Online Family Problem-solving Treatment for Pediatric Traumatic Brain Injury

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abstract

BACKGROUND AND OBJECTIVES: To determine whether online family problem-solving treatment (OFPST) is more effective in improving behavioral outcomes after pediatric traumatic brain injury with increasing time since injury.

METHODS: This was an individual participant data meta-analysis of outcome data from 5 randomized controlled trials of OFPST conducted between 2003 and 2016. We included 359 children ages 5 to 18 years who were hospitalized for moderate-to-severe traumatic brain injury 1 to 24 months earlier. Outcomes, assessed pre- and posttreatment, included parent-reported measures of externalizing, internalizing, and executive function behaviors and social competence.

RESULTS: Participants included 231 boys and 128 girls with an average age at injury of 13.6 years. Time since injury and age at injury moderated OFPST efficacy. For earlier ages and short time since injury, control participants demonstrated better externalizing problem scores than those receiving OFPST (Cohen's d = 0.44; $P = .008$; $n = 295$), whereas at older ages and longer time since injury, children receiving OFPST had better scores (Cohen's d = −0.60; $P = .002$). Children receiving OFPST were rated as having better executive functioning relative to control participants at a later age at injury, with greater effects seen at longer (Cohen's d = −0.66; $P = .009$; $n = 298$) than shorter (Cohen's d = −0. 28; $P = .028$) time since injury.

CONCLUSIONS: OFPST may be more beneficial for older children and when begun after the initial months postinjury. With these findings, we shed light on the optimal application of family problem-solving treatments within the first 2 years after injury.

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WHAT'S KNOWN ON THIS SUBJECT: Online family problem-solving treatment (OFPST) has been linked to improved executive functioning and reduced externalizing behaviors in adolescents after traumatic brain injury, with age and socioeconomic status moderating improvements. However, nothing is known regarding optimal treatment timing.

WHAT THIS STUDY ADDS: An individual participant data meta-analysis of 5 randomized controlled trials of OFPST versus online information and/or usual care involving 359 children revealed that OFPST delivery can be optimized by referring children who are postacute recovery and older at injury.

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Effective treatments to reduce behavioral morbidity after pediatric traumatic brain injury (TBI) are gravely needed.[1] Recent randomized controlled trials suggest that online family problem-solving therapy (OFPST) may be an effective approach to reducing behavior and executive function problems after TBI, particularly among older children and those who are at elevated risk secondary to disadvantaged social environments,[2–6] more severe injuries,[2,7] or preexisting behavior problems.[4,8]

The timing of behavioral intervention delivery remains a key issue. Emerging behavior problems may not be apparent initially after TBI,[9] making families reluctant to engage in treatment. Additionally, ongoing medical procedures and rehabilitation may tax the family's ability to participate in additional treatments to address behavior problems. Understanding the optimal timing for behavioral treatments could inform medical decision-making and maximize treatment effectiveness.

Data regarding the optimal timing of behavioral or rehabilitation interventions in humans is largely lacking, although longitudinal follow-up studies of neurocognitive recovery after pediatric TBI reveal that recovery plateaus after the initial 12 to 24 months after injury.[10] Animal models also offer conflicting information, with some studies suggesting that maximal neurologic reorganization occurs during the initial days and weeks after injury[11,12] and others indicating that early intervention may prove iatrogenic.[13,14] These limited and conflicting findings, coupled with evidence that behavioral recovery in children follows a different trajectory and is influenced by different factors than motor and cognitive recovery,[15] underscore the need for further study regarding optimal timing of behavioral treatments for pediatric TBI.

Small samples and study heterogeneity with regard to age and time since injury have precluded the examination of the optimal timing of behavioral interventions for pediatric TBI to date. Individual participant data meta-analysis[16] is a powerful tool for generating patient-centric conclusions from the analysis of collections of studies while capitalizing on their heterogeneity. In fact, the IMPACT (International Mission for Prognosis and Analysis of Clinical Trials in TBI) has served as a case study for the use of individual participant data meta-analysis of prognostic studies.[17]

Using data from 5 randomized trials examining the efficacy of OFPST for the management of behavioral problems after childhood TBI, we investigated the influence of time since injury on treatment outcomes. Because previous research revealed the heterogeneity of treatment effects, new exploration of treatment timing is most meaningful in the context of other possible moderators, including child age and parental education. Additionally, we examined the joint moderating effects of injury severity and time since injury.

