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RESEARCH ARTICLE

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Reductions of intimate partner violence resulting from supplementing children with omega-3 fatty acids: A randomized, double-blind, placebo-controlled, stratified, parallel-group trial

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Omega-3 supplementation has been found to reduce externalizing behavior in children. Reciprocal models of parent-child behavior suggest that improving child behavior could lead to improvements in parent behavior, however no study has examined whether omega-3 supplementation in children could reduce intimate partner violence or child maltreatment by their adult caregivers. In this randomized, double-blind, placebo-controlled, stratified, parallel group trial, a community sample of children were randomized to receive either a fruit drink containing 1 gm of omega-3 fats (Smartfish Recharge; Omega-3 group, $n = 100$) or the same fruit drink without omega-3's (Placebo group, $n = 100$). Child participants, adult caregivers, and research staff were blinded to group assignment. Adult caregivers reported inter-partner and child-directed physical assault and psychological aggression at baseline, 6 months (end of treatment) and 12 months (6 months post-treatment) using the Conflicts Tactics Scale. Caregivers of children in the omega-3 group reported long-term reductions in psychological aggression in a group × time interaction. Improvements in adult psychological aggression were correlated with improvements in child externalizing behavior scores. No differences were reported for child maltreatment. This study is the first to show that omega-3 supplementation in children can reduce inter-partner psychological aggression among adult caregivers not receiving supplements. Findings suggest that improving child behavior through omega-3 supplementation could have long-term benefits to the family system as a whole.

KEYWORDS
externalizing, intimate partner violence, maltreatment, nutrition, omega-3

1 | INTRODUCTION

Family violence is a major social problem, as well as an important public health concern (Campbell, 2002; Devries, Mak, García-Moreno, et al., 2013; Gelles, 1990; Hammond, 2003). Intimate partner violence, which can be physical or psychological (Coker et al., 2002; Breiding et al., 2015), is associated with a host of adverse health outcomes, including depressive symptoms, heavy alcohol use, injury, and chronic illness (Coker et al., 2002; Devries et al., 2014; Devries, Mak, Bacchus, et al., 2013). In addition, violence tends to cluster within families, and children who are exposed to intimate partner violence are also at higher risk of experiencing maltreatment themselves (Hamby, Finkelhor, Turner, & Ormrod, 2010; Osofosky, 2003; Taylor, Guterman, Lee, &

Rathouz, 2009). Physical and psychological aggression against children, including childhood corporal punishment that does not meet the threshold of abuse, is also linked to negative outcomes, including aggression and mental health problems in childhood and adulthood, as well as an increased likelihood of abusing one's own child or spouse in adulthood (Crombach & Bambonyé, 2015; Gershoff, 2002; Vissing, Straus, Gelles, & Harrop, 1991).

Nutritional supplementation has been examined as a prevention strategy for adverse health and behavioral outcomes, including depression and externalizing behavior (Gow & Hibbeln, 2014; Hibbeln, Ferguson, & Blasbalg, 2006). The current study examines the effect of a randomized controlled trial of nutritional supplementation in children on family violence, including intimate partner violence and child maltreatment. The study is informed by reciprocal models of parent-child behavior (Belsky, 1984; Dodge & Pettit, 2003; Patterson et al., 1992), which are based on the assumption that parents and children have bidirectional influences on one another.

1.1 | Nutrition

Poor nutrition during childhood is associated with increased externalizing behavior problems, including aggression and conduct disorder, in childhood and adolescence (Jackson, 2016; Liu, 2011; Liu, Raine, Venables, & Mednick, 2004). The association between poor nutrition and externalizing behavior has been shown to be independent of psychosocial adversity (Liu et al., 2004), and nutritional deficits are thought to be linked to externalizing behavior problems through their role in brain development (Liu & Raine, 2006). Inadequate ingestion of certain micronutrients, trace elements, and polyunsaturated fatty acids (PUFAs) has been linked to sub-optimal brain development and cognitive deficits (Gómez-Pinilla, 2008; Gow & Hibbeln, 2014), which in turn have been associated with externalizing behavior problems in children (Liu et al., 2004). Omega-3 PUFAs are of increasing interest because of their role in brain structural and functional development (Gow & Hibbeln, 2014; Hibbeln et al., 2006).

