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Functional trajectories before and after a new cancer diagnosis among community-dwelling older adults

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Abstract

Background—To characterize functional trajectories in the year before and after a new cancer diagnosis among older adults and to identify risk factors for worsening disability post-diagnosis.

Methods—We identified 170 participants 70+ years with monthly assessments of thirteen basic, instrumental, and mobility activities and with a new cancer diagnosis from 1998 to 2014. A group-based trajectory model identified distinct functional trajectories based on a total disability score during the twelve months pre- and post-diagnosis. We evaluated associations between potential risk factors at the time of cancer diagnosis and worsening disability post-diagnosis, explored functional transitions from pre- to post-diagnosis and identified participants whose functional trajectories worsened.

Results—Three pre-diagnosis functional trajectories were identified among 170 participants (mean age at diagnosis: 83 years (range: 73–105 years): mild, moderate, and severe disability. Three post-diagnosis functional trajectories were identified among 158 non-decedents: mild, moderate, and severe disability. Most participants (93.9%) with severe disability pre-diagnosis had severe disability post-diagnosis. Risk factors independently associated with worsening disability

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Conflict of Interests

Gross: 21st Century Oncology, Johnson & Johnson, Pfizer, Flatiron Health. Hurria: Novartis, Celgene, GlaxoSmithKline, GTx, Boehringer Ingelheim, on Q Health, Sanofi, OptumHealth Care Solutions, Pierian Biosciences, MJH Healthcare Holdings. Davidoff: Celgene, Boehringer Ingelheim.

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post-diagnosis included moderate or severe disability pre-diagnosis (adjusted risk ratio, aRR: moderate: 2.96; 95%CI: 2.11–4.16; severe: 5.11; 95%CI: 3.07–8.52) vs. mild (reference), poor physical capability (aRR: 1.57; 95%CI: 1.07–2.30), and incurable stage (aRR:1.99; 95%CI: 1.41–2.80). 40% of participants with a mild or moderate disability trajectory pre-diagnosis transitioned to a worse functional trajectory post-diagnosis.

Conclusion—Older adults followed distinct functional trajectories in the twelve months before and after cancer diagnosis. Functional trajectory pre-diagnosis, poor physical capability, and incurable stage were independent risk factors for worsening disability post-diagnosis.

Keywords

Functional status; Disability; Risk factors; Activities of daily living; Independent activities of daily living; Driving; Mobility

1. Introduction

By 2030, nearly two-thirds of all cancer diagnoses will be among adults aged 65 years or older [1,2]. Many oncologists consider a patient's age, Eastern Cooperative Oncology Group (ECOG) or Karnofsky performance status [3], and comorbidities when selecting treatment for older adults with cancer. However, at the time of a new cancer diagnosis, significant heterogeneity exists in functional status, which is not accounted for by age and ECOG performance status alone [4]. ECOG performance status was developed to predict toxicity, but was not designed to predict or prevent functional decline among older adults with a new cancer diagnosis [8]. More recently, geriatric-specific assessments [5–7] have been developed as management tools, which can help guide treatment for older adults with cancer [9]. However, current geriatric risk stratification tools focus solely on capturing an older adult's functional status at the time of a new cancer diagnosis [10,11] but do not incorporate the functional disability trajectory in the months preceding diagnosis. Prior work has shown that functional status changes with age and with certain types of intervening events [12–15]. Functional status is important as it could predict how well patients tolerate cancer therapy, as well as their risk for competing sources of morbidity and mortality.

Functional status is a key patient-centered outcome. It refers to the behaviors necessary to maintain independence in daily life and has been shown to be a strong predictor of both 90-day and two-year mortality post-discharge among hospitalized patients [16]. Functional disability is associated with increased mortality, loss of independent living, decreased quality of life, and considerable costs for older adults, their caregivers, and the healthcare system [17–19]. Importantly, prior work has suggested that three out of four older adults with severe disease, including cancer, would decline life-prolonging treatment if it resulted in severe functional impairment [20]. However, functional decline (i.e. worsening disability), whether transient or persistent, in older adults with cancer is a common phenomenon [21,22]. Clinical experience and research suggest that disability is a dynamic process that changes due to intervening illnesses or injuries (i.e. events) [13,23]. A new cancer diagnosis and cancer treatment are two examples of important intervening events that have yet to be evaluated in terms of their effects on functional trajectories and risk for worsening disability.

