Daily functioning in glioma survivors: associations with cognitive function, psychological factors and quality of life

Kathleen Van Dyk*,1,2, Lucy Wall1, Brandon F Heimberg1, Justin Choi3, Catalina Raymond4,5, Chencai Wang4,5, Albert Lai2,3, Timothy F Cloughesy2,3, Benjamin M Ellingson1,2,4,5 & Phioanh Nghiemphu2,3

1Department of Psychiatry & Biobehavioral Sciences, Semel Institute for Neuroscience & Human Behavior, University of California Los Angeles, Los Angeles, CA 90024, USA
2Jonsson Comprehensive Cancer Center, University of California Los Angeles, Los Angeles, CA 90024, USA
3Department of Neurology, David Geffen School of Medicine, University of California Los Angeles, Los Angeles, CA 90024, USA
4UCLA Brain Tumor Imaging Laboratory (BTIL), Center for Computer Vision & Imaging Biomarkers, David Geffen School of Medicine, University of California Los Angeles, Los Angeles, CA 90024, USA
5Department of Radiological Sciences, David Geffen School of Medicine, University of California Los Angeles, Los Angeles, CA 90024, USA

*Author for correspondence: KVanDyk@mednet.ucla.edu

Aim: Understanding and supporting quality of life (QoL) and daily functioning in glioma patients is a clinical imperative. In this study, we examined the relationship between cognition, psychological factors, measures of health-related QoL and functioning in glioma survivors.

Materials & methods: We examined neuropsychological, self-reported cognition, mood and QoL correlates of work and non-work-related daily functioning in 23 glioma survivors, and carried out linear models of the best predictors.

Results & conclusion: A total of 13/23 participants were working at the time of enrollment. The best model for worse work-related functioning (R² = .83) included worse self-reported cognitive function, depression, loneliness and brain tumor symptoms. The best model for worse non-work-related functioning (R² = .61) included worse self-reported cognitive functioning, anxiety, sleep disturbance and physical functioning. Neuropsychological variables were not among the most highly correlated with function. Worse cognitive, particularly self-reported and psychosocial outcomes may compromise optimal functioning in glioma survivors.

First draft submitted: 5 January 2022; Accepted for publication: 7 April 2022; Published online: 18 May 2022

Keywords: cancer • daily functioning • employment • function • glioma • quality of life • survivorship

Malignant gliomas are neuroepithelial tumors with recent US incidence rates of approximately 4.8 per 100,000 [1]. Lower grade glioma (LGG) survivors in particular benefit from more favorable outcomes compared with other tumor types and comprise approximately 40% of all glioma diagnoses [2]. LGG tends to occur in younger ages compared with other brain tumors and have better overall survival rates with some reports of survival up to 20 years [2,3]. Given the relatively higher likelihood of survival for years after treatment, understanding how to support quality of life (QoL) and daily functioning in glioma survivors, especially LGG, is a clinical imperative receiving growing attention [4–7].

Resuming normal activities in glioma survivorship is critical to QoL [8]. Unfortunately, the survivorship phase is often etched with disruptive cognitive and functional impairments; 30–50% of survivors encounter significant cognitive and functional impairment after treatment and it is one of the most concerning outcomes for patients [9–12]. Even though it is less likely that patients will suffer from more severe cognitive impairment seen in faster growing tumors, even mild cognitive changes can have a profound impact on higher-level functional goals [13,14]. For instance, approximately half of LGG survivors return to work after treatment [15]. Cognitive and other changes...
threaten glioma survivors’ ability to carry out complex daily life activities and limit the ability to return to work and fill meaningful and important roles [4–7,16,17].

To help elucidate key factors related to functioning in glioma survivorship, including LGG, we conducted a study of cognition, psychological factors, QoL and functioning in glioma survivors. We grounded our approach in the more developed extant literature available in the parallel field of non-CNS cancer survivors and assembled an extensive neuropsychological and psychosocial battery of measures. In this preliminary report of the first sample of recruited patients, we aimed to understand contributing factors to work and non-work-related daily functioning.