We hypothesized that time since injury would moderate the effectiveness of OFPST, with more pronounced benefits after OFPST seen when treatment is initiated later after injury. We further hypothesized that such differential effects would be strongest among older children, those of lower socioeconomic status (SES), and those with severe injuries.

METHODS

Overview

A comprehensive literature search was completed by a research librarian. The search yielded 138 studies with 28 from the current team. The 5 trials included here were the only ones involving a problem-solving, telehealth intervention for children with TBI. On the basis of this search, we jointly analyzed individual participant data from 5 randomized trials of OFPST for pediatric TBI involving 368 children between the ages of 5 and 18 years who were randomly assigned to the treatment or control group at 1 to 24 months after injury (Tables 1 and 2).[2,18–21] These 5 studies conducted since 2000 included OFPST, and did not select for children already experiencing problems.

This project was approved by the institutional review board, and deidentified data were analyzed. Across studies, potentially eligible children were identified by using the trauma registries of participating hospitals. Researchers in some studies used additional means of identification (Table 1). All participants were hospitalized overnight after TBI and met criteria for a complicated mild (Glasgow Coma Scale [GCS] score of 13–15 with positive findings on imaging) to severe TBI (lowest GCS score of 3–8).[22,23]

Treatment and Control Groups

OFPST

Across studies, OFPST involved 7 to 10 core sessions in which families (the child with TBI, parents and/or caregivers, and siblings when available) were provided with training in cognitive reframing, problem-solving, communication skills, and behavior management. Families could receive up to 4 additional supplemental sessions to address specific issues (ie, marital stress, sibling behavior, pain, or sleep difficulties). Treatment combined self-guided online, didactic modules and synchronous video conference sessions with a trained therapist to review online content and problem-solve around a family-identified goal. Skype sessions were 45 to 60 minutes in length. Outcomes were

TABLE 1 Recruitment Summary by Study

	Study 1[19]	Study 2[20]	Study 3[2]	Study 4[17]	Study 5[18]
Clinical trial No.	[a]	NCT00178022	NCT00409058	NCT00409448	NCT01042899
Descriptive name	Online problem-solving	Group versus individual online problem-solving	Teenage online problem-solving	Counselor-assisted problem-solving	Teenage online problem-solving multisite study
N[b]	43	42	41	132	101
Dates[c]	2003–2004	2005–2006	2006–2009	2007–2011	2010–2014
Typical procedure[d]	Recruitment from a trauma registry or during inpatient hospitalization and/or rehabilitation, with potential participants contacted by letter with follow-up by phone or in person at a clinic				
Procedure anomalies[e]	No inpatient recruitment	Additional recruitment at neurosurgery follow-up clinic but no inpatient recruitment	No inpatient recruitment	—	—
Age, y	5–18	5–18	11–18	12–17	11–18
Time since injury, mo	0–24	0–24	0–24	0–7	0–18
Injury severity[d,f]	Overnight hospitalization, GCS score <13 or 13–15 with positive neuroimaging findings				
Typical exclusionary criteria[d]	Abusive head trauma, insufficient recovery for child to participate, significant pre-injury intellectual impairment, pre-injury psychiatric hospitalizations, parent hospitalized for psychiatric reasons in past y				
Exclusionary criteria reductions[g]	Preinjury intellectual impairment, preinjury psychiatric hospitalizations, and parent hospitalization for psychiatric reasons	Preinjury psychiatric hospitalizations and parent hospitalization for psychiatric reasons	—	—	—
Treatment group	OFPST, IRC	OFPST, usual care	OFPST, IRC	OFPST, IRC	OFPST, IRC

IRC, Internet Resource Comparison; —, not applicable.
[a] Study predated clinicaltrials.gov.
[b] Number of participants assessed at baseline and randomly assigned to the OFPST or control group.
[c] Baseline assessment.
[d] Applies to all studies.
[e] Recruitment in addition to typical procedures or other deviations.
[f] Inclusionary criterion was identical for all studies.
[g] Typical exclusionary criteria that were not applied.

assessed before and after treatment (6 months later; Table 1).