Characterizing functional trajectories, how a cancer diagnosis and treatment affect functional trajectories, and understanding risk factors for worsening disability post-diagnosis are important to improving patient centered outcomes. Among older adults with cancer, prior studies have identified associations between depression and low instrumental activity of daily living (IADL) scores and functional decline after one cycle of chemotherapy [21]. Other studies have described “functional status” among older adults with cancer, although the evaluation of functional status has often been collapsed into one general question [19] or incorporated as part of a larger global assessment of quality of life i.e. EORTC-QLQ-C30 [24]. More recently, poor functional scores, as determined by the vulnerable elders survey, and socioeconomic status were associated with functional decline twelve months after a non-metastatic breast cancer diagnosis [25]. A more nuanced approach that evaluates functional status as a disability score would deepen our understanding of the development of disability post-cancer diagnosis. In addition, none of the prior studies considered the functional trajectory prior to the cancer diagnosis. Uncertainty persists on how to correctly identify and determine whether an older adult’s functional status changes after a new cancer diagnosis given their pre-cancer diagnosis (pre-diagnosis) functional trajectory and which risk factors are independently associated with worsening disability post-cancer diagnosis (post-diagnosis).

To address these knowledge gaps, we set out to identify and characterize functional trajectories before and after a new cancer diagnosis using a thirteen-item disability score and to identify participant characteristics that are associated with worsening disability in the twelve months post-diagnosis.

2. Methods

2.1. Study Sample

We used data from the Precipitating Events Project (PEP), an ongoing longitudinal study of 754 initially nondisabled community-living adults aged 70 years or older who have been followed since 1998 to present [13]. To be eligible, participants had to be independent or “non-disabled”, defined as requiring no personal assistance, in four basic activities of daily living: bathing, dressing, walking inside the house, and transferring from a chair. Exclusion criteria included significant cognitive impairment with no available proxy, diagnosis of a terminal illness, plan to move away from the area, and language barrier (e.g. non-English speaking). This cohort has previously been described in detail [13,26,27]. The Yale Human Investigation Committee approved the study. All participants provided verbal informed consent.

2.2. Data Collection

Comprehensive geriatric home-based assessments were completed at baseline and subsequently at eighteen-month intervals, while telephone interviews were completed monthly to obtain information on disability over time. Through June 2015, fewer than 6% of all PEP participants had dropped out of the study, and 99.2% of 82,587 monthly interviews were completed. The comprehensive home-based assessments included: demographics, smoking status, chronic conditions, medications, body mass index (BMI), cognition [28],

depressive symptoms [29], physical capability as measured by the short physical performance battery (SPPB [15,30,31,32]), grip strength [15,33–35,36], mobility [37], self-efficacy [38], and social support [39]. Candidate risk factors for worsening functional disability were selected from the comprehensive home-based geriatric assessment that immediately preceded the cancer diagnosis. Incurable cancer stage was defined as stage IV disease according to the American Joint Committee on Cancer Staging manual [40].

2.3. Data Linkage

PEP participants were linked to cancer-specific information from the Connecticut Department of Public Health tumor registry and to the following Medicare fee-for-service claims files: Medicare Provider and Analysis Review (inpatient hospitalizations and skilled nursing facilities), Outpatient, and Carrier (physician and supplier services). For participants with managed Medicare, the medical record was abstracted to provide additional information regarding hospitalizations, emergency department (ED) visits, and procedures, as in prior PEP studies [26]. Cancer treatment information was ascertained from a combination of Medicare claims, tumor registry data, and chart abstraction.

2.4. Analytic Sample

PEP participants were included in the analytic sample if they had at least one new cancer diagnosis during the study period (1998–2014). For participants with more than one primary cancer diagnosis, only the first since study enrollment was included. A primary cancer diagnosis of basal cell or squamous skin carcinoma was not included. We identified 170 participants with a new cancer diagnosis from 1998 to 2014 using tumor registry data, Medicare claims data, and review of medical records [41,42]. Detailed inclusion and exclusion criteria are provided in Fig. 1. Participants were included in the trajectory modeling if they contributed 1 or more disability scores during the twelve-month follow-up period [43,44]. Twelve participants died within a month of the new cancer diagnosis and were not included in the post-diagnosis analyses.

