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Exploring the effect of neurofeedback on postcancer cognitive impairment and fatigue: A pilot feasibility study

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ABSTRACT

Purpose: *Postcancer cognitive impairment (PCCI) and fatigue are adverse effects that often persist following cancer treatment, and impact quality of life. The study purpose was to evaluate feasibility and effect of neurofeedback on cognitive functioning and fatigue in cancer survivors. Specifically, we aimed to test feasibility of recruitment strategies and our study protocol including outcome measures.*

Design: *This pilot feasibility study used a 10-week wait-list design. Participants served as their own controls and received neurofeedback training twice a week for 10 weeks.*

Participants: *The sample consisted of breast cancer survivors from Kingston, Ontario (n = 16).*

Methods: *Outcomes were assessed using validated, self-report scales and neuropsychological tests before, during, and after neurofeedback.*

Findings: *The neurofeedback protocol was feasible and resulted in significant decreases in perceived cognitive deficits, fatigue, sleep, and psychological symptoms.*

Implications for psychosocial providers: *Neurofeedback may be an effective, non-invasive complementary therapy for PCCI in breast cancer survivors.*

Keywords: chemotherapy, cognitive impairment, cancer fatigue, integrative oncology, neurofeedback, alternative therapy

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Postcancer cognitive impairment (PCCI), often referred to as "brain fog", is an adverse effect during and following cancer therapy that negatively affects quality of life in cancer survivors (Patel et al., 2014; Pendergrass et al., 2018; Selamat et al., 2014). Cognitive changes in breast cancer survivors have been documented in association with chemotherapy, radiation therapy and endocrine therapy (Van Dyk & Ganz, 2021). Objective neuropsychological tests of cognitive functions show a decline in global cognitive functioning such as verbal skills, short-term learning, and attention (Biglia et al., 2012). The same study also found cancer treatment effects of depression, anxiety, and physical fatigue. Cancer-related fatigue is known to be the most prevalent, distressing, and disabling symptom reported by cancer survivors with clinically relevant levels present in about one-third of cancer survivors up to six years post-treatment (Jones et al., 2016). A systematic review on cognitive impairment after chemotherapy found perceived impairment to cause distressing changes to daily life such as employment (Hutchinson et al., 2012). Breast cancer patients who endured chemotherapy found it more difficult to return to work in their full capacity, and experienced declines in physical and mental health (Barnes et al., 2014). Following cancer treatment, PCCI forms a part of patients' ongoing cancer identity, but there is often a lack of recognition, support, and interventions available, because the state of being cancer-free overshadows side-effects post-treatment (Pertl et al., 2014).

With the increasing number of survivors across Canada and the US, there arises an ever-growing demand to identify and treat side effects of cancer and its treatments (McCabe et al., 2013). The few published studies have evaluated interventions for PCCI such as cognitive training, physical exercise, dietary modifications, and psychostimulants (Ahles et al., 2012). However, there is a need for an evidence-based, effective treatment for PCCI that has the potential to be used across diverse oncological health services. Cancer patients are actively seeking and using complementary and alternative medicine (CAM) therapies to manage their persistent symptoms despite lack of funding and health insurance coverage (Grant et al., 2019).

One novel CAM therapy with promising preliminary results is neurofeedback (NF). Neurofeedback is a cutting-edge

technology that harnesses the power of the brain to heal itself through principles of operant conditioning and neuroplasticity, an ability of the nervous system to respond to stimuli such as NF and reorganize its structure, function, and connections (Cochrane, 2010). Key strengths of NF are safety and long-term stability (Ros et al., 2014). Adverse effects are rare and transient such as headaches and fatigue (Hammond, 2010). Persistence of functional reorganization of the brain after NF training is an indicator of neuroplasticity (Sitaram et al., 2017) and supports the observation that benefits of NF training last beyond the end of the training period (Ros et al., 2014). With NF training, a person learns to change their brainwave patterns to achieve increased central nervous system (CNS) efficiency. Brainwave activity is read by scalp sensors, interpreted by computer software, and fed back to the brain in real time. Traditional NF approaches involve diagnosis and use of specific protocols to suppress or increase specific brainwave frequencies associated with particular problems.