Control Groups

Comparison conditions involved either access to online pediatric TBI resources (4 studies) or usual psychosocial care (1 study). Because these conditions are similar, we treated them as a single group. Participants who were randomly assigned to alternative active treatments in 2 of the trials were excluded.

Measures

Outcomes were assessed via interview and instrument completion before treatment initiation and 6 months afterward.

Background Interview

The parent and/or primary caregiver completed an interview regarding the child's medical and educational history. They also reported the parent's highest level of education, which served as a proxy for SES.

Injury Information

A research coordinator reviewed the medical chart and abstracted information regarding the injury mechanism, injury severity, and length of stay.[2,18–21]

Child Behavior Checklist

Parents completed the Child Behavior Checklist (CBCL),[24] a 112-item rating scale of child behavioral symptoms. The CBCL has high validity and reliability and is a widely used indicator of child adjustment.[25] We examined t scores on the Internalizing Problems and Externalizing Problems scales.

Behavioral Rating Inventory of Executive Functions

Parents completed the Behavioral Rating Inventory of Executive Functions (BRIEF),[26] an 86-item rating scale of everyday executive function that has been validated in both normative and TBI samples.[26,27] The Global Executive Composite (GEC) provided an overall index of executive function behaviors.

Home and Community Social Behavior Scale

Parents completed the Social Competence Scale of the Home and Community Social Behavior Scale (HCSBS)[27] to assess social

TABLE 2 Baseline Characteristics by Study

Characteristic	All	Online	CDC	TOPS Original	CAPS	TOPS RRTC
N[a]	359	43	42	41	132	101
Site, *n* (%)						
Cincinnati	174 (48.5)	43 (100.0)	42 (100.0)	16 (39.0)	45 (34.1)	28 (27.7)
Cleveland	62 (17.3)	0 (0.0)	0 (0.0)	0 (0.0)	41 (31.1)	21 (20.8)
Columbus	57 (15.9)	0 (0.0)	0 (0.0)	25 (61.0)	0 (0.0)	32 (31.7)
Denver	56 (15.6)	0 (0.0)	0 (0.0)	0 (0.0)	36 (27.3)	20 (19.8)
Mayo Clinic	10 (2.8)	0 (0.0)	0 (0.0)	0 (0.0)	10 (7.6)	0 (0.0)
Male sex, *n* (%)	188 (62.5)	21 (55.3)	22 (56.4)	17 (48.6)	78 (65.5)	50 (71.4)
White race, *n* (%)	251 (83.4)	28 (73.7)	33 (84.6)	32 (91.4)	98 (82.4)	60 (85.7)
Child of Hispanic and/or Latino ethnicity, *n* (%)	16 (4.5)	0 (0.0)	0 (0.0)	2 (4.9)	6 (4.5)	8 (7.9)
Primary caregiver, *n* (%)						
Mother	314 (87.5)	38 (88.4)	37 (88.1)	38 (92.7)	115 (87.1)	86 (85.1)
Father	34 (9.5)	5 (11.6)	1 (2.4)	2 (4.9)	13 (9.8)	13 (12.9)
Other	11 (3.1)	0 (0.0)	4 (9.5)	1 (2.4)	4 (3.0)	2 (2.0)
Parental education,[b] *n* (%)						
Less than HS	32 (8.9)	10 (23.3)	3 (7.1)	3 (7.3)	9 (6.8)	7 (6.9)
HS and/or GED	136 (37.9)	13 (30.2)	19 (45.2)	14 (34.1)	52 (39.4)	38 (37.6)
More than HS	191 (53.2)	20 (46.5)	20 (47.6)	24 (58.5)	71 (53.8)	56 (55.4)
Married, *n* (%)	214 (59.6)	20 (46.5)	26 (61.9)	28 (68.3)	82 (62.1)	58 (57.4)
Age at injury, y, *n* (%)	13.6 (2.8)	10.2 (3.2)	11.8 (3.5)	13.7 (2.5)	14.5 (1.7)	14.4 (2.1)
Time since injury, mo, *n* (%)	6.1 (5.0)	13.4 (6.9)	4.2 (3.2)	9.3 (5.1)	3.6 (1.8)	5.7 (3.9)
TBI severity,[c] *n* (%)						
Severe	141 (39.3)	12 (27.9)	12 (28.6)	18 (43.9)	51 (38.6)	48 (47.5)
Moderate and/or complicated mild	215 (59.9)	28 (65.1)	30 (71.4)	23 (56.1)	81 (61.4)	53 (52.5)
ADHD premorbidity,[c] mean (SD)						
Yes	47 (13.1)	5 (11.6)	7 (16.7)	2 (4.9)	19 (14.4)	14 (13.9)
No	309 (86.1)	36 (83.7)	35 (83.3)	39 (95.1)	112 (84.8)	87 (86.1)
Other E/B premorbidity,[c] mean (SD)						
Yes	288 (80.2)	0 (0.0)	35 (83.3)	39 (95.1)	122 (92.4)	92 (91.1)
No	26 (7.2)	0 (0.0)	7 (16.7)	2 (4.9)	9 (6.8)	8 (7.9)

