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Subjective cognitive functioning and associations with psychological distress in adult brain tumour survivors

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Abstract

Purpose The impact of brain tumour on subjective cognitive function (SCF) has received little attention despite the implications of these perceptions for quality of life. SCF consists of two related yet distinct components, perceived cognitive impairment (PCI) and perceived cognitive abilities (PCA). This study compared the SCF of adult brain tumour survivors and healthy controls and examined demographic, illness-related, and psychological factors associated with SCF.

Method Sixty-five adult survivors with primary brain tumour (age, 22–75 years), and 65 age- and sex-matched controls were recruited. Participants with brain tumour completed the Brief Test of Adult Cognition by Telephone, Functional Assessment of Cancer Therapy–Cognitive Function (FACT-Cog), ratings of physical symptoms, Depression Scale of the Depression Anxiety Stress Scales-21 (DASS-Depression), and Generalized Anxiety Disorder-7 (GAD-7) scale. Controls completed the FACT-Cog, DASS-Depression, and GAD-7.

Results Adult brain tumour survivors reported significantly greater PCI and lower PCA than controls, after accounting for anxiety. Higher PCI was significantly related to fatigue, pain, treatment-related side-effects, anxiety, and depression. Lower PCA was significantly associated with fatigue, pain, poorer objective cognitive function, lower education, anxiety, and depression. Anxiety uniquely accounted for 9–14% of variance in SCF.

Conclusions Adult brain tumour survivors were found to experience poorer SCF than healthy controls after accounting for anxiety. SCF was related to multiple factors after brain tumour; however, an independent association with anxiety was identified.

Implications for Cancer Survivors These findings highlight the potential value of psychological interventions targeting anxiety and cognitive effects to improve quality of survivorship after brain tumour.

Keywords Brain tumour survivors · Patient-reported outcomes · Perceived cognitive impairment · Perceived cognitive abilities · Psychological distress

Introduction

Primary brain tumours are relatively rare (2.6–6.6/100,000 per year, worldwide) but are associated with one of the lowest survival rates of all cancers [1]. Brain tumour poses a significant threat to life and is associated with diverse functional impairments which impact on the quality of life of survivors and their family caregivers [2, 3]. The detrimental effects of brain tumour on cognitive function are evident from objective neuropsychological tests and survivors' own subjective accounts, as measured through patient-reported outcome measures. While much research has investigated the impact of brain tumour and its treatment on objective measures of cognitive functioning (i.e., neuropsychological tests) [4], the impact on subjective cognitive functioning (SCF) is less well understood. Yet, in the general cancer literature, SCF has been found to be more closely associated with quality of life and psychological distress than objective cognitive functioning [5].

Cognitive impairment can arise from the direct effects of the brain tumour (i.e., compression, displacement, or infiltration of brain tissue) or effects of treatment [6]. Due to the varying location, size and spread of the tumour, and treatment types, survivors may experience diverse impairments in their

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cognitive functioning, as assessed through standardised neuropsychological tests. Previous studies suggest that up to 90% of brain tumour survivors experience cognitive impairments [7–9]. This may relate to selective impairments in memory, attention, visuospatial function, language, executive function, or global cognitive decline arising from mass effects (e.g., raised intracranial pressure) [10]. The neurotoxic effects of treatments (e.g., chemotherapy, radiation therapy, corticosteroids) on cognitive functioning for non-central nervous system cancers have been widely documented [11–13]. Treatment of brain tumour is typically multifaceted, involving surgery, chemotherapy, and radiotherapy, which may be used in combination or in isolation [14]. Overall, caution must be taken in inferring likely cognitive deficits based on tumour location or treatment type due to multiple potential mechanisms of brain disruption. Further, research indicates that there is only a weak-to-moderate association between objective and subjective measures of cognitive functioning [7, 15–17]; thus, cognitive deficits evident from neuropsychological tests may not be consistent with difficulties experienced in everyday life.