Materials & methods
Sample & study design
This is a cross-sectional observational study of cognitive and psychosocial functioning in glioma survivors. Participants with a history of glioma were recruited from the UCLA Neuro-Oncology clinic. Eligible participants were over the age of 18, had at least 5th grade proficiency in English, and had completed treatments (i.e., surgery, radiation and/or chemotherapy) at least 6 months prior to enrollment. They also must have had a Karnofsky performance status >60%, be able to undergo MRI and pregnant women were excluded.

Enrolled participants underwent same-day research evaluations added on to clinical follow-up appointments. Participants completed a self-report questionnaire framed in biopsychosocial theory, as well as a targeted battery of neuropsychological tests, detailed below. This study also involved extended neuroimaging with fMRI in addition to clinical structural scans, which are not included in the current report. This study was approved by the UCLA Institutional Review Board and all participants signed informed consent.

Neuropsychological & psychosocial measures
Dependent variables
Daily functioning was measured using the work productivity and activity impairment (WPAI) instrument [18], which yields continuous scores for how much the participant’s brain tumor affected: work productivity; and non-work ability or functioning outside the workplace. Scores range from 1 to 10 and are converted into percentages, with higher scores indicating more functional impairment.

Independent variables
The neuropsychological test battery was selected in consideration of expert recommendations for assessment patients with a primary brain tumor, International Cognition and Cancer Task Force recommendations and authors’ clinical experience [19,20]. The battery included the following measures: test of premorbid functioning [21]; The Hopkins Verbal Learning Test – Revised [22]; The Brief Visuospatial Memory Test – Revised [23]; The Trail-Making [24,25]; Wechsler Adult Intelligence Scale-IV [26] Coding and Digit Span subtests; The Connor’s Continuous Performance Test–II [27]; The Golden Stroop [28]; Verbal fluency – FAS and animal naming [29]; The Boston Naming Test [30]; and The Rey–Osterrieth complex figure [31]. Raw scores were transformed into standard scores using published normative data.

Subjective cognitive functioning was assessed using the functional assessment of cancer therapy-cognitive function (FACT-Cog) version 3 [32,33]. The FACT-Cog yields four sub scores derived from items using a 5-point Likert scale to rate impairment: perceived cognitive impairment; perceived cognitive ability; comments from others; and impact on QoL. Depression symptoms were assessed using the Beck depression inventory-2nd edition [34], anxiety using the Beck Anxiety Inventory [35] and trauma symptoms were evaluated using the revised Impact of Event Scale [36]. We measured sleep disturbance using the Pittsburgh Sleep Quality Index [37], with missing values replaced by the mean of completed items [38]. Fatigue was assessed using the multidimensional fatigue symptom inventory – short form [39].

Health-related QoL was measured using the FACT-brain, a global QoL measure for cancer survivorship that also incorporates items specific to the brain tumor population [40]. This scale yields the subscales physical well-being, social/family well-being, emotional well-being, functional well-being, the brain cancer subscale and a total. In order to avoid confounds with the outcome (i.e., functioning), we did not include the functional well-being or total in analyses.

Analytic approach
Simple demographic information was summarized for the sample (see Table 1). We also compared those who
Table 1. Demographic characteristics of study population.