ADHD, attention-deficit/hyperactivity disorder; CAPS, counselor-assisted problem-solving; CDC, Centers for Disease Control and Prevention; E/B, emotional and/or behavioral; GED, general education diploma; HS, high school; RRTC, Rehabilitation Researcher and Training Center; TOPS, teenage online problem-solving.

[a] Number of participants assessed at baseline.

[b] Reported education of the primary caregiver.

[c] Unknown values are omitted from display but are included in the percentage calculation.

competence. The HCSBS is well validated in relation to other social behavior measures and has good reliability.[28]

Data Management and Statistical Analysis

Because the current authors helped design the included trials, measures overlapped significantly across studies. This consistency obviated many barriers to individual participant data meta-analyses[17] and enabled us to focus on high-quality studies with largely consistent procedures.[29] Variables were recoded for consistency across studies, and data checks were used to identify potential inconsistencies. Nine cases were excluded because of local irregularity in treatment implementation that risked biasing the analyses. Fifty-one of the remaining cases had no measures at follow-up for an overall attrition rate of 14.27%. Additionally, 4 patients who had no TBI severity record and 4 to 5 participants who did not complete 1 or more follow-up measures are excluded from relevant analyses (Table 3). Analyzable sample sizes for child behavior, executive function, and social competence were 295, 298, and 294, respectively.

Demographic, premorbid, and injury characteristics were summarized by using descriptive statistics by study. Four linear mixed effect models were used to examine how OFPST timing may impact outcomes in 3 domains: child behavior, executive function, and social competence. Analyses were controlled for study-to-study differences (ie, potential similarities among participants in the same study) by including a random effect for the study indicator. All analyses also were adjusted for baseline score and child sex. Other potentially important control variables and treatment moderators were identified via backward elimination. Analyses began with a complex model that included a 3-way interaction among treatment, injury severity, and time since injury as well as treatment moderation by age at injury and parental education via 2-way interaction terms. More parsimonious models were identified by iteratively removing terms via F-tests based on a within-domain