NeurOptimal® Dynamical Neurofeedback™ is an advanced user-friendly technology that harnesses dynamical properties of the brain (Ros et al., 2014) and the only NF system using nonlinear mathematics (Suzuki, 2018). Unlike linear systems, no diagnosis is involved in dynamical NF. NeurOptimal enables the individual brain to train toward its own optimal functioning by providing information about emerging turbulence of the brain's electrical activity through auditory feedback (Cochrane, 2010). This promotes self-regulation, flexibility and resilience within the brain and CNS, which regulates all other inter-related, inter-dependent systems within the body (Cochrane, 2010; Suzuki, 2018). Self-regulation of brain activity has been practiced for thousands of years in meditation, yoga, and the martial arts; however, NF can provide similar results more rapidly and efficiently (Swingle, 2008).

Neurofeedback is a novel holistic approach to cancer survivorship care that can be classified as a mind-body CAM therapy. Mind-body therapies promote healing on all levels: emotional, physical, mental, and spiritual. Large numbers of cancer survivors report use of CAM including mind-body therapies (Carlson et al., 2017). NF is used frequently in psychology to complement or as an alternative to conventional psychotherapy and/or pharmaceuticals, but it has not been adopted by mainstream medical practice and research, where there is sparse funding for non-pharmaceutical strategies. A recent survey concluded that some cancer survivors are using a variety of NF approaches for efficacious management of long-term symptoms, such as fatigue, cognitive impairment, anxiety, depression, and sleep problems (Luctkar-Flude et al., 2017). NF providers and client participants in an interview study credited NF with helping cancer survivors manage their symptoms and regain control of their lives (Luctkar-Flude et al., 2019). A study by Alvarez and colleagues (2013) called for further investigation of this CAM as a safe and effective therapy for PCCI after their preliminary study found significant improvement in self-reported cognitive function, fatigue, sleep quality, and psychological well-being among breast cancer survivors who received 10 weeks of dynamical NF. The present study used the same measures to attempt to replicate and extend beyond their results in demonstrating NF as an effective CAM therapy for PCCI. The study purpose was to evaluate feasibility and effect of nonlinear dynamical NF on cognitive functioning and fatigue in cancer survivors. Specifically, we aimed to test feasibility of recruitment strategies and our study protocol including outcome measures to assess the effect of a nonlinear dynamical NF therapy option for cancer survivors' symptoms of PCCI and secondarily for related symptoms such as fatigue, sleep quality, and psychological symptoms.

METHODS

This pilot feasibility study explored the effect of NF on PCCI, fatigue, sleep quality, and other symptoms reported by post-treatment cancer survivors. The study design used a 10-week wait-list with participants serving as their own controls. The wait-list control design is frequently used in clinical settings to control for changes that may be attributed to natural progression of a condition, passage of time, self-treatments, or participant expectations. The 10-week wait-list period allows the researcher to determine whether there have been any improvements in symptoms occurring naturally. If not, any significant improvements occurring during and following the neurofeedback training may be attributed to the therapy. This study will determine feasibility for a randomized controlled trial to evaluate the effectiveness of NF. Further, study outcomes will provide insight and preliminary data for determining a protocol by validating instruments, confirming recruitment strategies, and establishing effect size for calculation of sample size for a larger trial.

Participants

Post-treatment cancer survivors with PCCI (n = 16) were recruited through posters/postcards in community/healthcare settings, notices in local newspapers and through clinics at the Cancer Centre of Southeastern Ontario. Individuals were considered for this study if they had completed primary cancer treatment (surgery, chemotherapy and/or radiation treatment) for earlier stage (I-III) cancers and self-reported a moderate to severe level of cognitive impairment (score of 4 or higher on a 10-point scale) and/or cancer-related fatigue. Individuals with advanced cancer or metastases, epilepsy, or dementia (based on self-report) were excluded. To recruit a more homogenous sample, we targeted breast cancer survivors, as they are known to have high levels of fatigue and cognitive impairment. By having participants act as their own controls in the wait-list design, we maximized our statistical power to detect an effect, as the wait-list design requires half the number of participants compared to a two-group experimental design.