| Characteristic                        | Total sample (n = 23) |
|--------------------------------------|-----------------------|
|                                      | n         | Percent |
| Age, years                           |           |         |
| Mean                                 | 44.26     |         |
| SD                                   | 12.24     |         |
| Education                            |           |         |
| Mean                                 | 16.04     |         |
| SD                                   | 1.77      |         |
| Time since surgery, years            |           |         |
| Mean                                 | 7.60      |         |
| SD                                   | (5.06)    |         |
| Intelligence quotient (IQ)           |           |         |
| Mean                                 | 104.96    |         |
| SD                                   | 12.33     |         |
| Gender                               |           |         |
| Male                                 | 15        | 34.8    |
| Female                               | 8         | 65.2    |
| Race                                 |           |         |
| White, non-Hispanic                  | 21        | 91.3    |
| African–American                     | 1         | 4.3     |
| Asian                                | 1         | 4.3     |
| Employment status                    |           |         |
| Full or part-time                    | 10        | 43.5    |
| Not employed                         | 13        | 56.5    |
| Tumor location                       |           |         |
| Left frontal                         | 5         | 21.7    |
| Left occipital                       | 1         | 4.3     |
| Left parietal                        | 1         | 4.3     |
| Left temporal                        | 4         | 17.4    |
| Right frontal                        | 6         | 26.1    |
| Right frontal temporal               | 1         | 4.3     |
| Right occipital                      | 1         | 4.3     |
| Right parietal                       | 2         | 8.7     |
| Right temporal                       | 1         | 4.3     |
| Subcortical                          | 1         | 4.3     |
| IDH mutant                           |           |         |
| Yes                                  | 15        | 65.2    |
| No                                   | 3         | 13      |
| N/A                                  | 4         | 17.4    |
| Missing                              | 1         | 4.3     |
| Radiation therapy                    |           |         |
| Yes                                  | 21        | 91.3    |
| No                                   | 2         | 8.7     |
| Chemotherapy                         |           |         |
| Yes                                  | 21        | 91.3    |
| No                                   | 2         | 8.7     |
| Chemotherapy type                    |           |         |
| PCV, tamoxifen                       | 1         | 4.3     |
| TMZ/PCV/CCNU/procarb/vincristine     | 1         | 4.3     |

AA: Anaplastic astrocytoma; AOA: Anaplastic oligoastrocytoma; AOG: Anaplastic oligodendrogliomas; CCNU: Lomustine; GBM: Glioblastoma; LA: Low grade astrocytoma; LO: Low grade oligodendroglioma; PCV: Procarbazine + Lomustine + Vincristine chemotherapy; PPA: Pilocytic astrocytoma; PXA: Pleomorphic xanthoastrocytoma; SD: Standard deviation; TMZ: Temozolomide (Temodar).
were still working to those who stopped working on neuropsychological and self-report outcomes using \( t \)-tests (see Table 2). For descriptive purposes, we identified those with cognitive impairment defined as having more than two tests >-2 z-score compared with normative data, consistent with International Cognition and Cancer Task Force guidelines accounting for the number of tests in the battery [19,41]. We took a two-step approach toward modeling WPAI work productivity (among those still working) and WPAI non-work ability (among the entire sample. First, preliminary correlations were conducted to identify relevant correlates to include in the models (see Table 3). We then conducted two exploratory linear regression models of WPAI Work Productivity and WPAI non-work ability to evaluate the magnitude of effects (see Table 4). Since this is a small sample we minimized the number of predictors to four in each model [42]. We also examined model diagnostics to ensure <5% of standardized residuals were greater than 1.96. All analyses were conducted using IBM SPSS Statistics for Mac software, v. 24. (IBM Corp., NY, USA).

Results
We recruited 24 gliomas survivors for the study. Participants had various glioma diagnoses, predominantly lower grade, including anaplastic astrocytoma (AA; 5/23), anaplastic oligoastrocytoma (AOA; 3/23), anaplastic oligodendroglial gliomas (AOG; 2/23), anaplastic mixed glioma (1/23), glioblastoma (GBM; 4/23), low grade astrocytoma (LA; 4/23), low grade oligodendroglioma (LO; 2/23), pilocytic astrocytoma (PPA; 1/23) and pleomorphic xanthoastrocytoma (PXA; 1/23). Broadly, participants were more likely to be positive for the IDH mutation, with nearly half of participants with frontal tumor location (11/23). Participants were also likely to have received radiation therapy (21/23) and chemotherapy (21/23), with TMZ adjuvant as the most common type (18/23). One participant was excluded for low English fluency detected during testing. The analytic sample included 23 participants, demographic and clinical characteristics displayed in Table 1. In general, the sample was mostly male, White, with an average estimated verbal IQ. At the time of this study, 13 participants were currently working; 11 reported no change in employment and two had reduced their time at work. Ten participants were not working, of which seven reported they had stopped working due to the brain tumor. Table 2 displays comparisons on neurocognitive and psychosocial factors between those currently working and those not working (neuropsychological scores are summarized in Supplementary Table 1). No differences were observed on neurocognitive outcomes between those working and those not working. Compared with working survivors, those not currently working reported higher levels of anxiety, worse perceived cognitive impairment, worse emotional well-being, worse symptoms related to brain cancer and lower sense of self-efficacy (\( p < .05 \)). Mean WPAI work productivity scores were 18.46% (±23.75) among the 13 working and mean WPAI non-work ability scores were 22.17% (±27.13%), with higher percentages indicating greater impairment.
Table 2. Psychosocial factors between diffuse glioma survivors currently working or not working.

