigue at the moment of assessment, their usual level of fatigue, and the worst fatigue they experienced within the past 24 hours were significantly correlated to physical functioning (P < 0.05). Fatigue at the moment of assessment, usual fatigue, activity, mood, working, relationships with others, and enjoyment of life were significantly correlated to physical role function and bodily pain (P < 0.05). Fatigue at the time of assessment, usual fatigue, the worst fatigue they experienced within the past 24 hours, activity, and enjoyment of life were significantly correlated with general health (P < 0.05). Fatigue at the time of assessment, usual fatigue, the worst fatigue they experienced within the past 24 hours, activity, working, relationships with others, and enjoyment of life were significantly correlated with vitality (P < 0.05). Activity and relationships with others were significantly correlated with social functioning (P < 0.05). Activity, mood, working, relationships with others, and enjoyment of life were significantly correlated with emotional role function (P < 0.05). Activity, mood, working, and relationships with others were significantly correlated with mental health (P < 0.05). Among healthy subjects, usual fatigue, the worst fatigue they experienced within the past
24 hours, activity, walking, working, and relationships with others were significantly correlated with physical functioning (P < 0.05). Mood, relationships with others, and enjoyment of life were significantly correlated with physical role function (P < 0.05). Usual fatigue, the worst fatigue experienced within the past 24 hours, activity, and working were significantly correlated with general health (P < 0.05). Mood, walking, relationships with others, and enjoyment of life were significantly correlated with vitality (P < 0.05). Finally, mood, relationships with others, and enjoyment of life were significantly correlated with social functioning, emotional role function, and mental health (P < 0.05).

Discussion
In this study, we showed that cancer survivors had decreased muscle strength, higher TUG, lower QOL for some subscales, and higher levels of fatigue for one subscale when compared to healthy subjects. Furthermore, we found that the body sway test was significantly correlated to time from cancer diagnosis in cancer survivors and to some subscales for QOL among subjects in both groups. However, healthy subjects more frequently had subscales for QOL that were related to the body sway test parameters than cancer survivors. Conversely, some subscales for fatigue were related to subscales for QOL in both groups. The relationship between fatigue and QOL was more frequently observed among cancer survivors than healthy subjects. Our findings suggest that there are characteristic differences in physical function, balance function, QOL, and fatigue among cancer survivors and healthy subjects.

Both grip and knee extensor strength were significantly decreased in cancer survivors when compared to healthy subjects, regardless of the fact that there was no decrease in BW or BMI. Burden et al. 26 found that early-stage colorectal cancer patients had a handgrip strength that was less than 85% of the age-matched reference range. Another study showed that patients with advanced prostate cancer undergoing androgen deprivation therapy handgrip strength 29% lower than that among healthy controls 27. Furthermore, breast cancer survivors had decreased muscle strength (20%-30%) compared to healthy individuals 28. Thus, our findings were in line with those from previous studies. As cancer survivors tend to have decreased muscle strength, they should perform upper and lower extremity resistance training.
The TUG time was higher among cancer survivors when compared to healthy subjects. TUG has been used in the past to assess a person’s mobility and requires both static and dynamic balance. Our findings suggest that cancer survivors have decreased balance function for mobility when compared to healthy subjects. However, there were no significant differences in any of the parameters investigated in the body sway test, which was used to measure postural stability, between the two groups. Despite the decreased muscle strength, cancer survivors did not have decreased postural stability in this study. Few studies have investigated postural control using body sway measurements among cancer survivors and healthy subjects. One study showed that cancer survivors exhibited a greater mediolateral RMS distance and increased velocity of the CoP when compared to that of age-matched healthy subjects. Another study showed that adult survivors of childhood cancer who were treated with <12 years of chemotherapy had significantly poorer postural control when compared to healthy subjects. However, there was no significant difference in postural control between adult survivors of childhood cancer treated with >12 years of chemotherapy and healthy subjects. To date, few studies have investigated postural stability among cancer survivors; the findings on postural stability are not in agreement. Based on our findings, we believe that cancer survivors may first experience a decline in muscle strength, followed by a decline in postural stability.