2.5. Outcome Measures

During monthly telephone interviews, disability was assessed for twelve basic, instrumental, or mobility activities [15]. For each activity, disability was defined as the need for personal assistance or inability to perform the activity. The twelve activities included: four activities of daily living (ADLS): bathing, dressing, walking, and transferring; five independent activities of daily living (IADLS): shopping, housework, meal preparation, taking medications, managing finances; and three mobility activities: walk a quarter mile, climb a flight of stairs, or lift or carry ten pounds. An additional mobility activity was driving a car in the past month where disability was defined as not driving. The disability score was defined as the sum all thirteen activities (0–13) during each of the twelve months before and after the date of cancer diagnosis. Worsening disability post-diagnosis was defined as an increased score on the thirteen item disability scale during the twelve-month follow-up period, relative to pre-diagnosis.

2.6. Statistical Analysis

The distribution of baseline characteristics prior to the new cancer diagnosis was described in the total sample and according to pre-diagnosis functional trajectories using the chi-square test. A group-based trajectory model (SAS Proc Traj [44, 43]) was used to identify distinct functional trajectories in the twelve months immediately before and after a new cancer diagnosis, respectively. This technique fits a semiparametric (discrete) mixture model to longitudinal data using maximum-likelihood estimation [41]. For both pre- and post-diagnosis analyses, we modeled the number of disabilities each month for the twelve months before and after the date of diagnosis as a zero-inflated Poisson distribution. The Bayesian information criterion (BIC) was used to inform the optimal number of possible trajectories [45]. Posterior probability of assignment (PPA) to class membership was used to assess model fit. For both the pre- and post-diagnosis periods, a final model was selected based on statistical and clinical criteria previously described [14,46]. For the final functional trajectories, we characterized candidate risk factors for worsening disability post-diagnosis according to patients' pre- and post- diagnosis trajectory group membership using mean ($\pm$ Standard Deviation) or frequency (%), as appropriate.

We used a random intercept model to evaluate the association between candidate risk factors and the thirteen-item disability score assessed monthly during the twelve-month post-diagnosis as a Poisson outcome. In this analysis, we included the same set of pre-diagnosis risk factors captured during the twelve-month pre-diagnosis period, as described above, plus pre-diagnosis trajectories and two cancer-specific factors, the stage/curability of the cancer and receipt of treatment within twelve months post-diagnosis. Adjusted Risk Ratio (aRR) and their 95% confidence intervals (CI) were derived from the model using a robust variance estimator. As a sensitivity analysis, we refit the adjusted random intercept model using the thirteen-item disability score during the month prior to cancer diagnosis, instead of the pre-diagnosis trajectories, to define mild (score 0–2), moderate [3–6] and severe [7–13] disability.

Finally, we evaluated “transitions” from the pre-diagnosis to post-diagnosis functional trajectories by cross-tabulations, and we calculated percentages of participants who transitioned to a worse functional trajectory post-diagnosis (e.g., from mild disability trajectory pre-diagnosis to moderate or severe disabled trajectory post-diagnosis) or remained on the same functional trajectory pre- and post-diagnosis. For hypothesis-generating purposes, we compared patient characteristics according to the “transition” types using overall Chi-square test (degree of freedom = 3). For this exploratory analysis, the small number of participants who transitioned to a better trajectory (N = 7) were excluded. All analyses were performed using the SAS software (version 9.4). A two-sided P value<0.05 was considered statistically significant.

3. Results

Among 170 participants with a new cancer diagnosis, the mean age at diagnosis was 82.2 years (range: 73–105 y); 29% of the sample was 85 years, ~60% were female, and the majority were non-Hispanic white race (Table 1). The most common cancer types included genitourinary (21.8%), lung (16.5%), breast (11.2%), hematologic (11.2%),

pancreaticobiliary (9.4%), colorectal (8.8%), and gynecologic (7.1%). One third had an incurable cancer stage at diagnosis. The majority (77.2%) received treatment post-diagnosis with chemotherapy, radiation, surgery, or hormones. Surgery was the most common treatment received post-diagnosis (Appendix Table S1). Of the fourteen participants who received chemotherapy, nine had hematologic diagnoses and 50% had mild or moderate disability pre-diagnosis. Of the 36 participants who did not receive treatment, 66.7% were in the severe disability trajectory post-diagnosis. Because data on treatment was not prospectively collected, this study was unable to determine exactly why these participants were not offered treatment.