| Variable                                      | Working (n = 13) | Not working (n = 10) | Total sample (n = 23) |
|-----------------------------------------------|-----------------|----------------------|-----------------------|
| Employment change post brain tumor, n (%)    |                 |                      |                       |
| No                                            | 11 (85)         | 3 (30)               | 14 (61)               |
| Yes (reduced, personal time, stopped)         | 2 (15)          | 7 (70)               | 9 (39)                |
| Age, mean (SD)                                | 42.85 (14.69)   | 46.10 (8.49)         | 44.26 (12.24)         |
| Gender, n (%)                                 |                 |                      |                       |
| Male                                          | 10 (77)         | 5 (50)               | 15 (65)               |
| Female                                        | 3 (23)          | 5 (50)               | 8 (35)                |
| Years of education, mean (SD)                | 16.23 (1.301)   | 15.80 (2.30)         | 16.04 (1.77)          |
| IQ, mean (SD)                                 | 105.08 (14.69)  | 104.8 (9.16)         | 104.96 (12.33)        |
| Time since surgery (years), mean (SD)        | 8.08 (5.78)     | 6.96 (4.14)          | 7.60 (5.06)           |
| Impaired on two or more neuropsychological tests ≤-2 z-score, n (%) | 7 (54)          | 5 (50)               | 12 (52)               |
| BDI-II, mean (SD)                             | 8.08 (8.751)    | 11.6 (9.08)          | 9.61 (8.87)           |
| BAI, mean (SD)                                | 5.15 (5.94)     | 12.3 (9.61)          | 8.26 (8.38)           |

FACT-Br, mean (SD)

|                      |                 |                      |                       |
| Physical well-being  | 24.92 (4.07)    | 23.6 (4.74)          | 24.35 (4.32)          |
| Social/family well-being | 21.69 (6.41)   | 20.7 (5.06)          | 21.26 (5.75)          |
| Emotional well-being | 21 (2.92)       | 17.9 (3.9)           | 19.65 (3.65)          |
| Functional well-being| 20.15 (8.05)    | 18.7 (5.06)          | 19.52 (6.81)          |
| Brain cancer subscale (n = 22)                | 74.96 (14.75)   | 59.78 (17.98)        | 68.75 (17.49)         |
| Total (n = 22)                                 | 162.73 (26.35)  | 139.11 (29.85)       | 153.07 (29.62)        |

FACT-Cog, mean (SD)

|                      |                 |                      |                       |
| Perceived cognitive impairments                | 54.38 (18.19)   | 37.5 (18.05)         | 47.04 (19.67)         |
| Comments from others                           | 13.92 (2.93)    | 13 (3.53)            | 13.52 (3.16)          |
| Perceived cognitive abilities                  | 18.08 (7.66)    | 12.1 (7.23)          | 15.48 (7.91)          |
| Impact of quality of life (n = 22)             | 14.42 (2.43)    | 10.3 (5.31)          | 12.55 (4.43)          |

MFSI-SF, mean (SD)

|                      |                 |                      |                       |
| General scale       | 6.27 (7.12)     | 5.1 (4.47)           | 5.76 (6.01)           |
| Physical scale      | 2.54 (3.97)     | 5.1 (5.08)           | 3.65 (4.57)           |
| Emotional scale     | 3.69 (3.90)     | 5.75 (5.83)          | 4.59 (4.73)           |
| Mental scale        | 5.58 (5.17)     | 10.1 (6.83)          | 7.54 (6.24)           |
| Vigor scale         | 15.08 (5.42)    | 12.8 (6.22)          | 14.09 (5.76)          |
| Total score         | 3 (22.06)       | 13.25 (23.43)        | 7.46 (22.74)          |