Measures

Primary Outcome Measures: Feasibility and PCCI

Feasibility was assessed by study participation, survey response, and study withdrawal rates. PCCI was measured by an objective neurocognitive assessment (CNS Vital Signs) and a standardized patient-reported outcome (PRO) measure, the FACT-Cognition Scale. CNS Vital Signs is a computerized neurocognitive test battery with psychometric properties similar to the conventional neuropsychological tests upon which

they are based (Gualtieri & Johnson, 2006). This objective assessment evaluates 11 Neurocognitive Clinical Domains and provides an overall Neurocognitive Index (NCI) score. These domains include composite memory, visual memory, psychomotor speed, reaction time, complex attention, cognitive flexibility, processing speed, executive function, simple attention, motor speed, and the NCI. Due to the costs associated with administering the objective testing, this measure was assessed at only three key time periods (Week 0, 10, and 20); whereas subjective measures were administered at five time points. For a more detailed understanding of the timeline and when participants were trained with NF, please see Table 1.

The Functional Assessment of Cancer Therapy—Cognitive Function (FACT-Cog) Scale measures perceived cognitive deficits related to quality of life reported by cancer patients (Wagner et al., 2009). The FACT-Cog demonstrated similar psychometric properties to the European Organization for Research and Treatment of Cancer—Quality-of-Life Questionnaire-C30 Cognitive Functioning Scale. However, the FACT-Cog assesses broader aspects of cognitive complaints (Jacobs et al., 2007). This measure was assessed at 0, 10, 15, 20, and 25 weeks to establish baseline and follow-up measure of these effects, as well as measure any changes throughout NF therapy. The total FACT-Cog score is of primary interest; however, individual effects across four subscales of this measure (perceived cognitive impairment, cognitive abilities, impact on quality of life, and comments from others) were assessed as secondary outcomes.

Secondary Outcome Measures: Fatigue, Sleep Quality, and Psychological Symptoms

Secondary outcomes of fatigue, sleep quality and psychological symptoms were also measured by PROs. The Functional Assessment of Cancer Therapy-Fatigue (FACT-Fatigue) is a 13-item Fatigue Subscale and is a brief, reliable (Cronbach's alpha = 0.93/0.95; test-retest correlation = 0.90) measure of fatigue in persons with cancer (Yellen et al., 1997). This measure, along with all other PROs was assessed at 0, 10, 15, 20, and 25 weeks. Pittsburgh Sleep Quality Index (PSQI) assesses sleep quality over a one-month time interval. Nineteen individual items generate seven component scores and a global score. The PSQI demonstrates acceptable measures of internal homogeneity, consistency, validity, and distinguishes well between good and poor sleepers (Buysse et al., 1989). The Brief Symptom Inventory (BSI-18) assesses 18 items on a five-point scale to measure psychological distress across three subscales: somatization, anxiety, and depression. Reliability of the Global Severity Index (GSI), also known as the total BSI score (BSI GSI) across the three scales, is reported as .95 (Derogatis & Melisaratos, 1983).

Procedures

The intervention consisted of 20 NeurOptimal™ sessions delivered twice a week over a 10-week period by a certified technician. Session length is 45 minutes including set-up time. Additional time was required when subjective/objective testing measures were due. After completing the wait-list control, participants began NF sessions 10 weeks after consenting. Participants completed surveys evaluating their symptoms at five points in time (totalling an additional 30 minutes) and objective measures of cognitive function at three points in time (totalling an additional 60 minutes). See Table 1 for the complete timeline of the study procedure. Participants had the option to participate in a qualitative interview at follow-up (an additional 30 minutes), results of which will be reported elsewhere.