This study showed that cancer survivors had a lower QOL and higher levels of fatigue for one subscale than healthy subjects. Many cancer survivors have other symptoms that may affect QOL and fatigue such as sleep dysfunction, pain, depression, and anxiety. Previous studies have shown that cancer survivors have a lower QOL than healthy subjects. One study found that cervical cancer survivors had lower physical function scores for QOL when compared to healthy subjects in the control group. Similarly, long-term cervical cancer survivors showed decreased QOL when compared to the healthy population. Finally, decreased QOL was observed among ovarian cancer survivors when compared to healthy women. Thus, our current results are consistent with those from previous studies.

Fatigue is one of the most common and distressing side effects of cancer and its treatment, and it
may persist for years after treatment completion in otherwise healthy survivors. Most cancer survivors show reduced fatigue in the first 6 months after the conclusion of treatment, and in this study, only “usual fatigue” in nine subscales showed a higher score in cancer survivors than in healthy subjects. A previous review suggested that the intensity and duration of fatigue experienced by cancer patients and survivors is significantly greater than that among healthy controls. Numerous previous studies have demonstrated increased levels of fatigue in post-treatment cancer survivors when compared to control groups. Thus, our findings are also in line with the previous reports on fatigue.

In this study, we found that balance function in the “eyes open” and “eyes closed” testing conditions, CoP, and length per time were significantly correlated to time from cancer diagnosis. These findings suggest that longer times from cancer diagnosis tend to worsen balance function. There are no previous studies showing the relationship between balance function and time from cancer diagnosis. A previous study investigated the relationship between postural stability and QOL in elderly adults; it reported that QOL could be explained by postural sway variables. For the relationship between balance function and QOL, we initially expected that cancer survivors would have a more prominent relationship between any parameter in the body sway test and QOL than the healthy subjects would. However, cancer survivors had a minimal relationship between some parameters in the body sway test and QOL when compared to healthy subjects. A previous study reported that cancer survivors have a relationship between muscle strength and QOL. Based on our findings, we confirmed that muscle strength is related to QOL in cancer survivors; however, QOL was not influenced by postural stability. Conversely, cancer survivors had a greater relationship between subscales for fatigue and QOL when compared to healthy subjects. Some studies have reported that fatigue may be related to QOL among cancer survivors. Fatigue experienced by cancer patients and survivors is significantly greater than in healthy controls and causes greater impairment in QOL. Thus, our findings are consistent with those in previously published studies. Cancer survivors’ QOL may
therefore be influenced by fatigue.

This study has some limitations. First, the statistical power of the results is limited by the small sample size. As a result of the small sample size, we could not use results from one type of cancer diagnosis, which made it difficult to interpret the findings. Thus, we need a larger sample size to determine the accuracy of our findings. Second, the sample was obtained from a local city and included only Asian individuals, thereby also limiting the ability to generalize the results. Third, we did not have detailed clinical information about the cancer survivors; thus, we could not investigate the prevalence of peripheral neuropathy following chemotherapy and radiation. Peripheral neuropathy may have influenced balance function among the cancer survivors. In future studies, neuropathy assessment should be performed in cancer survivors. Fourth, we evaluated muscle strength, balance function, and QOL/fatigue in cancer survivors with Eastern Cooperative Oncology Group performance status scores of 0 and 1 only. Cancer survivors with Eastern Cooperative Oncology Group performance status scores ranging from 2–4 are known to have worse balance function, which is greater than of the subjects enrolled in this study. In a future study, we will evaluate muscle strength, balance function, QOL, and fatigue in patients with lower performance statuses. Despite these limitations, we believe that the findings of this study will be relevant in assisting the planning of rehabilitation programs for cancer survivors, as this study is clinically meaningful. First, cancer survivors have significantly decreased muscle strength, increased TUG, lower QOL, and higher levels of fatigue compared to healthy subjects. Physicians and rehabilitation staff should recognize these findings and suggest exercises to improve muscle strength and mobility for cancer survivors. Second, we found that decreased balance function was associated with duration from cancer diagnosis. Physicians and rehabilitation staff should pay attention to decreases in balance function in long-term cancer survivors and suggest exercises to improve their balance function. Finally, cancer survivors exhibited a relationship between fatigue and QOL; previous literature, through a systematic review, has shown that physical exercise improves fatigue and QOL. Cancer survivors thus, should exercise to feel less fatigued and have improved QOL.