Within the general cancer literature, survivorship has increasingly been recognised as a distinct phase of cancer care [14], with an increasing research emphasis on improving quality of survivorship. In such literature, poorer SCF is consistently found to be associated with lower quality of life [5, 18, 19]. The factors most commonly related to poor SCF include older age, female sex, menopause, longer disease duration or advanced stage, cancer treatment type, greater physical symptoms (e.g., fatigue), and psychological distress [12, 19–26].

In a theoretical model of subjective and objective cognitive outcomes in cancer by Green et al. [27], psychological distress was proposed as a key factor contributing to the development and maintenance of poor SCF. Accordingly, the unique contribution of psychological distress to poorer SCF has been supported in research on survivors with mixed cancer types [5, 22], colorectal cancer [20], and breast cancer [11, 19, 28]. Unlike non-CNS cancers, brain tumour directly impacts neural structures that underlie cognitive functioning and self-awareness of functional changes. Therefore, the factors related to SCF in adult brain tumour survivors may differ from those identified in the broader cancer literature.

Despite the high prevalence of cognitive complaints in this population and the implications for quality of life, only six studies have assessed SCF in the context of brain tumour [7, 9, 15–17, 29]. Some studies were largely descriptive in nature or used non-validated measures of SCF [9, 16, 29]. In the three studies that examined factors related to SCF, weak-to-moderate associations were found between measures of objective cognitive function and SCF [7, 15, 17]. Moderate-to-large associations were reported between SCF and psychological distress in studies by Klein et al. [7] and Pranckeviciene et al. [17]. However, the influence of demographic characteristics and illness-related factors was not accounted for through multivariate analyses. In a large glioma sample ($n = 183$), Gehring et al. [15] used a multivariate approach to investigate the relative influence of demographic characteristics, illness-related factors, physical symptoms, objective cognitive functioning, and mental health on SCF. They found that female sex, motor dysfunction, fatigue, communication deficits, and mental health were significantly related to poorer SCF. Mental health uniquely accounted for 16% of the variance in SCF. Notably, this study mainly focused on objective cognitive functioning and utilised a brief 6-item measure of SCF. Research indicates that SCF is a multidimensional construct, with two related, yet distinct components of perceived cognitive impairment (PCI) and perceived cognitive abilities (PCA) [30]. Different factors have been found to be related to PCA and PCI in the general cancer literature, thus supporting the need to assess both components of SCF [20].

The broad objectives of the current study were to understand the impact of brain tumour on SCF and factors associated with PCA and PCI. To build upon previous research, a healthy control group was employed to determine whether adult brain tumour survivors experience poorer SCF after controlling for psychological distress. It was hypothesised that adult brain tumour survivors would report poorer SCF (i.e., greater PCI and lower PCA) than age- and sex-matched controls, irrespective of levels of psychological distress. Additionally, it was hypothesised that psychological distress would be significantly related to greater PCI and lower PCA after controlling for demographic and illness-related factors.

Methods

Participants

Adult brain tumour survivors were recruited from the multidisciplinary brain tumour clinic of a major metropolitan hospital and a community cancer support service over an 18-month period (2016–2017). Treating health professionals initially screened potential participants during routine clinical contact according to the following inclusion criteria: (1) diagnosis of primary brain tumour, (2) aged 18–75 years, and (3) adequate cognitive function and receptive and expressive language skills to provide informed consent and complete questionnaires. Individuals with a metastatic cancer, major premorbid psychiatric condition (e.g., psychosis or substance abuse disorder), or very severe cognitive or language impairments were excluded. Participants' cognitive capacity and receptive and expressive English language skills were further assessed through a telephone-based cognitive screening tool.

Control participants aged 18–75 years with no history of a neurological condition were recruited from an undergraduate psychology research subject pool and the general community

through online advertisements posted to social media platforms.