RESULTS

Participants recruited for the study ($n = 16$) were all females diagnosed with breast cancer within six years prior to study enrolment. Participant ages ranged from 45 to 75 years, with an average age of 56 years. Symptom severity of PCCI at baseline was rated from 4 to 7 out of 10 with an average score of 5. Fatigue at baseline was rated from 2–8 with an average score of 4. See Table 2 for further details related to participant characteristics.

Primary Outcome Measures: Feasibility and PCCI

Regarding feasibility and attrition, all participants ($n = 16$) who started the NF protocol completed all 20 sessions of NF. However, not everyone completed all scheduled assessments.

Table 1

A detailed timeline of the study procedure

Outcome Measures	Scales	Baseline Week 0	Pre-NF Week 10	Mid-NF Week 15	End-NF Week 20	Follow-Up Week 25
Objective	CNS Vital Signs	60 min	60 min		60 min	
Subjective	FACT-Cognition FACT-Fatigue PSQI (sleep) BSI-18 (symptoms)	30 min	30 min	30 min	30 min	30 min
Qualitative Interviews						30 min
Total Testing Time		90 min	90 min	30 min	90 min	60 min

Table 2

Participant characteristics

Characteristic	Number (%)	Mean (SD)	Range
Age (years)		56.3 (8.5)	45–75
Marital Status			
Married/Common-Law	11 (69%)		
Single/Divorced/Separated/Widowed	5 (31%)		
Highest Educational Attainment			
High School	1 (6%)		
College/Undergraduate University	11 (69%)		
Graduate Degree	4 (25%)		
Annual Family Income			
< $50,000	4 (25%)		
$51,000–$100,000	5 (31%)		
$101,000–$150,000	4 (25%)		
> $150,000	3 (19%)		
Cancer Stage			
Stage 1	4 (25%)		
Stage 2	7 (44%)		
Stage 3	5 (31%)		
Time Since Diagnosis (years)		3.5 (1.9)	1–6
Treatments			
Surgery	16 (100%)		
Chemotherapy	15 (94%)		
Radiation Therapy	14 (88%)		
Endocrine Therapy	10 (63%)		
Targeted Therapy	3 (19%)		
Time Since Treatment End (years)		3 (1.7)	1–5
Comorbidities			
Lung Problems	4 (25%)		
Heart Problems	4 (25%)		
Neurological Problems	1 (6%)		
Mental Health Problems	7 (44%)		
Number of Medications		4.5 (3.6)	0–12
Symptom Severity at Baseline (0–10)			
Cognitive Problems		5.1 (2.4)	4–7
Fatigue		4.4 (2.1)	2–8
Drowsiness		3.7 (2.8)	1–9
Pain		1.2 (2.0)	0–8
Anxiety		2.7 (2.3)	0–8
Depressive Symptoms		1.7 (2.1)	0–7

Most missing data (four participants) occurred at the follow-up in which participants were not receiving NF anymore and, therefore, data collection occurred via mailed study packages rather than at the NF clinic. Difficulty reaching participants to fill out questionnaires, therefore does not indicate that NF sessions twice a week were difficult for participants to fit into their schedule.

A table highlighting the complete primary and secondary results of the study across all five time points can be found in Table 3. In total, 11 participants had complete data to conduct the analyses across the five time periods, including follow-up. In addition to reporting the F value and p values, we report the partial eta squared (η_p^2), which reflects the effect size of the intervention, with η_p^2 greater than 0.14 indicating a large effect size (van den Berg, 2021).

For the CNS NCI measure, higher scores indicate improved performance across 11 neurocognitive domains with a total NCI score. A repeated-measures ANOVA indicated the mean NCI scores were not significantly different from baseline (96.1) to the end of the NF sessions (92.2), $F(1.04, 13.5) = .637$, $p = .444$. Table 4 provides a complete list of analyses across the 11 neurocognitive domains.