There were three distinct functional trajectories identified in the twelve months pre-diagnosis: mild disability (left panel of Fig. 2; 40.0% of participants, PPA = 0.99), moderate disability (38.8%, PPA = 0.98), and severe disability (21.2%, PPA = 1.00). The trajectory slope remained flat for participants with mild disability but increased modestly for those with moderate and severe disability. Similarly, there were three distinct functional trajectories identified in the twelve months post-diagnosis among the 158 participants who did not die within a month of their cancer diagnosis: mild (right panel of Fig. 2; 28.5%, PPA = 0.97), moderate (29.7%, PPA = 0.99), and severe (41.8%, PPA = 0.98) disability. The post-diagnosis functional trajectory slopes for each disability type remained relatively flat throughout the twelve-month follow-up period except for severe disability, which had slightly diminishing disability over the twelve-month follow-up period. Overall, 51 (32%) participants died in twelve-month follow-up period. The functional trajectories of the 51 decedents post-cancer diagnosis showed nine had moderate disability (median time to death post-cancer: 6.0 months Interquartile range (IQR): 4–8) and 42 (80%) had severe disability (median time to death: 3.0 months (IQR: 1–6)).

Participant characteristics differed across the three pre-diagnosis functional trajectories for age ≥ 85, high school education level, chronic conditions ≥ 3, low SPPB, slow gait speed, weak grip strength, low minimal status exam, depressive symptoms, and low self-efficacy (Table 2). The mean number of disabilities for each trajectory type in the month prior to cancer diagnosis was: mild disability: 0.63 (SD 1.04), moderate disability: 3.9 (SD 2.7), and severe disability: 9.1 (SD 2.9) on the thirteen-item disability scale.

Fig. 3 provides adjusted risk ratios for worsening disability scores in the twelve -month post-diagnosis follow-up period. Moderate and severe disability pre-diagnosis were significantly associated with worsening disability post-diagnosis relative to mild disability pre-diagnosis, with aRR of 2.96 (95% CI: 2.11–4.16) and 5.11 (3.07–8.52), respectively. Other significant risk factors for worsening disability post-diagnosis included poor physical capability as measured by the SPPB (aRR: 1.57; 95% CI: 1.07–2.30) and incurable stage (aRR: 1.99; 95% CI: 1.41–2.80). Depressive symptoms were also marginally associated with worsening disability post-diagnosis (aRR: 1.33 (95% CI: 0.95–1.84) $P = .09$)).

Sensitivity analyses using the 13-item disability score at the month prior to cancer diagnosis yielded comparable aRRs (3.49 (95% CI: 2.51–4.86) for moderate and 5.24 (95% CI: 3.32–8.27)) for severe disability, as defined in the statistical methods. These point estimates fall

within the 95% CI of each corresponding aRR for the functional trajectory groups, suggesting a similar association with worsening disability post-diagnosis.

Nearly all participants (93.9%) with severe disability pre-diagnosis remained severely disabled post-diagnosis (Table 3), while 52 (41.6%) of the 125 participants with mild or moderate disability trajectories pre-diagnosis transitioned to a worse functional trajectory post-diagnosis (Table 3). Of these 52 participants the majority (>50%) were female (59.6%), had low SPPB (59.6%) and weak grip strength (63.5%), and received treatment (78.8%); these characteristics differed significantly from those of participants whose trajectories were the same i.e. stable pre- and post-diagnosis. (Table 4). Additional characteristics that differed significantly between the worse and stable trajectory groups included age ≥ 85 y, slow gait speed, low MMSE, depressive symptoms, low self-efficacy, and incurable stage.