Measures

Participant characteristics Data concerning demographic and health background characteristics were obtained from all participants via telephone (adult brain tumour survivors) or an online or hard copy survey (controls). Data on brain tumour and treatment characteristics were accessed through medical records.

Subjective cognitive function The Functional Assessment of Cancer Therapy–Cognitive Version 3 (FACT-Cog, Version 3) [30] is a measure of SCF developed for the cancer population. Only the PCI and PCA scales were administered in this study and these were scored in accordance with Functional Assessment of Chronic Illness Therapy FACT-Cog scoring recommendations. The 20-item PCI subscale broadly assesses difficulties with processing, attention, verbal and visual memory, orientation, and communication (e.g., "My thinking has been slower than usual"). Scores range from 0 = "never" to 4 = "several times a day". Items on the PCI subscale are reverse coded when scored, which means that higher total PCI scores refer to lower perceptions of cognitive impairment. However, for ease of interpretation, the term "higher PCI" (i.e., lower total PCI scores) will refer to greater perceived cognitive impairment in the current study. The nine items of the PCA assess competence with concentration, remembering, and processing information (e.g., "I have been able to remember to do things, like take medicine or buy something I needed"). Scores range from 0 = "not at all" to 4 = "very much", with higher scores indicating greater perceived ability or cognitive capability. A factor analysis indicated that the PCI and PCA assess related but distinct constructs [31]. The subscales demonstrate high internal consistency (α = .89–.93) [32] and have been found to correlate with the cognitive functioning scale of the European Organization for Research and Treatment of Cancer Quality of Life Core Questionnaire (r = 0.73) [33]. Internal consistency was excellent for the brain tumour (α = .92–.96) and control samples (α = .93–.95) in this study.

Psychological distress Psychological distress was measured using the Depression subscale of the Depression, Anxiety and Stress Scales (DASS-21) [34] and the Generalized Anxiety Disorder 7-item (GAD-7) scale [35]. The DASS-21 Depression subscale is a self-report measure consisting of 7 items, assessing the severity of symptoms associated with depression (e.g., "I couldn't seem to experience any positive feeling at all"). Items are rated from 0 = "did not apply to me at all" to 4 = "applied to me very much, or most of the time", with higher scores indicating more severe depressive symptoms [34]. Item scores are summed and then doubled, with scores of ten and above considered clinically elevated [34]. This scale has been found to be a reliable and valid measure of mood symptoms for persons with brain tumour [36]. Internal consistency was excellent for the brain tumour (α = .90) and control samples (α = .93) in this study.

The GAD-7 [35] is a validated 7-item self-report measure, assessing symptoms of generalised anxiety disorder. Items are rated on a 4-point scale ranging from 0 = "not at all" to 3 = "nearly every day", with higher scores indicating greater frequency of anxiety symptoms [35]. An example item includes "not being able to stop or control worrying". Scores of five and above were considered clinically elevated [35]. The GAD-7 is commonly used to assess anxiety after brain tumour (e.g., Arnold et al., [37]). Internal consistency was excellent for the brain tumour (α = .91) and control samples (α = .92) in the current study.

Physical symptoms To examine the influence of specific physical symptoms on SCF, four items were selected from the physical well-being subscale of the Functional Assessment of Cancer Therapy-General (FACT-G) [38]. These symptoms were perceived fatigue, nausea, pain, and treatment-related side-effects. Each item was rated from 0 = "not at all" to 4 = "very much", with higher scores indicating increased severity of each symptom.

Objective cognitive function The Brief Test of Adult Cognition by Telephone (BTACT) [39] was used as a brief screening tool for adult brain tumour survivors, in order to provide a global index of their cognitive status. The BTACT is a reliable and valid telephone-based measure of adult cognition [39, 40]. Five subtests were administered in this study, as follows: Digits Backward, Word List Short-Delay Recall, Backwards Counting, Category Fluency, and Word List Delayed Recall. These tasks measure working memory, episodic verbal memory (immediate and delayed), processing speed, and executive function [39]. Two subtests from the BTACT (Attention-Switching/Reaction Time and Reasoning) were not administered due to prior brain tumour research indicating some challenges with administration of these tasks over the telephone [41]. Raw scores on each subtest were converted to age-adjusted Z-scores based on the norms. A global composite score was derived by summing and averaging age-adjusted Z-scores for each subtest.