TABLE 3 Regression Estimates and *P* Values From Parsimonious Regression Models

Effect	Child Behavior		Executive Function	Social Competence
	CBCL External (n^{a} = 295)	CBCL Internal (n^{a} = 295)	BRIEF GEC (n^{a} = 298)	HCSBS (n^{a} = 294)
Baseline score[b]	0.76 (<0.001)	0.75 (<0.001)	0.82 (<0.001)	0.71 (<0.001)
Female sex	−1.96 (0.03)	−0.82 (0.41)	−1.89 (0.04)	0.76 (0.42)
OFPST	15.19 (0.003)	−0.95 (0.33)	15.60 (0.003)	1.76 (<0.001)
Age at injury	0.54 (0.01)	0.12 (0.52)	0.44 (0.57)	0.11 (0.53)
Parent education				
Less than HS	−2.25 (0.41)	0.39 (0.96)	−0.65 (0.16)	−4.21 (0.22)
More than HS	−0.52 (0.41)	−0.12 (0.96)	−1.85 (0.16)	1.82 (0.22)
TBI severity	0.45 (0.63)	−0.62 (0.54)	−0.77 (0.41)	−0.18 (0.85)
Time since injury[c]	2.12 (0.65)	2.12 (0.10)	0.28 (0.08)	−0.11 (0.93)
Age at injury, treatment, OFPST	−0.96 (0.004)	—	−1.08 (0.002)	—
Parent education, OFPST				
Less than HS	—	—	—	7/98 (0.04)
More than HS	—	—	—	−0.42 (0.04)
Time since injury,[c] treatment, OFPST	−5.28 (0.02)	—	−4.66 (0.04)	—

P values from F-tests of each variable's exclusion from the model are shown. Coefficient estimates and tests are only reported for the covariates remaining in the parsimonious models after trimming. HS, high school; —, not applicable.
[a] Number of cases included in each analysis.
[b] Baseline score is the relevant response score as measured at baseline.
[c] At baseline.

significance level of .05, which was corrected .025 (.05 divided by 2) for the behavioral domain with 2 outcomes. We evaluated model assumptions via residual plots and tests for curvilinear effects of continuous variables. In post hoc analyses, we examined model-based treatment effects at the 10th and 90th percentiles of time since injury (ie, 0.13 and 1.10 years, respectively) and age at injury (ie, 9.83 and 16.88 years, respectively). Analyses and plotting were completed by using SAS version 9.4 (SAS Institute, Inc, Cary, NC) and R version 3.4.3,[30] respectively.

RESULTS

Child Behavior

Models revealed that both age at injury and time since injury moderated baseline-adjusted posttreatment ratings on the CBCL Externalizing Scale (Table 3). Post hoc contrasts (Fig 1) revealed that children with earlier ages at injury (9.83 years) and less time since injury at baseline (0.13 years) had lower average externalizing problem scores after receiving control treatment than those receiving OFPST (t[281] = 2.66; *P* = .008; effect size = 0.44), whereas the opposite pattern appears among children with later ages at injury (16.88 years) and longer times since injury (1.1 years; t[281] = −3.09; *P* = .002; effect size = −0.60). Among the other 2 subpopulations (children with later age at injury and shorter time since injury, or with earlier age at injury and longer time since injury), average externalizing problem scores at 6 months did not significantly differ across treatments. Age at injury, time since injury, and parental education failed to moderate OFPST effects on average internalizing problems. Contrary to previous analyses, the joint analysis did not indicate that parental education moderated treatment effects on child behavior and also provided no evidence that the moderation of treatment response by time since injury varied as a function of injury severity.

Executive Function Behaviors

Both age at injury and time since injury moderated OFPST's effect on executive function behaviors at follow-up (Table 3). Post hoc contrasts (Fig 2) revealed a pattern of treatment effects among subpopulations defined by age at injury and time since injury similar to that described for externalizing behaviors. Among children injured at an earlier age and treated at a short time since injury, the control treatment may be preferable to OFPST (t[283] = 2.21; *P* = .03; effect size = 0.37). OFPST appeared to be beneficial relative to control among children who were injured at a later age at both longer (t[283] = −3.35; *P* = .009; effect size = −0.66) and shorter times since injury (t[283] = −2.21; *P* = .03; effect size = −0.28). As with the CBCL, no evidence was found that parental education or injury severity moderated the treatment effect.