Conclusion
Cancer survivors have significantly decreased muscle strength, increased TUG, lower QOL, and higher levels of fatigue compared to healthy subjects. However, there were no significant differences in the body sway tests between the two groups. We found that balance function in the “eyes open” and “eyes closed” testing conditions, CoP, and length per time were positive and significantly correlated to time from cancer diagnosis. There was a relationship between the body sway tests and QOL among cancer survivors; however, these relationships were weaker than those observed among healthy subjects. Additionally, there was a relationship between fatigue and QOL among cancer survivors; this was stronger than that observed among healthy subject. Cancer survivors initially tend to experience a decrease in muscle strength, followed by a potential decrease in postural stability. These findings might be helpful for planning future studies of exercise therapies for cancer survivors. We recommend that cancer survivors should engage in physical exercise to increase muscle strength and improve mobility; in particular, long-term cancer survivors should exercise to enhance balance function. Thus, improving physical function may contribute to a better QOL and lower fatigue in cancer survivors. This was a pilot study to investigate the differences in muscle strength, balance function, QOL, and fatigue between cancer survivors and healthy subjects. In future studies, we need to establish a control using only one type of cancer diagnosis at a time interpret the findings accurately. Further, we aim to investigate the relationship between cancer treatment types and fatigue levels in cancer survivors.

Declarations

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Ethics approval and consent to participate
This pilot study was approved by the institutional review board of Niigata University of Health and Welfare (Approval No. 18065-180820) on July 11, 2017 and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants enrolled in this study.

Competing interests statement
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data sharing statement
Data will be available if requested.

AUTHOR CONTRIBUTIONS
SM: conceived the study question and contributed to the study design, supervision of data collection, data analysis and interpretation, and writing of the manuscript. SM: performed the research, analysed and interpreted the data, and revised the manuscript. RH provided clinical expertise, assisted in data collection and compiling the database, and interpreted the data. AT assisted in providing clinical expertise and data interpretation. OA assisted in data collection and providing clinical expertise. JBF, HO, TT was contributed to the study design and undertook data collection, analysis, and interpretation and writing of the manuscript. All authors have read and approved the final manuscript for publication.

Informed consent
Informed consent was obtained from all individual participants included in this study.

Consent to publish
Not applicable.

Availability of data and materials
The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.
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Tables
Table 1. Clinical and demographic characteristics of enrolled subjects

| Characteristics     | cancer survivors (n = 41) | healthy subjects (n = 33) | P-value |
|---------------------|--------------------------|--------------------------|---------|
| Age, years          | 49.6 ± 10.5              | 49.2 ± 11.7              | 0.895   |
| Men, n (%)          | 8 (20)                   | 9 (27)                   | 0.43    |
| Female              | 33 (80)                  | 24 (73)                  |         |
| Height, cm          | 160.2 ± 6.1              | 161.7 ± 7.9              | 0.378   |
| Body weight, kg     | 59.3 ± 10.5              | 56.4 ± 14.6              | 0.317   |
| BMI                 | 23.1 ± 3.9               | 21.3 ± 4.0               | 0.059   |
| Diagnosis, n (%)    |                          |                          |         |
| Breast cancer       | 22 (53.6)                |                          |         |
| Colorectal cancer   | 3 (7.3)                  |                          |         |
| Acute Leukemia      | 3 (7.3)                  |                          |         |
| Endometrial cancer  | 2 (4.9)                  |                          |         |
| Thyroid cancer      | 2 (4.9)                  |                          |         |
Lung cancer 1 (2.4)
Retroperitoneal sarcoma 1 (2.4)
Ewing's sarcoma 1 (2.4)
Tongue cancer 1 (2.4)
Cervical cancer 1 (2.4)
Ovarian cancer 1 (2.4)
Bladder cancer 1 (2.4)
Testicular cancer 1 (2.4)
Malignant lymphoma 1 (2.4)