PSQI, mean (SD)

|                      |                 |                      |                       |
| Global (n = 18)      | 4.86 (4.11)     | 6.71 (3.45)          | 5.58 (3.87)           |
| Global with avg missing items (n = 22) | 5.73 (5.59) | 6.58 (3.27) | 6.08 (4.71) |
| Loneliness scale total (n = 22), mean (SD) | 4.23 (1.42) | 5.11 (1.96) | 4.59 (1.68) |
| Self-efficacy scale total, mean (SD) | 50.92 (10.02) | 39.1 (17.07) | 45.78 (14.49) |
| Impact of event scale total, mean (SD) | 10.92 (10.5) | 20.8 (15.12) | 15.22 (13.37) |

1 p < 0.05.

BAI: Beck Anxiety Inventory; BDI-II: Beck Depression Inventory – second edition; FACT-Br: The functional assessment of cancer therapy – brain; FACT-Cog: The functional assessment of cancer therapy – cognitive function; IQ: Intelligence quotient; MFSI-SF: Multidimensional fatigue symptom inventory – short form; PSQI: The Pittsburg Sleep Quality Index; SD: Standard deviation.

Preliminary bivariate correlations identified several associations with both WPAI work productivity and WPAI non-work ability scores, see Table 3. Among demographic and clinical variables, none were associated with WPAI work productivity or WPAI non-work ability. Few neuropsychological test scores were significantly correlated with either measure except better learning was associated with higher WPAI work productivity and better attention was associated with higher WPAI non-work ability (p’s < .05). In contrast, several self-report correlates emerged for both measures including mood, physical well-being, brain tumor symptoms, perceived cognitive impairment, loneliness and sleep disturbance. Given the small sample and relatively large effects, we selected the four strongest relationships for each measure for exploratory regression models; of note, we selected the highest of the two
### Table 3. Correlations with work productivity and activity impairment

| Demographic and clinical variables                     | WPAI productivity (n = 13) | WPAI ability (n = 23) |
|--------------------------------------------------------|-----------------------------|-----------------------|
| Age                                                    | 0.236                       | -0.074                |
| Gender                                                 | -0.357                      | -0.147                |
| Education, years                                       | -0.311                      | 0.329                 |
| IQ                                                     | -0.269                      | 0.036                 |
| Time since surgery                                      | 0.364                       | -0.002                |
| Chemotherapy (yes/no)                                  | 0.345                       | 0.193                 |
| Neuropsychological tests, normed                       |                             |                       |
| Letter fluency total                                   | -0.447                      | 0.124                 |
| Animal naming total                                    | -0.421                      | -0.132                |
| BNT-2 total                                            | -0.366                      | -0.163                |
| BVMT-R total recall                                    | -0.394                      | 0.029                 |
| BVMT-R delayed recall                                  | -0.368                      | 0.049                 |
| Coding total                                           | -0.261                      | -0.426                |
| Digit span total                                       | -0.325                      | -0.273                |
| HVLT-R total recall                                    | -0.624                      | -0.276                |
| HVLT-R delayed recall                                  | -0.467                      | -0.151                |
| HVLT-R recognition                                     | -0.367                      | -0.198                |
| Rey-O copy                                             | -0.401                      | -0.409                |
| Stroop word reading                                    | -0.360                      | -0.128                |
| Stroop color naming                                    | -0.263                      | -0.223                |
| Stroop color-word                                      | -0.391                      | -0.308                |
| Stroop interference                                    | -0.451                      | -0.114                |
| TOPF                                                   | -0.269                      | 0.036                 |
| Trails A time                                           | 0.131                       | -0.068                |
| Trails B time                                           | -0.144                      | -0.346                |
| Impaired on two or more neuropsychological tests        |                            |                       |
| Impaired on two or more neuropsychological tests ≤ -2 z-score, n (%) | 0.479                      | 0.374                 |
| Self-report measures                                   |                             |                       |
| BDI-II raw                                              | 0.827                      | 0.576                 |
| BAI Raw                                                 | 0.468                       | 0.609                 |
| FACT-Br physical well-being                           | -0.621                      | -0.583                 |
| FACT-Br social/family well-being                       | -0.469                      | -0.446                |
| FACT-Br emotional well-being                          | -0.269                      | -0.469                 |
| FACT-Br functional well-being                         | -0.250                      | -0.533                 |
| FACT-Br brain cancer subscale                          | -0.612                      | -0.506                 |
| FACT-Cog perceived cognitive impairments              | -0.760                      | -0.542                 |
| FCAT-Cog perceived cognitive abilities                | -0.851                      | -0.564                 |
| PSQI global                                            | 0.587                      | 0.721                 |
| Loneliness scale total                                 | 0.818                      | 0.414                 |
| Impact of event scale total                           | 0.607                      | 0.527                 |