A one-way, repeated-measures ANOVA with a Greenhouse-Geisser correction was completed for the FACT-Score. There

Table 3

Results of noteworthy primary and secondary analyses

Measure	Within-Subjects Effects (F, *p*)	η_p^2	Baseline Week 0 Mean(SD)	Pre-NF Week 10 Mean(SD)	Mid-NF Week 15 Mean(SD)	End-NF Week 20 Mean(SD)	Follow-Up Week 25 Mean(SD)
CNS Vital Signs							
Neurocognition Index	.637, .444		96.1(15.4)	99.5(16.6)	N/A	92.2(44.5)	N/A
FACT-Cog: Total Score							
Score range: 0–132	3.00, .093		68.3(18.0)	69.7(17.9)	79.7(33.0)	82.3(36.3)	87.4(32.8)
FACT-Fatigue*							
Score range: 0–52	5.40, .014	.375	29.5(9.1)	34.4(7.7)	36.3(12.5)	39.4(11.4)	40.4(9.0)
FACT-Cog: Perceived Cognitive Impairment*							
Score range: 0–72	4.43, .029	.307	32.5(12.9)	33.5(10.6)	40.1(19.2)	41.8(22.0)	44.4(20.3)
FACT-Cog: Cognitive Abilities**							
Score range: 0–28	7.50, .003	.429	11.6(4.0)	13.9(5.5)	16.6(6.8)	16.5(7.8)	17.2(6.1)
FACT-Cog: Impact on QOL							
Score range: 0–16	1.92, .177		8.1(4.0)	8.7(2.9)	9.1(5.8)	10.6(5.2)	11.6(4.4)
FACT-Cog: Comments from Others							
Score range: 0–16	.326, .733		13.4(2.8)	13.6(3.1)	13.9(3.6)	13.5(4.3)	14.2(4.0)
BSI-18 GSI (Total)* Score range: 0–72	3.93, .009	.282	12.3(5.7)	12.4(7.6)	9.0(10.2)	7.7(10.2)	6.3(6.4)
PSQI (Total)**							
Score 5 or higher indicates "poor sleep quality".	8.87, .001	.470	9.1(2.8)	7.8(2.6)	7.6(2.9)	6.5(2.3)	6.5(2.7)

* $p > .05$, ** $p > .005$

Table 4

Repeated measures ANOVA for the neurocognition index

Domain Name	Baseline Week 0 Mean (SD)	Pre-NF Week 10 Mean (SD)	End-NF Week 20 Mean (SD)	F, *p*	η_p^2
Neurocognition Index	96.1(15.4)	99.5(16.6)	92.2(44.5)	.637, .444	
Composite Memory	100.8(15.9)	103.6(16.0)	102.8(18.6)	.228, .798	
Verbal Memory	98.6(18.1)	107.0(16.4)	103.1(20.1)	1.41, .262	
Visual Memory	103.6(11.6)	99.3(13.9)	102.0(16.3)	.593, .560	
Psychomotor Speed**	92.1(19.4)	96.4(20.4)	98.1(20.7)	7.592, .003	.369
Reaction Time	92.2(25.7)	96.2(22.3)	95.0(22.5)	.559, .578	
Complex Attention	96.0(20.2)	98.8(19.3)	95.7(150.4)	.778, .395	
Cognitive Flexibility	97.7(17.4)	102.4(17.9)	99.5(28.0)	.908, .416	
Processing Speed*	101.8(17.2)	107.5(10.0)	108.2(15.6)	4.22, .026	.245
Executive Function	99.0(17.3)	102.8(18.7)	99.1(28.2)	.785, .467	
Social Acuity	104.2(12.2)	110.6(11.1)	103.5(15.1)	2.61, .093	
Reasoning*	101.5(12.8)	107.1(10.6)	103.6(11.9)	3.47, .046	.211
Working Memory	104.1(11.6)	106.2(8.4)	107.2(10.2)	.484, .622	
Sustained Attention	106.0(8.3)	106.5(7.9)	107.4(9.7)	.103, .902	
Simple Attention	93.3(28.8)	87.7(47.7)	-64.5(605.5)	1.04, .327	
Motor Speed	88.4(18.2)	90.6(22.1)	91.9(19.1)	2.13, .139	

* $p > .05$, ** $p > .005$

was no significant difference from baseline (68.3) to the end of the NF treatments (82.3), F(1.47, 14.66) = 3.00, $p = .093$.