Procedure

Ethical clearance was obtained through hospital and university ethics committees. Adult brain tumour survivors were approached by treating professionals who provided an overview of the study and obtained initial verbal consent for researchers to contact prospective participants. Informed consent was obtained from all individual participants included

in the study. After providing informed consent, participants with brain tumour were initially sent a paper-based copy of the rating scales for each questionnaire. They completed a structured telephone-based assessment comprised of the following measures: BTACT, DASS-21, GAD-7, FACT-Cog, and physical symptoms ratings. The researcher read each item out aloud to the participant, who referred to the corresponding rating scale for each measure. After providing informed consent, control participants completed either a hard copy survey or an online survey. The survey included demographic and health background questions, DASS-21, GAD-7, and FACT-Cog.

Data analysis

Statistical analyses were conducted using the IBM Statistical Package for the Social Sciences (SPSS, Version 24). Data screening identified missing data for five participants on the BTACT, which were managed using a pairwise deletion approach in relevant analyses. Data for the brain tumour and control groups were examined for univariate and multivariate outliers, assumptions of normality, homoscedasticity, and linearity. A one-way multivariate analysis of covariance (MANCOVA) was used to compare the SCF (PCI and PCA) of adult brain tumour survivors and controls, with psychological distress treated as a covariate. Univariate main effects for PCI and PCA were examined using ANCOVA with a Bonferroni correction ($\alpha = .025$). Pearson's correlations and a series of one-way ANOVAs were conducted to examine associations between each component of SCF and age, education, physical symptoms, objective cognitive functioning, depression, anxiety, sex, time since diagnosis, tumour stage (initial or recurrence), tumour type, and treatment type. Hierarchical regression analyses were then performed to determine whether psychological distress was significantly related to poorer SCF (greater PCI and lower PCA) after controlling for relevant demographic and illness-related variables.

Results

Sample characteristics

Sixty-five adult brain tumour survivors aged 22–75 years ($M = 49.97$, SD = 11.47) were recruited into the study (see Table 1). Tumour subtypes included benign (46%), low-

Table 1 Participants' demographic and health characteristics

	Brain tumour sample $n = 65$ *M* (SD), range, *N* (%)	Control sample $n = 65$ *M* (SD), range, *N* (%)
Age (years)	49.97 (14.46), 22–75	49.42 (12.34), 22–74
Sex		
Male	23 (35.4%)	22 (33.8%)
Female	42 (64.6%)	43 (66.2%)
Years of education	12.52 (2.33), 9–17	14.02 (3.59), 8–26
Time since diagnosis (years)	5.29 (5.62), .08–22	
WHO tumour grade		
Grade I	30 (46.2%)	
Grade II	11 (16.9%)	
Grade III	15 (23.1%)	
Grade IV	9 (13.8%)	
Tumour type		
Benign	30 (46.2%)	
Low-grade glioma	12 (18.5%)	
High-grade glioma	23 (35.4%)	
Treatment type		
Monitoring only	16 (24.6%)	
Surgery only	14 (21.5%)	
Surgery and radiotherapy	10 (15.4%)	
Surgery, radiotherapy, and chemotherapy	22 (33.8%)	
Radiotherapy and chemotherapy	1 (1.5%)	
Surgery and chemotherapy	2 (3%)	

WHO World Health Organization

grade glioma (19%), and high-grade glioma (35%). Time since diagnosis ranged from 1 month to 22 years ($M = 5.29$; SD = 5.62). The 65 control participants were successfully matched to the brain tumour sample on the basis of age and sex ($p > .05$).