1. *p < 0.05.
2. *p < 0.01.
3. Variable significantly skewed ($Z > 1.96$), Spearman's rank correlation coefficient.

BAI: Beck Anxiety Inventory; BDI-II: Beck Depression Inventory – second edition; BNT-2: Boston naming test, 2nd edition; BVMT-R: Brief visuospatial memory test-revised; FACT-Br: The functional assessment of cancer therapy – brain; FACT-Cog: The functional assessment of cancer therapy – cognitive function; HVLT-R: Hopkins verbal learning test-revised; IQ: Intelligence quotient; PSQI: The Pittsburg Sleep Quality Index; Rey-O: Rey–Osterrieth complex figure test; Stroop: Stroop golden; TOPF: Test of premorbid functioning; WPAI: Work productivity and activity impairment questionnaire.
mood measures highly correlated with WPAI non-work ability (i.e., the BAI). We also examined part and partial correlations in the models for further scrutiny of unique effects since the strongest associations were in self-report measures.

The model statistics for both WPAI Work Productivity and WPAI non-work ability are presented in Table 4. For WPAI Work Productivity, 83% of the variance was explained by the BDI-II, Loneliness, the FACT-Cog Perceived Cognitive Abilities, and the FACT-Brain Physical Well-Being, F(4,8) = 9.92, p < .01. The FACT-Cog Perceived Cognitive Abilities score was the strongest and only significant predictor in the model, but given the small sample size we also examined the partial and part correlations of the other predictors, which each seem to carry some unique predictive value to the model with small to moderate effect sizes after accounting for the other predictors. The model of WPAI non-work ability was also significant, F(4,17) = 6.65, p < .01, explaining 61% of the variance with measures of subjective cognitive functioning (FACT-Cog Perceived Cognitive Abilities), anxiety (the BAI), sleep disturbance (PSQI) and physical functioning (FACT-brain physical well-being). Again, the FACT-Cog Perceived Cognitive Abilities score was the strongest and only significant factor. Examining partial and part correlations revealed some small to moderate unique effects of the BAI and FACT-brain physical well-being, but the PSQI dropped to negligible effects in the presence of the other factors.

**Discussion**

Functioning in brain tumor survivorship is an important factor to promote QoL in these patients, a critical clinical mandate [43]. The present study is a preliminary report of functional outcomes among glioma survivors participating in a comprehensive QoL study. Our goal in this report was to begin understanding factors that contribute to work and non-work related daily functioning in glioma survivors, including LGG, which comprised the majority of our sample. In our sample, roughly half of the survivors were not currently employed, consistent with others’ findings [15]. Rates of impairment in work productivity and non-work ability were comparable to those reported in other samples of patients with chronic conditions (i.e., multiple sclerosis) [44]. The majority of those no longer working reported that it was due to the impact a brain tumor has had on their life. At the bivariate level, we found a range of psychological factors associated with both work and non-work related functioning, including objective and subjective cognitive measures, mood, self-reported physical functioning and self-reported loneliness. Linear models of work and non-work related functioning both highlighted perceived cognitive functioning, physical well-being and mood as unique predictors.