Time from cancer diagnosis (days)
Mean (± SD) 2071 ± 2255
Median (range) 1391 (390-9640)

Values are presented as means ± standard deviations (SD) unless stated otherwise. Statistical testing at baseline was performed using independent Student's t-tests or Pearson's χ² tests.

Abbreviations: BMI = body mass index; SD = standard deviation

Table 2. Differences in muscle strength and balance function between cancer survivors and healthy subjects

| Variables                  | Cancer survivors (n = 41) | Healthy subjects (n = 33) |
|----------------------------|--------------------------|--------------------------|
|                            | Mean   | SD    | Mean   | SD    | p value |
| Right hand grip (kgf/BW)   | 0.43   | 0.11  | 0.54   | 0.09  | 0.000   |
| Left hand grip (kgf/BW)    | 0.43   | 0.11  | 0.52   | 0.09  | 0.000   |
| Right knee ext (kgf/BW)    | 0.35   | 0.11  | 0.40   | 0.12  | 0.034   |
| Left knee ext (kgf/BW)     | 0.33   | 0.10  | 0.39   | 0.09  | 0.011   |
| Timed up and go            | 5.8    | 1.1   | 5.2    | 0.9   | 0.026   |
**Eyes open condition**

|                          | Eyes open condition | Eyes closed condition |
|--------------------------|---------------------|-----------------------|
| Length of CoP (cm)       | 39.4                | 54.4                  |
| Length / time (cm/sec)   | 1.3                 | 1.8                   |
| Length / Environmental area (cm/cm²) | 40.3          | 38.5                  |
| Environmental area of CoP (cm²) | 1.7            | 2.1                   |
| Rectangle area of CoP (cm²) | 5.7             | 7.8                   |
| RMS of CoP (cm²)         | 2.2                 | 2.3                   |

Values are presented as means ± standard deviations (SD) unless otherwise noted. Statistical testing was performed using unpaired t-tests.

Abbreviations: BW = body weight; CoP = center of pressure; RMS = root mean square
Table 3 Differences Health related QOL and fatigue between cancer survivors and healthy subjects

| Variables              | Cancer survivors (n = 41) | Healthy subjects (n = 33) | p value |
|------------------------|--------------------------|---------------------------|---------|
| **Health related QOL** |                          |                           |         |
| Physical functioning   | 86.7 ± 16.1              | 94.7 ± 9.2                | 0.009   |
| Role-physical          | 79.1 ± 20.7              | 92.0 ± 14.3               | 0.002   |
| Bodily pain            | 73.6 ± 20.7              | 79.1 ± 18.9               | 0.241   |
| General health         | 55.1 ± 12.5              | 67.5 ± 17.4               | 0.001   |
| Vitality               | 56.7 ± 15.8              | 62.1 ± 17.4               | 0.166   |
| Social functioning     | 83.8 ± 18.6              | 85.6 ± 22.8               | 0.715   |
| Role-emotional         | 79.3 ± 20.1              | 87.9 ± 20.2               | 0.072   |
| Mental health          | 76.7 ± 19.6              | 82.0 ± 26.3               | 0.320   |
|                      | Mean | SD  | Mean | SD  | Mean | SD  | p    |
|----------------------|------|-----|------|-----|------|-----|------|
| Fatigue              |      |     |      |     |      |     |      |
| Fatigue right now    | 3.8  | 2.5 | 2.8  | 1.9 | 0.115|
| Usual fatigue        | 4.2  | 2.4 | 3.0  | 2.1 | 0.032|
| Worst fatigue        | 4.5  | 3.0 | 3.4  | 2.5 | 0.129|
| Activity             | 2.6  | 2.8 | 1.9  | 2.3 | 0.308|
| Mood                 | 2.5  | 2.8 | 1.8  | 2.6 | 0.209|
| Walking              | 1.5  | 2.3 | 1.0  | 2.1 | 0.247|
| Working              | 2.3  | 2.8 | 1.9  | 2.5 | 0.503|
| Relation to others   | 1.5  | 2.2 | 1.9  | 2.5 | 0.405|
| Enjoyment of life    | 2.1  | 2.6 | 1.6  | 2.4 | 0.413|