Descriptive statistics

As shown in Table 2, levels of SCF for adult brain tumour survivors varied considerably, with a range of 7–72 on PCI ($M = 40.55$, SD = 17.30) and 2–28 on PCA ($M = 15.23$, SD = 6.30). Scores on the psychological distress measures indicated that 58.5% and 43.1% of brain tumour participants experienced clinically elevated levels of anxiety and depression, respectively. The mean composite score for global cognitive status on the BTACT was within the average range; however, performance ranged from below average ($z = -2.13$) to above average ($z = 2.27$), relative to age norms.

Comparison of SCF between adult brain tumour survivors and controls

A preliminary analysis ($n = 130$) identified significant correlations between anxiety and PCI ($r = -.54$, $p < .001$) and depression and PCI ($r = -.45$, $p < .001$), and between anxiety and PCA ($r = -.46$, $p < .001$) and depression and PCA ($r = -.45$, $p < .001$). Levels of anxiety were significantly higher for brain tumour survivors ($M = 6.63$, SD = 5.26) compared with controls ($M = 4.63$, SD = 5.37), ($t(128) = 2.15$, $p = .03$). Brain tumour survivors ($M = 10.25$, SD = 8.59) also reported higher levels of depression than controls ($M = 8.43$, SD = 8.46); however, this difference was not significant ($t(128) = 1.12$, $p = .26$). Due to the large correlation between anxiety and depression ($r = .75$, $p < .001$), and the finding that levels of anxiety, but not depression, were significantly higher for participants with brain tumour than controls, anxiety was treated as the covariate.

A one-way MANCOVA identified that brain tumour survivors had significantly poorer SCF than controls (Wilk's

Table 2 Descriptive statistics for the adult brain tumour survivors and control participants

Measures	Adult brain tumour survivors ($n = 65$) *M* (SD), range/*N* (%)	Control participants ($n = 65$) *M* (SD), range/*N* (%)
FACT-Cog		
PCI[a]	40.55 (17.30), 7–72	57.22 (11.91), 23–72
PCA	15.23 (6.30), 2–28	20.80 (5.50), 7–28
DASS-21 (Depression)	10.25 (8.59), 0–34	8.43 (8.46), 0–36
Clinically elevated (≥ 10)	28 (43.1)	25 (38.5)
Normal range (< 10)	37 (56.9)	40 (61.5)
Mild (10–13)	7 (10.8)	9 (13.8)
Moderate (14–20)	11 (16.9)	10 (15.4)
Severe (21–27)	7 (10.8)	3 (4.6)
Extremely severe (28+)	3 (4.6)	3 (4.6)
GAD-7 (anxiety)	6.63 (5.26), 0–20	4.63 (5.37), 0–21
Clinically elevated (≥ 5)	38 (58.5)	26 (40)
Normal range (< 5)	27 (41.5)	39 (60)
Mild (5–9)	19 (29.2)	16 (24.6)
Moderate (10–14)	13 (20)	4 (6.2)
Severe (15–21)	6 (9.2)	6 (9.2)
BTACT (global composite *Z*-score)	− 0.31 (0.75), − 0.213–2.27	–
Physical symptoms		
Fatigue	1.94 (1.39), 0–4	–
Nausea	0.62 (0.96), 0–4	–
Pain	1.26 (1.33), 0–4	–
Treatment-related side-effects	1.62 (1.44), 0–4	–

BTACT, Brief Test of Adult Cognition by Telephone; *DASS-21*, Depression, Anxiety and Stress Scales; *FACT-Cog*, Functional Assessment of Cancer Therapy–Cognitive; *GAD-7*, Generalized Anxiety Disorder; *PCA*, perceived cognitive abilities; *PCI*, perceived cognitive impairment

[a] Higher PCI scores indicate more positive perceptions of cognitive functioning or lower cognitive impairment

$\lambda = .77$, $F(2, 126) = 19.16$, $p < .001$, partial $\eta p^2 = .23$), after controlling for psychological distress (see Table 3). Further, a significant group effect was identified for both PCI ($F(1, 130) = 36.58$, $p < .001$, $\eta p^2 = .22$), and PCA ($F(1, 130) = 23.19$, $p < .001$, $\eta p^2 = .15$). Therefore, adult brain tumour survivors reported higher PCI and lower PCA than controls irrespective of their levels of anxiety.