Secondary Study Outcomes: Fatigue, Sleep Quality and Psychological Symptoms

Regarding secondary study outcomes in the FACT-Cog Measure, some subscales indicated statistically higher scores at the end of the NF therapy indicative of improved well-being. There were significantly better scores on perceived cognitive impairment from baseline (32.5) to the end of the NF sessions (41.8), F(1.84, 18.42) = 4.43, $p = .029$; $\eta_p^2 = .307$. There were also significantly better scores on perceived cognitive ability from baseline (11.6) to the end of the NF sessions (16.5), F(2.12, 21.24) = 7.50, $p = 0.003$; $\eta_p^2 = .429$. (Table 3). There were significantly better scores on self-reported fatigue scores on the FACT-Fatigue subscale, from baseline (29.5) to treatment end (39.4), F(2.01, 18.08) = 5.40, $p = .014$; with a small effect size ($\eta_p^2 = .375$).

For the Pittsburgh Sleep Quality Index, a score of 4 or less is associated with good quality sleep. A score of 5 or above is associated with poor sleep quality and the higher the score, the worse the quality (Buysse et al., 1989). There was a significant decrease in scores from baseline (9.1) to the end of NF sessions (6.5), F(2.13, 21.34) = 8.87, $p = .001$; partial eta squared = .470. Finally, for the Brief Symptoms Inventory, there was a significant decrease in the total score encompassing the anxiety, depression, and somatic scales from baseline (12.3) to the end of NF sessions (7.7), F(4, 40) = 3.93, $p = .009$; $\eta_p^2 = .282$.

There were no distressing side effects or adverse events reported by participants during or following NF sessions, which contributed to their completing the NF protocol and supports the safety of this CAM therapy for cancer survivors. Additionally, at follow-up, some participants reported that they have scheduled additional NF sessions to work on achieving further improvements in their cognitive functioning.

DISCUSSION

The overall aim of the study was to improve survivorship care and quality of life of cancer survivors by researching the effectiveness of NF as a potential CAM to mitigate the various side effects of chemotherapy in breast cancer survivors. These side effects include PCCI, cancer-related fatigue, and other domains, such as sleep. This study tested a protocol designed to measure the effectiveness of NF training on breast cancer

survivors who had completed cancer treatment in the past and measured the changes in various domains. These domains included an objective neurocognitive assessment (CNS Vital Signs), a standardized patient-reported outcome (PRO) measure (the FACT-Cognition Scale), as well as secondary outcomes: fatigue, sleep quality, and psychological symptoms.

There was little effect on CNS Vital Signs before and after the NF sessions. In fact, the mean scores post-NF decreased from the initial baseline, but the mid-NF scores were the highest of all three trials. One may argue that the baseline assessment may have been higher because there was less cognitive fatigue since patients did not receive NF training that day. However, it is interesting that the mid-NF trial and the end trial were higher and lower than the baseline score respectively. As this test required quick responses, the results may have been affected by testing results, such as taking a reactivity test at the end of the day may yield worse results. Studies have shown this measure is a reliable battery of tests when comparing test-retest scores (Gualtieri & Johnson, 2006), however, perhaps a third trial negatively affects participants' scores. Also, a summary of the medical literature found cancer survivors may experience cognitive impairment in various domains that are not easily identifiable without thorough neurophysiological testing (Argyriou et al., 2011), and survivors often report cognitive problems that do not correlate well with standard neuropsychological tests (Lange et al., 2019). This may indicate that such domains are too complex to measure in a single, short assessment or that traditional neuropsychological tests lack the sensitivity to detect subtle changes in cognition experienced by cancer survivors. Additionally, imaging studies suggest compensatory activation of additional brain regions in cancer survivors during testing; thus, despite impaired cognitive functioning affecting day-to-day life, cancer survivors may be able to perform relatively well in a testing environment that is free from distraction (Lange et al., 2019).