4. Discussion

In a cohort of community-dwelling older adults, we identified three distinct functional trajectories in the twelve months before and twelve months after a new cancer diagnosis, respectively. During the twelve months pre-diagnosis, 21% and 39% of the participants started at a *severe* or *moderate* level of disability, respectively, and experienced progressive disability up until the month of cancer diagnosis, while the remaining 40% of participants had mild disability. Similarly, three trajectories also emerged post-diagnosis, with minimal change in disability during the twelve -month follow-up period. Nearly all participants with severe disability pre-diagnosis remained severely disabled post-diagnosis. Model fit for each pre and post diagnosis trajectory was excellent based on a posterior probability of assignment (PPA) of 0.90 or greater. We also determined that pre-diagnosis functional trajectory, poor physical capability and incurable cancer stage were independent risk factors for worsening disability post-diagnosis. Our results demonstrate the ability to characterize distinct functional trajectories pre- and post-cancer diagnosis and to evaluate transitions between these distinct sets of functional trajectories in the setting of a new cancer diagnosis. Importantly, we were also able to identify two modifiable risk factors for worsening disability as potential targets for future intervention studies, namely poor physical capability and depressive symptoms. In addition, the sensitivity analysis suggests that characterizing disability at the month of cancer diagnosis may be as effective as using the full twelve -month disability trajectory.

Currently, insufficient information about the functional antecedents, outcomes, and prognostic determinants of a new cancer diagnosis perpetuates uncertainty in cancer treatment for a growing, highly vulnerable population of older adults with cancer [47]. Despite efforts from the cooperative oncology groups to study older adults with cancer, evidence-based guidelines are primarily based on younger and healthier patients who are entered into cancer clinical trials [1,48,49]. Only 3% of older patients are treated in cancer trials, and this percentage remains stagnant [50]. As a result, there is building, yet limited evidence about the efficacy and tolerability of cancer treatment in older adults, especially among those who are 75+ years and/or vulnerable because of comorbidities and other geriatric conditions [47,49,50]. There is even less known about the course of disability before and after a new cancer diagnosis.

Our study is one of the first to fully characterize functional trajectories. Importantly, this study suggests assessing disability at the month of cancer diagnosis can be as effective as characterizing the patient's disability course over the prior twelve -months, which oncology clinicians usually do not have in-hand at the time of a new cancer diagnosis. This finding has major implications for prospective study design. In general, incorporating functional status into clinical trial design and documenting the development/progression of disability as an important clinical outcome will greatly advance how we treat older adults with cancer. Documenting functional status using a more detailed approach, such as a thirteen-item disability scale, in addition to ECOG performance status, at the time of a new cancer diagnosis and longitudinally during cancer treatment is critical for adapting clinical trial designs to capture the development or progression of disability during the post-diagnosis period.

Geriatric oncology research designed for older adults with moderate or severe disability at the time of diagnosis, poor physical capability, as measured by the SPPB, and incurable cancer stage, is needed as we found these risk factors are independently associated with worsening disability post-diagnosis. These results will guide interventional study design for older adults with a new cancer diagnosis. For example, targeting poor physical capability with specific exercise intervention trials may be of benefit to prevent worsening disability post-diagnosis. Currently, exercise intervention trials are underutilized among older adults with cancer [51]. In addition, the presence of depressive symptoms was marginally significant. Depression has also been shown to be significantly associated with worse survival and poor prognosis, particularly among patients with lung cancer [52,53]. By understanding potential risk factors for disability among older adults with cancer, we are able to intervene in a meaningful way to either prevent or delay functional decline and loss of independent living, improving quality-of-life and healthcare utilization. In a future study, we plan to evaluate functional trajectories 24 months post-diagnosis and identify predictors of maintaining a stable functional trajectory versus developing a worse functional trajectory post-diagnosis. Our next step is to validate candidate risk factors for worsening functional disability in a prospective cohort study among older adults with lung cancer.

We found that 40% of participants with a mild or moderate disability trajectory pre-cancer diagnosis transitioned to a worse functional trajectory post-diagnosis. These findings are consistent with prior disability research [22]. and are very concerning as worsening disability has important public health implications for older adults. First, older adults are the fastest growing age group in the country and will contribute to a 45% increase in cancer incidence by 2030 [54]. If almost half of older adults will transition to a worse functional trajectory post-cancer diagnosis and the vast majority will not return to their pre-diagnosis disability status, this will place an enormous strain on patients, families, and an already stressed healthcare system. Disability in older adults has already been shown to be associated with increased mortality, loss of independent living, poorer quality of life, and considerable costs [17–19]. In an increasingly costly healthcare environment, it is critical for clinicians, payers, policymakers, and healthcare delivery systems to help older adults maintain functional status and prevent disability, particularly after a new cancer diagnosis.