Social Competence

Unlike other domains, parental education moderated treatment effects on social competence, but there was little evidence of similar moderation by time since injury (Table 3). Post hoc analyses revealed greater benefits of OFPST versus the control for social competence among the subpopulation whose parents who had less than a high school education (t[279] = 3.17; *P* = .002; effect size = 0.98). Time since injury,

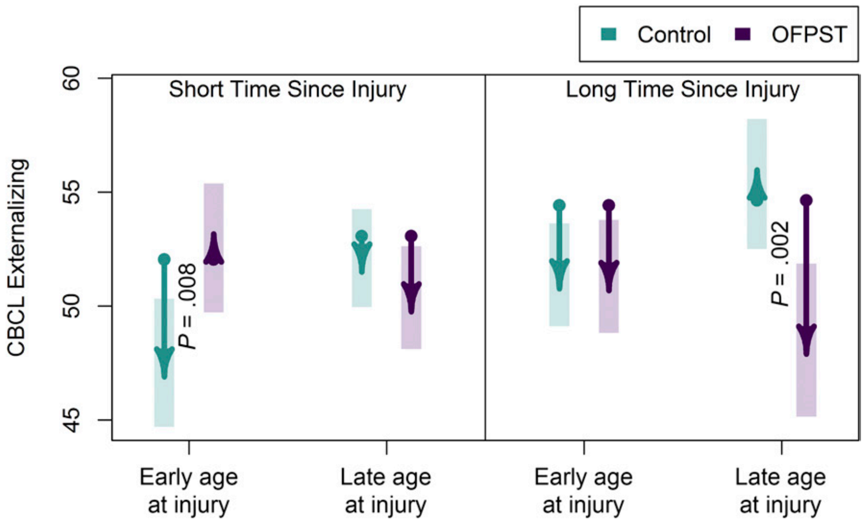

FIGURE 1
Adjusted mean levels of CBCL externalizing problems on time since injury for early and late age at injury. In post hoc model-based analyses, we compared expected 6-month externalizing scores (arrowhead; shaded bars indicate 95% confidence intervals) for OFPST and control conditions within each of 4 groups defined by time since injury and age at injury, and the baseline score (dot) is set to the observed mean within the group defined by the median age at injury and time since injury (13.93 and 0.38 years, respectively); sex, parent education, and TBI severity are set at their sample-wide mean values. Age at injury and time since injury are set to the 10th and 90th percentiles (9.83 and 16.88 years, respectively; 0.13 and 1.11 years, respectively). Based on interpreting our model at pre-specified ages at injury and time since injury, we estimated statistically significant differences in average 6-month externalizing problem scores due to different treatment assignment for early age at injury and short time since injury ($P = .03$) and for late age at injury and long time since injury ($P < .001$).

age at injury, and injury severity did not moderate the treatment effect on parent-reported social competence.

DISCUSSION

We examined individual-level data from 5 randomized trials of OFPST for children with complicated mild-to-severe TBI who were 1 to 24 months postinjury. Our joint analyses revealed that the benefits of OFPST on externalizing and executive function behaviors were more apparent for children who began treatment longer after injury. However, our analyses did not reveal that injury severity moderates treatment effect. Our analyses confirmed our hypotheses and previous findings that age at injury moderated the efficacy of OFPST, with children who are injured at an older age exhibiting fewer externalizing behaviors and less executive dysfunction after OFPST compared with similar children in the control treatment. We did not find evidence of moderation by age at injury for internalizing behaviors or social competence. Also consistent with previous findings, parent education (our proxy for SES) moderated improvements in social competence. Taken together, these findings shed important light on the optimal application of family problem-solving treatments within the first 2 years after injury.

We found evidence that OFPST was not as beneficial when implemented in the early phase of recovery. This finding is consistent with that in animal models of TBI that reveal that delaying the introduction of enrichment, an analog for treatment, was associated with greater improvement than an immediate introduction of enrichment.[13] Additionally, the finding is consistent with anecdotal parental reports that an early initiation of the intervention exacerbated family burden. Family problem-solving training has been used successfully with a number of chronic pediatric medical conditions,[31] including asthma[32] and diabetes.[33] However, TBI, unlike these other diagnoses, causes profound acute changes in attention,[34] processing speed,[34] and self-regulation[35] that may impair children's ability to engage with their parents in the problem-solving process soon after diagnosis. Although we did not find evidence that the drawbacks of introducing OFPST soon after injury were more pronounced after severe TBI, the initial fatigue[36] and concentration difficulties[37] that occur after TBI likely reduce a child's ability to directly benefit from treatment. With greater time since injury, adolescents may learn to employ the problem-solving process and related metacognitive strategies in their everyday lives. Additionally, parents may view TBI-related challenges as more persistent, rather than transient, thus heightening their engagement. OFPST differs from some other problem-solving approaches in its involvement of both parents and the child with brain injury, and as a consequence, its efficacy may be more directly a function of the child's stage of recovery and development than treatment with the parents alone.