Associations between SCF and demographic and illness-related factors and psychological distress for participants with brain tumour

Higher levels of PCI were significantly correlated with greater fatigue ($r = -.41$, $p = .001$), pain ($r = -.34$, $p = .006$), treatment-related side-effects ($r = -.33$, $p = .006$), depression ($r = -.46$, $p < .001$), and anxiety ($r = -.55$, $p < .001$). Higher PCA was significantly correlated with lower fatigue ($r = -.31$, $p = .01$) and pain ($r = -.27$, $p = .04$), better objective cognitive functioning ($r = .41$, $p < .001$), higher education ($r = .27$, $p = .047$), lower depression ($r = -.41$, $p = .001$), and anxiety ($r = -.40$, $p = .001$). Age, sex, nausea, time since diagnosis, tumour stage, tumour type, and treatment type (e.g., treatment vs. symptom monitoring, surgery vs. no surgery, chemotherapy vs. no chemotherapy) were not significantly associated with either component of SCF ($p > .05$). The pattern of significant associations guided selection of factors examined in the regression analyses.

Multivariate analysis of factors related to SCF

Due to the large significant correlation between depression and anxiety ($r = .75$), only anxiety was entered in the regression analyses. As shown in Table 4, in step 1 of the first regression model, fatigue, pain, and treatment-related side-effects significantly accounted for 24% of the shared variance in PCI; however, only fatigue accounted for significant unique variance ($\beta = -3.84$, $p = .017$). Anxiety was entered in step 2 and significantly explained an additional 14% of the variance in PCI. Anxiety was the only factor that accounted for significant unique variance in PCI in the final model ($\beta = -1.41$, $p < .001$). Thus, greater levels of anxiety were significantly related to higher PCI, after controlling for physical symptoms.

In step 1 of the second regression model, pain, fatigue, objective cognitive functioning, and education significantly accounted for 32% of the shared variance in PCA. Objective cognitive functioning ($\beta = 3.24$, $p = .002$) accounted for significant unique variance in PCA. Entered in step 2, anxiety significantly explained an additional 9% of the variance in PCA. Objective cognitive function ($\beta = 3.40$, $p = .001$) and anxiety ($\beta = -0.38$, $p = .015$) accounted for significant unique variance in PCA in the final model. Overall, greater levels of anxiety were related to lower levels of PCA, after controlling for physical and cognitive function.

Discussion

Due to treatment advances and improved prognosis, there is increasing emphasis on the quality of survivorship for people with brain tumour. Accordingly, this study aimed to examine the impact of brain tumour on SCF and the factors associated with PCI and PCA. As hypothesised, adult brain tumour survivors perceived significantly greater cognitive impairment and lower cognitive abilities than controls. Poorer SCF was significantly related to greater fatigue, pain, and treatment-related side-effects, poorer objective cognitive functioning, lower education, and higher levels of depression and anxiety. As hypothesised, psychological distress (i.e., anxiety) was significantly related to lower SCF after controlling for physical symptoms and objective cognitive functioning.