Values are presented as mean ± SD unless otherwise noted. Statistical testing was performed using unpaired t-test in QOL and Statistical testing was performed using Mann-Whitney's U test in fatigue.
Abbreviations: QOL = quality of life

Table 4 Correlations between balance function and quality of life among cancer survivors and healthy subjects

| Group                                      | Physical functioning | Role-physical | Bodily pain | General health | Vitality | Social functioning | Role-emotional |
|--------------------------------------------|----------------------|---------------|-------------|----------------|----------|--------------------|----------------|
| Timed up and go test (sec) Cancer survivors (n = 41) |                      |               |             |                |          |                    |                |
| Body Sway Testing Eyes open condition      |                      |               |             |                |          |                    |                |
| Length of CoP (cm) Cancer survivors (n = 41) |                      |               |             |                |          |                    | -0.39*          |
| Healthy subjects (n = 33)                  |                      |               |             |                |          |                    |                |
| Length / time (cm/sec) Cancer survivors (n = 41) |                      |               |             |                |          |                    |                |
|                                | Healthy subjects (n = 33) | Cancer survivors (n = 41) |
|--------------------------------|---------------------------|---------------------------|
| **Length/Environmental area (cm/cm²)** |  | -0.39* |
| Environmental area of CoP (cm²) |  | -0.31* 0.32* |
|                                | Healthy subjects (n = 33) | Cancer survivors (n = 41) |
| Rectangle area of CoP (cm²)    | -0.39* -0.48** -0.36* -0.44** |
|                                | Healthy subjects (n = 33) | Cancer survivors (n = 41) |
| RMS of CoP (cm²)               | -0.39* -0.49** -0.42* -0.36* |
| Body Sway Testing Eyes closed condition | Length of CoP (cm) | Length / time (cm/sec) | Length / Environmental area (cm/cm²) |
|----------------------------------------|-------------------|------------------------|--------------------------------------|
| Healthy subjects (n = 33)               |                   |                        |                                      |
| Cancer survivors (n = 41)               |                   |                        |                                      |
| Healthy subjects (n = 33)               | -0.38*            | -0.35*                 |                                      |
| Cancer survivors (n = 41)               |                   |                        |                                      |
| Healthy subjects (n = 33)               | -0.35*            | -0.35*                 |                                      |
| Cancer survivors (n = 41)               |                   |                        |                                      |
|                           | Cancer survivors (n = 41) | Healthy subjects (n = 33) |   |   |   |   |
|---------------------------|---------------------------|----------------------------|---|---|---|---|
| **Environmental area of CoP (cm²)** |                           | -0.38*                     | -0.50** | -0.45** |   |   |
| **Rectangle area of CoP (cm²)** |                           | -0.44**                     |   | -0.39* |   |   |
| **RMS of CoP (cm²)**       |                           | -0.50**                     | -0.45** | -0.39* |   |   |

Statistical analysis using Pearson correlation coefficient  

**p < 0.01 *p < 0.05**

Only significant correlation coefficients are presented.

Abbreviations: CoP = center of pressure; RMS = root mean square