This is one of the few studies to characterize functional trajectories in the 12 months before and after a new cancer diagnosis. The longitudinal design with monthly disability assessments captured functional status on a much more granular level than is possible using data on patients with cancer from the Atherosclerosis Risk in Communities [55], the Health and Retirement Study [56], or the Medicare Current Beneficiary Survey [57]. A second major strength was the ability to incorporate specific risk factors such as number of chronic conditions, cognition, social support, and physical capability often not captured in cancer-specific clinical trials. Lastly, this cohort has the advantage of using patient reported data, claims data, and tumor registry data with minimal attrition for reasons other than death over the course of the study period. Despite its strengths, this cohort study was not nationally representative and included a small, largely white, high-school educated sample, limiting its external generalizability. Very few patients improved their functional status during this study, limiting our ability to evaluate functional recovery. In addition, most participants received treatment with surgery. Future longitudinal cohort studies are needed to investigate functional status and the development/progression of disability among older adults receiving treatment with non-surgical interventions such as novel chemotherapy and immunotherapy drugs in both the curative and non-curative settings.

In conclusion, the development of worsening disability after a new cancer diagnosis is significantly influenced by an older adult's pre-diagnosis functional trajectory along with the presence of poor physical capability, an incurable cancer stage, and possibly depressive symptoms. Future research is needed to determine whether a more nuanced measurement of functional status and targeted interventions for patients with poor pre-diagnosis functional status, diminished physical capability, and/or depressive symptoms can reduce the risk of worsening disability post-cancer diagnosis.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Fig. 1.

Assembly of Analytic Sample: Medical chart review was performed on any participant with managed care coverage or any potential cancer case identified based on Medicare claims data, self-report, or a death certificate. CMS = Center for Medicare and Medicaid Services.

Fig. 2.

Functional Trajectories Before and After a New Cancer Diagnosis among Older Adults: Number and percentage of participants for each trajectory are shown in parentheses. The number of disabilities ranged from 0 to 13 based on 4 basic activities (bathing, dressing, walking inside the house, and transferring from a chair), 5 instrumental activities (shopping, housework, meal preparation, taking medications, and managing finances), and 4 mobility activities (walking a quarter mile, climbing a flight of stairs, lifting or carrying 10 pounds, and driving). The solid lines represent the unadjusted observed monthly least square means of total disability within each trajectory and the dashed lines are the predicted mean disability counts (95% CIs) based on the latent class trajectory model. The average posterior probabilities of assignment (PPA) for the trajectories before and after cancer diagnosis were both >0.9 ; whereas the Bayesian information criterion was -3417.8 for the pre-cancer and -3259.5 for the post-cancer diagnoses trajectories, respectively. Twelve (7.1% of the 170) participants who died immediately after their cancer diagnosis were not included in the post-cancer diagnosis trajectories. Of these 12, 2 (2.9% of 68) had mild disability, 7 (10.6% of 66) had moderate disability, and 3 (27.8% of 36) had severe disability pre-cancer diagnosis. The functional trajectories post-cancer diagnosis included 51 participants who died after contributing 1 or more disability scores. Of these 51, 9 had moderate disability (median time to death post-cancer: 6.0 months Interquartile range (IQR): 4–8) and 42 had severe disability (median time to death: 3.0 months (IQR: 1–6)). The decline in disability score for the severe disability trajectory post-diagnosis is attributable to differential losses to follow-up of decedents ($n = 42$) having the highest disability scores. BMI: Body mass index, low defined as < 23 . SPPB: Short physical performance battery, low defined as score < 7 . Slow gait speed defined as >10 s on the rapid gait test. Weak grip strength defined as lowest quartile for non-dominant limb based on the first 356 enrolled participants using a hand-held Chatillon 100 dynamometer. MMSE: Mini-mental status examination, low defined as score < 24 .

Fig. 3.