A key novel finding was that adult brain tumour survivors reported significantly poorer SCF than controls after accounting for anxiety symptoms. This finding suggests that poor SCF after brain tumour cannot be attributed entirely to

Table 3 MANCOVA comparing SCF between the adult brain tumour survivors and controls

Variables	Brain tumour sample ($n = 65$)		Control sample ($n = 65$)		Wilk's λ	F	p	η_p^2
	M	SD	M	SD				
PCI	40.55	17.30	57.22	11.91				
PCA	15.23	6.30	20.80	5.50				
MANCOVA					.77	19.16	< .001	.23
Anxiety (covariate)					.72	24.32	< .001	.28

Interpretation of η_p^2 effect sizes; small: $\eta_p^2 = .01$–$.059$; medium: $\eta_p^2 = .09$–$.139$; large: $\eta_p^2 = \geq .14$. *PCA*, perceived cognitive abilities; *PCI*, perceived cognitive impairment. Items on the PCI are reverse scored

Table 4 Hierarchical regression analysis of anxiety, education, physical symptoms, and objective cognitive functioning on subjective cognitive functioning

Variable	R^2	ΔR^2	B	SE (B)	β	t	sr^2
Perceived cognitive impairment (PCI)							
Step 1	.24**	–					
Fatigue			− 3.84	1.56	− .31	− 2.46*	.08
Pain			− 2.98	1.59	− .23	− 1.89	.04
Treatment-related side-effects			− 1.20	1.61	− .10	− .75	.00
Step 2	.38***	.14***					
Fatigue			− 2.80	1.45	− .23	− 1.94	.04
Pain			− 2.27	1.46	− .18	− 1.56	.02
Treatment-related side-effects			.28	1.52	.02	.19	.00
Anxiety			− 1.41	.38	− .43	− 3.74**	.14
Perceived cognitive abilities (PCA)							
Step 1	.32**	–					
Fatigue			− .75	.54	− .18	− 1.37	.03
Pain			− .79	.62	− .16	− 1.28	.03
Objective cognitive functioning			3.24	.99	.42	3.29**	.17
Education			.571	.34	.21	1.68	.04
Step 2	.41***	.09**					
Fatigue			− .30	.54	− .07	− .55	.00
Pain			− .56	.59	− .12	− .94	.01
Objective cognitive functioning			3.40	.93	.44	3.65**	.18
Education			.60	.32	.22	1.86	.05
Anxiety			− .38	.15	− .32	− 2.55*	.09

*$p < .05$; **$p < .01$; ***$p < .001$

symptoms of anxiety, which are often clinically elevated for this population [37]. Consistent with previous cancer and brain tumour research [7, 15–17, 19–26], SCF was significantly associated with a combination of physical, cognitive, and psychological factors. Specifically, higher PCI was associated with greater fatigue, pain, treatment-related side-effects, and psychological distress; whereas, lower PCA was associated with greater fatigue, pain, and psychological distress and lower objective cognitive functioning and education. The somewhat different pattern of factors related to PCI and PCA reinforces the views of Wagner et al. [30] and Lai et al. [31] that these scales measure distinct components of SCF. In contrast to previous findings in the general cancer literature, age and sex were not significantly related to SCF [20–22]. This may be due to the differing demographic profile of adult brain tumour survivors compared with other cancer types. For example, the mean onset of brain tumour in adulthood is 54 years [42], as compared with 33 years for breast cancer [43].

A further main finding was that objective cognitive functioning was significantly related to PCA but not PCI. Interestingly, such findings mirror those of Dhillon et al. [20] who reported a significant association between objective cognitive function and PCA, but not PCI. Although it is unclear why this is the case, it is possible that the items on the PCA scale (i.e., memory, attention, and word retrieval) more closely correspond to the abilities assessed by the BTACT than the PCI subscale. Further, items on the PCA scale may relate more to self-efficacy judgements related to everyday activities (e.g., remembering medication) whereas, items on PCI may reflect negative self-appraisals of an individual's "thinking" difficulties [20].