Consistent with the previous individual studies, our meta-analysis revealed that age at injury and SES also moderated treatment efficacy. However, the moderation effects varied across outcomes such that age at injury moderated effects on externalizing behaviors and executive dysfunction, whereas parent education moderated effects on social competence. Evidence indicates that development of the brain regions that subserve self-regulation and problem-solving, which are skills targeted by OFPST, continues through adolescence and early adulthood.[38] Consequently,

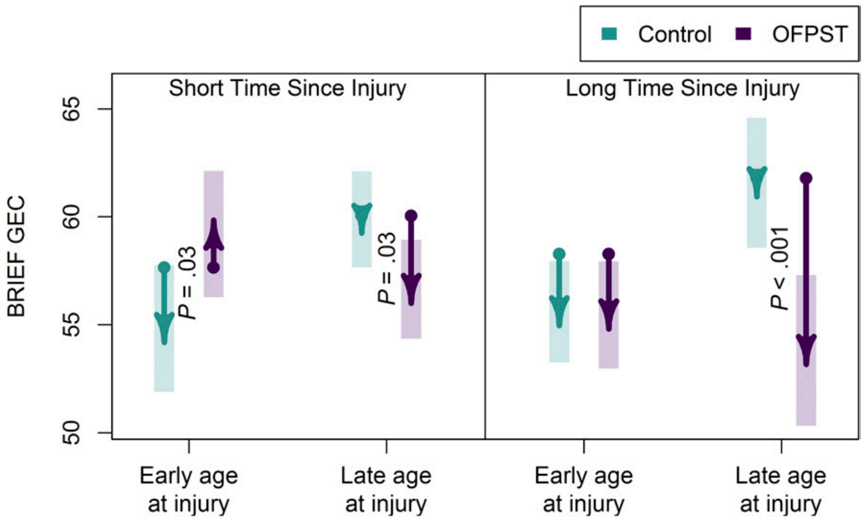

FIGURE 2
Adjusted mean levels of the BRIEF GEC of the time since injury for early and late age at injury. In post hoc model-based analyses, we compared expected 6-month BRIEF GEC scores (arrowhead; shaded bars indicate 95% confidence intervals) for OFPST and control conditions within each of 4 groups defined by the time since injury and age at injury, and the baseline score (dot) is set to the observed mean within the group defined by the median age at injury and time since injury (13.93 and 0.38 years, respectively); sex, parent education, and TBI severity are set at their sample-wide mean values. Age at injury and the time since injury are set to the 10th and 90th percentiles (9.83 and 16.88 years, respectively; 0.13 and 1.11 years, respectively). Based on interpreting our model at pre-specified ages at injury and time since injury, we estimated statistically significant differences in average 6-month BRIEF GEC scores due to different treatment assignment for short time since injury and early or late age at injury ($P = .03$ for both) and for long time since injury and late age at injury ($P < .001$).

OFPST may more closely align with the adolescent brain and social-behavioral development.[39] Thus, OFPST's emphasis on inhibition, self-regulation, and problem-solving may contribute to improvements in externalizing symptoms and executive function skills among older children and adolescents who are able to employ those skills in their day-to-day lives.

Interestingly, for younger children, the control condition was associated with significantly fewer externalizing symptoms and executive dysfunction at follow-up than OFPST, suggesting that problem-solving therapy involving a younger child with TBI is not an effective treatment. The developmental psychopathology literature suggests that parenting plays a critical role in the emergence of self-regulation in young children with parenting interventions contributing to enhanced self-regulation in children with a range of behavioral challenges, including those associated with pediatric TBI.[40–43] OFPST, alternatively, may have increased parents' awareness of problems that their young children were experiencing in the context of the limited direct benefit of the intervention on the children's behavior.