Risk Ratios for Worsening Disability Scores over 12 months Post-Cancer Diagnosis (N = 158 participants). Potential patient risk factors were present prior to or at the time of cancer diagnosis except for receipt of treatment, which was post-cancer diagnosis. The adjusted risk ratio (aRR) for each risk factor was derived from the multivariable random intercept Poisson model that included all the risk factors in Table 1. For the pre-cancer diagnosis trajectory, mild disability group served as the reference group for aRR of the moderate and severe disability groups. Predicted disability scores were based on the least-squared mean derived from the same longitudinal Poisson model according to the presence versus absence of each risk factors.

Table 1

Characteristics of 170 study participants.

Prior to cancer diagnosis	No.	(%) ^a
Age, mean (SD), years	82.2	(5.6)
Age ≥ 5 years	49	(28.8)
Female	101	(59.4)
Non-Hispanic white race	152	(89.4)
High school (HS) education	119	(70.0)
Current smoker	10	5.9
Chronic conditions, mean (SD)	2.3	(1.2)
Chronic conditions >3	63	(37.1)
Low BMI ^b	46	27.1
SPPB ^c score, mean (SD)	6.0	(2.9)
Low SPPB	97	(57.1)
Slow gait speed ^d	73	42.9
Weak grip strength ^e	109	64.1
MMSE ^f score, mean (SD)	26.4	(3.2)
Low MMSE score	23	(13.5)
Depressive symptoms ^g	52	30.6
Low self-efficacy ^h	73	42.9
Low social support ⁱ	36	21.2
Cancer type at diagnosis	n	%
Genitourinary	37	21.8
Lung	28	16.5
Breast	19	11.2
Hematologic	19	11.2
Pancreaticobiliary	16	9.4
Colorectal	15	8.8
Gynecologic	12	7.1
Melanoma	9	5.3
Upper GI	3	1.8
Brain	3	1.8
Head and neck	2	1.2
Musculoskeletal	2	1.2
Unknown	5	2.9

^aData are given as number (percentage) of participants unless otherwise indicated.^bBody mass index, low defined as < 23.^cShort physical performance battery, low defined as score < 7.

^d Slow gait speed defined as >10 s on the rapid gait test.

^e Weak grip strength defined as lowest quartile for non-dominant limb based on the first 356 enrolled participants using a hand-held Chatillon 100 dynamometer.

^f Mini-mental status examination, low defined as score < 24.

^g Depressive symptoms defined as Center for Epidemiologic Studies Depression Scale score ≥ 16.

^h Low self-efficacy defined as score ≤ 27 on the modified activities of daily living efficacy scale.

ⁱ Modified version of Medical Outcomes Study social support survey, low defined as score ≤ 18.

Table 2

Characteristics of study participants (N = 170) according to functional trajectory pre-cancer diagnosis.

Characteristic ^a	Pre-cancer diagnosis functional trajectory						P-value ^b
	Mild (N = 68)		Moderate(N = 66)		Severe (N = 36)		
	n	%	n	%	n	%	
Age 85 y	13	19.1	16	24.2	20	55.6	<0.001
Female	40	58.8	34	51.5	27	75.0	0.069
Non-Hispanic White Race	59	86.8	59	89.4	34	94.4	0.480
High School Education	55	80.9	47	71.2	17	47.2	0.002
Current smoker	5	7.4	3	4.6	2	5.6	0.784
Chronic conditions 3	17	25.0	29	43.9	17	47.2	0.028
Low BMI ^c	16	23.5	18	27.3	12	33.3	0.563
Low SPPB ^d	22	32.4	41	62.1	34	94.4	<0.001
Slow gait speed ^e	10	14.7	31	47.0	32	88.9	<0.001
Weak grip strength ^f	30	44.1	50	75.8	29	80.6	<0.001
Low MMSE ^g	3	4.4	7	10.6	13	36.1	<0.001
Depressive symptoms ^h	15	22.1	22	33.3	15	41.7	<0.001
Low self-efficacy ⁱ	10	14.7	34	51.5	29	80.6	<0.001
Low social support ^j	14	20.6	15	22.7	7	19.4	0.917

^a Includes only characteristics for candidate risk factors for worsening disability postdiagnosis.

^b Derived from chi-square test on the overall differences across the 3 trajectory groups (df = 2).

^c Body mass index, low defined as < 23.

^d Short physical performance battery, low defined as score < 7.