Regarding the primary PRO outcome (FACT-Cog scale), two of four subscales had significantly higher scores post-NF indicating improvement in perceived cognitive impairment and cognitive abilities after NF treatment. The cognitive comments subscale did not have significantly different baseline and post-NF scores; however, both mean scores were quite high (13.4 and 13.5). One may infer that this indicates that others' perceptions of the self are not a problem with this demographic. More research is needed to confirm this hypothesis. The FACT-Cog has been used on other cancer-related fatigue CAMs such as acupuncture, which did not find significant results partially due to a small sample size after recruiting problems (Johnston et al., 2011). Some of our subscales demonstrated significant differences and all had higher means at the end of NF, as well as at follow-up. This may indicate that NF, as an alternative CAM, could demonstrate sustained improvement in PCCI symptoms. Further, it is less invasive than other CAMs such as acupuncture, which may make it more attractive to cancer survivors. A significant, small effect was also found for the FACT-Fatigue measure. A study on breast cancer patients and yoga as a CAM found similar favourable results on the FACT-Fatigue, as well as other measures of wellbeing. They stressed the importance of adherence to treatment, as improved attendance was associated with better health outcomes (Danhauer et al., 2009), which is something to consider when referring any patient for a CAM therapy—including NF.

There was also a significant decrease in sleep quality scores indicating improved sleep. However, when applying the PSQI assessment guidelines, the mean score was still higher than 5 indicating poor sleep quality. Regardless, it is noteworthy that this score decreased from 9.1 to 6.5. The BSI GSI (Total Score) also had a significant decrease in symptoms post-treatment, indicating potential positive effects of NF on anxiety, depression, and somatic symptoms associated with cancer survivors. A recent meta-analysis found that cancer-related changes to the individual are multifaceted including the disease itself, cancer treatment, and other extenuating factors like depression and fatigue (Marshall, 2018). Therefore, not only can NF potentially attend to cognitive deficits due to cancer-related effects, it may also attend to comorbidities that are contributing to the worsening of symptoms. A systematic review on three different CAMs (acupoint stimulation, massage therapy, and expressive writing) found favourable but discrete results on fatigue, pain, anxiety, and quality of life for the various interventions, noting that no individual CAM exhibited overall effectiveness across all measured outcomes in women with breast cancer (Lee et al., 2016). While pain was not directly measured in this study, NF demonstrated positive results across various domains including fatigue, sleep, anxiety, depression, and quality of life, which may make it a strong contender as an emerging CAM for breast cancer survivors. Finally, it is noteworthy that these results mirror the Alvarez et al. (2013) study, in which significant improvements in scores were found across all measures during and after NF demonstrating replicability and, therefore, strengthening the argument for this CAM as a therapy for post-chemotherapy symptoms and PCCI in breast cancer survivors.

Limitations of the study include recruitment challenges due to limited funding to support advertising, and missing data and attrition as some participants did not complete all measures, largely at follow-up. Strategies to mitigate loss-to-follow-up in a larger RCT will include booking follow-up appointments to complete the measures, rather than relying on mailed surveys. Also, it should be noted that there was variance in the time that follow-up data was completed. While intended to be gathered five weeks after finishing NF, this data was obtained more accurately between five to 10 weeks after treatment completion.

CONCLUSION

Findings from this study demonstrated the feasibility of using the NeurOptimal nonlinear dynamical NF approach with post-treatment breast cancer survivors. The positive preliminary results support the efficacy and safety of dynamical NF. There is a need for further research to confirm these effects in a larger sample of cancer survivors, and to determine the optimal timing, frequency, and number of NF sessions to alleviate persistent debilitating symptoms such as PCCI, fatigue and sleep problems in cancer survivors. Data from this study will inform the development of a protocol for a larger scale RCT.

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