Parents with less education reported better social competence among children receiving OFPST than among those receiving the control treatment. Social competence deficits were not a primary target of OFPST, although researchers in 2 trials incorporated core content regarding reading nonverbal communication and problem-solving in social situations, and the administrators of all OFPST programs discussed the social challenges that often accompany TBI. However, social challenges may be more salient for children of lower SES given that family income and education exert profound effects on children's neurodevelopment, with parental responsiveness partly mediating this association.[44] SES has also been linked to poorer problem-solving skills.[45] Thus, OFPST may contribute to enhanced child social competence through improvements in parental responsiveness and problem-solving. Taken together, findings suggest that the characteristics of those who are most likely to benefit may vary depending on the treatment target and confirm previous research regarding potential benefits for older children and those of lower SES.

Among children who were older at the time of injury, effect sizes ranged from 0.60 (externalizing problems) to 0.66 (executive function behaviors). Effects of the intervention on social competence among less educated parents were large (0.98). Results suggest that OFPST has medium-sized effects on behavior problems among older children and those with a longer time since injury and more substantial effects on social competence among the subset with low levels of parental education.

Our newfound evidence regarding treatment timing was made possible via individual participant data meta-analysis, which offers statistical advantages over traditional meta-analysis, including more clinically relevant results. The joint analysis of individual patient data both advances our understanding of effective treatment strategies for pediatric TBI and helps propel the field toward individualized medicine. Although a single large prospective study may have been preferable, practical limitations of working with difficult-to-study populations precluded that approach. We hope that the current study can serve as an exemplar to encourage more widespread adoption of individual participant data meta-analysis for researching populations similar to survivors of pediatric TBI.

We favored an "opportunistic"[46] approach to identifying studies that allowed for us to avoid potential analytical difficulties, including inconsistency in recruitment, data collection, and variable definitions, but raised the possibility of potential selection bias. That is, our results may be more representative of patients and care in the US Midwest or may be reflective of minor design choices consistently made by this group of investigators when compared with a random sample of studies. However, given the persistent difficulties of retrieving data from original study authors,[47,48] we believe that the selection bias introduced is small and justified by expected advantages related to cost, practicality, and precision, especially because our literature search failed to reveal other studies of OFPST. Because all participants were <24 months postinjury at enrollment, we cannot draw conclusions regarding the relative efficacy of OFPST across longer time frames postinjury. Additionally, racial and ethnic diversity across studies was relatively limited, potentially reducing generalizability. Finally, all studies were largely conducted as part of a single research consortium, raising potential concerns regarding the ability of outside investigators to implement the treatment. However, 4 of the 5 studies were implemented at multiple sites with different site directors, in part mitigating concerns regarding reproducibility.

CONCLUSIONS

With these findings, we add to the limited literature on evidence-based treatments for behavioral challenges after pediatric TBI and inform the delivery of family-centered treatments. Results suggest that a later introduction of family-centered treatment is likely to be associated with greater improvements in externalizing problems and executive dysfunction; this is possibly due to a child's greater capacity to participate in and directly benefit from treatment. Precision medicine is a concept that incorporates individual variability in genes, environments, and lifestyles to identify the optimal management approach for each individual.[49,50] Current findings are used to inform a precision medicine approach for the delivery of OFPST after pediatric TBI by defining the optimal time after injury and the age of individuals who are most likely to benefit. Future research in which other factors that characterize the individuals who are most likely to benefit from treatment, such as genetic and environmental factors, are determined will be important. Overall, these findings can be used to inform the clinical delivery of OFPST and other family-centered treatments involving children.

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ABBREVIATIONS

BRIEF: Behavioral Rating Inventory of Executive Functions
CBCL: Child Behavior Checklist
GCS: Glasgow Coma Scale
GEC: Global Executive Composite
HCSBS: Home and Community Social Behavior Scale
OFPST: online family problem-solving treatment
SES: socioeconomic status
TBI: traumatic brain injury

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