Surprisingly, neuropsychological outcomes were not strongly associated with functional outcomes. We found no differences on individual neurocognitive test scores between those currently working and those not working, nor different rates of cognitive impairment. Further, no neurocognitive measure was as strongly associated with self-reported cognition for either work or non-work-related daily functioning. There are high rates of cognitive

### Table 4. Linear regression models of work productivity and activity impairment productivity and ability.

| DV                  | Variable                          | R²   | R² adjusted | β     | Standard error | Standardized β | Partial correlation | Part correlation | Variance inflation factor |
|---------------------|-----------------------------------|------|-------------|-------|----------------|-----------------|---------------------|---------------------|--------------------------|
| WPAI productivity   | FACT-Cog perceived cognitive abilities | 0.832| 0.748       | -0.302† | 0.120          | -0.974          | -0.665              | -0.365              | 7.128                    |
|                     | FACT-br physical well-being       |      |             | -0.209 | 0.172          | -0.359          | -0.395              | -0.176              | 4.152                    |
|                     | BDI-II raw                        | 0.075| 0.076       | 0.277  | 0.076          | 0.076           | 0.329               | 0.143               | 3.756                    |
|                     | Loneliness scale total            | -1.072| 0.717     | -0.643 | -0.467         | -0.216          |                     |                     |                           |
| WPAI ability        | FACT-Cog perceived cognitive abilities | 0.610| 0.518       | -0.158† | 0.073          | -0.448          | -0.465              | -0.328              | 1.861                    |
|                     | FACT-br physical well-being       | -0.238| 0.139     | -0.386 | -0.383         | -0.259          |                     |                     |                           |
|                     | BAI raw                           | 0.078| 0.066       | 0.246  | 0.066          | 0.246           | 0.277               | 0.180               | 1.861                    |
|                     | PSQI global                       | -0.085| 0.147     | -0.146 | -0.139         | -0.087          |                     |                     |                           |

†p < 0.05.

BAI: Beck Anxiety Inventory; BDI-II: Beck Depression Inventory – second edition; FACT-Br: The functional assessment of cancer therapy – brain; FACT-Cog: The functional assessment of cancer therapy – cognitive function, v.3; PSQI: The Pittsburg Sleep Quality Index; WPAI: Work productivity and activity impairment questionnaire.
impaired in glioma patients across their trajectory of treatment and into survivorship, and even in lower grade tumors [14,45,46]. Cognitive impairment is a significant risk to QoL and functioning in patients with glioma [43]. Noll and colleagues’ reported that neuropsychological functioning significantly predicted independent functioning among newly diagnosed patients with temporal lobe tumors of mixed type [47]. They found specifically memory and executive function measures predicted functional independence, although self-reported cognition measures were not included. By comparison, our study employed several of the same neuropsychological measures, but our sample was smaller and comprised mostly of glioma survivors well after completing treatment, with varying tumor locations. Our results do not frankly contradict their conclusion about the ecological validity of neuropsychological measures: we did observe some relationships during preliminary correlational analyses consistent with their findings, and the correlation coefficients in many instances are relatively high and of a similar magnitude to the Noll et al. study, if non significant – notably the cognitive impairment variable and memory and executive function measures. Since, this was a small preliminary study, further research will be critical to more fully understand neuropsychological predictors of functioning.

Even in this small sample, though, our preliminary findings do point to a few important lines of inquiry that will require further pursuit with larger samples. Our results highlight a unique role of perceived cognitive function. The significance of perceived cognitive impairment on function in the non-CNS cancer survivorship literature is also gaining attention. Cognitive changes in glioma patients, including LGG, may be more mild than those experienced by patients with other types of brain tumor, as seen in our sample [48]. Even if mild, can significantly compromise higher-level functional goals such as returning to work or resuming family roles [16,17]. While objective neuropsychological testing is critical to characterizing deficits, self-reported cognitive functioning may provide a unique window into the patient's experience and priorities that can help signal need for attention and intervention, such as cognitive rehabilitation.