Consistent with the findings in the general cancer literature [5, 19, 20, 22, 28] and brain tumour research by Gehring et al. [15], psychological distress accounted for unique variance in SCF. However, the present study demonstrated that this was the case for both PCI and PCA in brain tumour survivors. Such findings may be explained by Eysenck's Processing Efficiency Theory [44], which proposes that intrusive and worrying thoughts impair cognitive functioning through reduced processing capacity. This is consistent with previous research which indicates that anxiety is associated with poorer cognitive performance [45–47]. Notably, however, there was no significant association between anxiety and global cognitive status on the BTACT ($r = .04$, $p = .74$). Alternatively, it is possible that heightened anxiety may reduce people's self-

efficacy or confidence in their ability to process, attend to, and recall information, as measured by the PCI and PCA subscales. Consistent with this explanation, greater anxiety symptoms have been found to be associated with low-perceived self-efficacy and greater memory complaints in the general population [48, 49].

Methodological limitations

A key limitation of the current study relates to the heterogeneity of adult brain tumour survivors in terms of their demographic characteristics, tumour type, treatment, and time since diagnosis. The varying sample characteristics affect the ability to generalise the findings to survivors with a specific tumour type or stage of illness. Further, the sensitivity of the BTACT for detecting the cognitive effects of brain tumour has not been determined and, as a brief cognitive screen, it does not reflect the full range of cognitive functions that may be impaired. As an additional assessment issue, all measures were administered to the participants with brain tumour over the telephone, whereas controls completed the measures through an online or a hard copy survey, anonymously. Due to responding to questions orally, it is possible that the responses of participants with brain tumour were more likely to be influenced by demand characteristics inherent in the interaction with the researcher.

Due to the cross-sectional design, caution is needed in inferring the direction of associations between anxiety and SCF. Perceptions of cognitive impairment or ability may influence or be influenced by individuals' level of anxiety. In other brain injury research, Malec et al. [50] proposed that the relationship between symptom reporting and mood is reciprocal, or mutually enhancing. Prospective longitudinal research is needed to examine changes in SCF and psychological distress over time, and to investigate the potentially bi-directional relationship between these internal states. Finally, it is recognised that symptoms such as fatigue and pain are multidimensional constructs, and therefore the use of single-item measures is not ideal.

Clinical implications

As noted by Armstrong [51], subjective functional impairments can have profound implications for quality of survivorship after brain tumour. The current findings highlight the importance of routine assessment of SCF, alongside measures of physical symptoms and psychological distress. Multidisciplinary (i.e., medical, nursing, allied health, and psychological) approaches are recommended which include cognitive rehabilitation and management of pain, fatigue, treatment-related side-effects, and anxiety. Although there is some evidence that cognitive rehabilitation improves SCF and objective cognitive function in adult brain tumour survivors, no associated improvements in mental health were reported [52].

Cognitive behavioural approaches such as mindfulness show promise for managing cancer-related anxiety [53]. According to the European Association for Neuro-Oncology [54], presently, only one psychological intervention study by Ownsworth et al. [55] has demonstrated efficacy for improving psychological well-being in adult brain tumour survivors. However, the impact of this intervention on SCF was not examined. Further research is needed to determine the efficacy of psychological support for reducing anxiety and improving SCF. Specifically, it would be useful to examine whether SCF improves through interventions targeting anxiety, or whether the combined management of SCF and anxiety is optimal. It is also recommended that future studies examine the subjective meaning of cognitive complaints and their impact on everyday life (i.e., return to work and maintaining relationships). Guided by such research, psychological interventions could be developed to improve quality of survivorship in the brain tumour population.

Conclusions

The broad objective of this study was to investigate the impact of brain tumour on SCF and to identify factors related to perceived cognitive impairment and abilities. A key finding was that adult brain tumour survivors reported significantly poorer SCF than controls after accounting for anxiety symptoms. Additionally, level of anxiety was associated with poorer SCF after controlling for physical symptoms and objective global cognitive status. Such findings highlight the potential value of developing psychological interventions that target anxiety symptoms as part of the management of SCF for the brain tumour population.

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Compliance with ethical standards Ethical clearance was obtained through hospital and university ethics committees. Adult brain tumour survivors were approached by treating professionals who provided an overview of the study and obtained initial verbal consent for researchers to contact prospective participants. Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare that they have no conflicts of interest.

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