^e Slow gait speed defined as >10 s on the rapid gait test.

^f Weak grip strength defined as lowest quartile for non-dominant limb based on the first 356 enrolled participants using a hand-held Chatillon 100 dynamometer.

^g Mini-mental status examination, low defined as score < 24.

^h Depressive symptoms defined as Center for Epidemiologic Studies Depression Scale score ≥ 16.

ⁱ Low self-efficacy defined as score ≤ 27 on the modified activities of daily living efficacy scale.

^j Modified version of Medical Outcomes Study social support survey, low defined as score ≤ 18.

Table 3

Transitions between Functional Trajectories Pre- and Post-Cancer Diagnosis, n (%).

Pre-cancer diagnosis (N = 170 ^a)	Post-cancer diagnosis (N = 158)		
	Mild disability n = 45 (row %)	Moderate disability n = 47 (row %)	Severe disability n = 66 (row %)
Mild disability ^b	40	17	9
n = 66	(60.6)	(25.8)	(13.6)
Moderate disability ^b	5	28	26
n = 59	(8.5)	(47.5)	(44.1)
Severe disability ^b	0	2	31
n = 33	(0.0)	(6.1)	(93.9)

^aOf the 170 participants pre-cancer diagnosis, 12 (7%) died before their first interview post-cancer diagnosis and thus are not included in these results. Of these 12 participants, 2 were in mild disability, 7 moderate disability, and 3 in severe disability trajectory pre-diagnosis.

^bRow percentages.

Table 4

Characteristics of participants who transitioned to a worse functional trajectory vs. maintained a stable functional trajectory pre- and post-cancer diagnosis.

Transition	Worse Trajectory		Stable Trajectory						
Risk Factor	Total N = 52		Mild Disability N = 40		Moderate Disability N = 28		Severe Disability N = 31		P-value ^a
	n	%	n	%	n	%	n	%	
Age 85 y	11	21.2	8	20.0	7	25.0	19	61.3	<0.001
Female	31	59.6	25	62.5	10	35.7	25	80.6	0.006
Non-Hispanic White	8	15.4	6	15.0	2	7.1	2	6.5	0.485
Race									
<High School	14	26.9	8	20.0	9	32.1	15	48.4	0.068
Education									
Current smoker	2	3.8	3	7.5	1	3.6	2	6.5	0.837
Chronic conditions 3	20	38.5	8	20.0	12	42.9	14	45.2	0.098
Low BMI ^b	14	26.9	10	25.0	5	17.9	11	35.5	0.492
Low SPPB ^c	31	59.6	9	22.5	15	53.6	29	93.5	<0.001
Slow gait speed ^d	20	38.5	5	12.5	12	42.9	28	90.3	<0.001
Weak grip strength ^e	33	63.5	15	37.5	20	71.4	26	83.9	<0.001
Low MMSE ^f	4	7.7	3	7.5	3	10.7	12	38.7	<0.001
Depressive symptoms ^g	17	32.7	6	15.0	10	35.7	14	45.2	0.045
Low self-efficacy ^h	22	42.3	4	10.0	12	42.9	26	83.9	<0.001
Low social support ⁱ	12	23.1	9	22.5	6	21.4	6	19.4	0.092
Incurable stage	24	46.2	2	5.0	5	17.9	12	38.7	<0.001
Received Treatment	41	78.8	36	90.0	25	89.3	15	48.4	<0.001

Of the 158 participants with post-diagnosis trajectories, 7 who transitioned to an improved trajectory were excluded due to small number.

^aP-value derived from overall chi-square test (df = 3) of distributional difference across the 4 groups.

^bBody mass index, low defined as < 23.

^cShort physical performance battery, low defined as score < 7.

^dSlow gait speed defined as >10 s on the rapid gait test.

^eWeak grip strength defined as lowest quartile for non-dominant limb based on the first 356 enrolled participants using a hand-held Chatillon 100 dynamometer.

^fMini-mental status examination, low defined as score < 24.

^gDepressive symptoms defined as Center for Epidemiologic Studies Depression Scale score ≥ 16.

^hLow self-efficacy defined as score ≤ 27 on the modified activities of daily living efficacy scale.

ⁱModified version of Medical Outcomes Study social support survey, low defined as score ≤ 18.