The rich literature in non-CNS cancer populations similarly portrays functioning be complex, shaped by multiple factors including, but not limited to, cognitive impairment [10,19,49] and emphasizes the importance of self-reported cognitive function [50]. Our findings from this preliminary study are well-aligned with this position, suggesting a cluster of influences on daily functioning including cognitive function and psychological factors. Overall, the results of our study adds a new dimension of appreciating self-reported cognitive challenges in brain tumor survivors as well as the likely contributions of psychological factors and highlights the need for more study.

The need to address psychological needs in brain tumor survivors is intensifying [51,52]. We know that cognitive and functional changes often manifest in the setting of psychosocial risk factors such as the well-described increases in anxiety and depression symptoms in brain tumor and other cancer patients [53–55]. Similar to our findings, Feuerstein and colleagues examined contributing factors to work productivity in brain tumor survivors and also found depressive symptoms to independently contribute [56]. Others have similarly found mood to be a predictor of health-related QoL in recently diagnosed glioma patients [57]. Furthermore, patients’ functional goals and sense of meaning can be altered by brain tumor diagnosis and an anticipated shortened survival [51]. Loughan and colleagues recently found high rates of death-related distress in primary brain tumor patients irrespective of tumor grade [58]. Given the complexity of needs, it is critical to incorporate a biopsychosocial framework in developing models of optimal functioning for these patients, as also advocated by others [5,8,51].

This study has limitations. First, we acknowledge the restrictions of small sample size in terms of statistical power and generalizability. Glioma survivors, especially LGG, are a fraction of all brain tumor survivors, which are a small fraction of all cancer survivors in general. There is also substantial heterogeneity in our study sample including cognitive impairment, time since treatment and tumor location, which could be influencing outcomes and limiting our ability to detect relationships with factors such as cognitive function. Importantly, we also primarily focused on cognitive, psychological and QoL outcomes – it remains important to understand the full nature of potential contributing factors to functioning in this population, such as specific physical impairments and type of work. Despite the limitations of size of the population from which we sampled, UCLA is a tertiary center and draws patients from a wide region, permitting accrual of relatively larger samples than seen in general oncology clinics. Thus, while small by statistical standards, the collected sample is a unique aggregate of data from this population. Additionally, our sample was predominantly White with higher levels of educational attainment and more study in more diverse samples is imperative.
**Conclusion**

This study lends preliminary evidence to support a multi-factorial approach to providing supportive care in glioma survivorship. Despite favorable outcomes in terms of longevity for LGG survivorship, the cognitive and psychological toll of this experience compromises optimal functioning and it is critical to further study and develop interventions for optimizing functioning and QoL for these patients.

**Summary points**

- Survival among glioma survivors, especially lower grade, is improving.
- However, 30–50% of survivors experience significant functional impairment.
- To better support glioma survivors, it is important to understand factors contributing to functional impairment.
- This preliminary study examines cognitive, psychological and quality of life predictors of work and non-work-related functional impairment in 23 glioma survivors. A total of 13/23 survivors in our sample were currently working.
- Linear models of the strongest correlates of work productivity included self-reported cognitive function, depression, loneliness and brain tumor symptoms, explaining 83% of the variance.
- Linear models of the strongest correlates of non-work-related ability included self-reported cognitive function, anxiety, sleep disturbance and brain tumor symptoms.
- The results of our preliminary study highlight a multifactorial approach to supporting functioning in glioma survivorship including cognitive, both objective and self-report and psychological factors. Further research in this area with larger samples will be important for developing targeted and effective supportive interventions in this population.

**Supplementary data**

To view the supplementary data that accompany this paper please visit the journal website at: www.futuremedicine.com/doi/suppl/10.2217/cns-2022-0002

**Financial & competing interests disclosure**

This research was supported by the National Cancer Institute at the National Institutes of Health grant K08CA241337 to KVD, grant P50CA211015 to BE, UCLA Neuro-Oncology Program Brain Cancer Research Fund, IGN foundation and donations in memory of David Hanneman and Jeri Weiss. KVD is also supported in part by R35CA197289 and R01AG068193. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

No writing assistance was utilized in the production of this manuscript.

**Ethical conduct of research**

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

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