Because of the putative nutrition-brain-behavior pathway, several randomized controlled trials have examined omega-3 supplementation as a strategy for preventing aggression and offending in adults (Gesch, Hammond, Hampson, Eves, & Crowder, 2002; Long & Benton, 2013; Zaalberg, Nijman, Bulten, Stroosma, & vanderStaak, 2010). A meta-analysis of 54 effect sizes, found that omega-3 supplementation was associated with small, but significant reductions in aggression (Gajos & Beaver, 2016; Cohen's $d = 0.20$, $p < 0.001$). Although several of the studies included in the meta-analysis examined the effect of omega-3 supplementation on aggression in children, most studies in children examined the effect of omega-3 supplementation on externalizing behavior in clinical samples with diagnosed psychiatric disorders, such as autism spectrum disorders (Bent, Bertoglio, Ashwood, Bostrom, & Hendren, 2011; Johnson, Handen, Zimmer, & Sacco, 2009) or ADHD (Gustafsson et al., 2010; Hirayama, Hamazaki, & Terasawa, 2004). Few studies have examined the effects of omega-3 supplementation on externalizing behavior in children and adolescents in community samples (Itomura et al., 2005; Raine et al., 2016; Richardson, Burton, Sewell, Spreckelsen, & Montgomery, 2012).

A recent study using the current sample addressed this limitation by randomly assigning 200 children ages 8–16 years in a community sample in Mauritius to either an omega-3 supplementation or a placebo group (Raine, Portnoy, Liu, Mahoomed, & Hibbeln, 2015). Children who were randomly assigned to receive omega-3 supplementation showed reductions in caregiver-reported externalizing and internalizing behavior 6 months post-treatment. Caregivers of children who received omega-3 supplementation also showed reductions in psychopathy 6 months post-treatment. Improvement in child behavior following treatment accounted for 38.7% of the improvement in caregiver antisocial behavior. The results suggest that improving child behavior through omega-3 supplementation may also improve caregiver behavior.

1.2 | Reciprocal models of parent-child behavior

This observed improvement in caregiver behavior (Raine et al., 2015) is consistent with the reciprocal model of parent-child behavior. The reciprocal model recognizes that parent effects on children and child effects on parents are not independent; instead, parents and children have reciprocal effects on the behavior of one another through an ongoing, bidirectional process (Belsky, 1984, Dodge & Pettit, 2003, Patterson et al., 1992). Difficult child behavior and temperament is thought to elicit negative parental behavior, including poor parenting and child maltreatment, which in turn adversely influences the child's future behavior (Belsky, 1980).

Research in this area has documented reciprocal influences of child behavior and parenting practices, including physically and verbally aggressive discipline (Pardini, Fite, & Burke, 2008; Sheehan & Watson, 2008; Xing, Wang, Zhang, He, & Zhang, 2011), although there is some evidence of cross-cultural differences (Xing et al., 2011). Sheehan and Watson (2008), for instance, found that mother's use of physically aggressive discipline predicted later child aggression and child aggression predicted later physically aggressive discipline, suggesting a reciprocal process. In addition to child-directed behavior, researchers are now also beginning to examine reciprocal influences on other measures of parent behavior and well-being, with studies finding support for reciprocal influences of child behavior and maternal depression (Gross, Shaw, Moilanen, Dishion, & Wilson, 2008) and parents' marital dissatisfaction and conflict (Cui, Donnellan, & Conger, 2007). Cui et al. (2007), for instance, found that adolescent delinquency predicted later inter-parental conflict, which in turn predicted later adolescent delinquency and marital dissatisfaction. These results suggest that child behavior may also influence inter-partner conflict in addition to child-directed behavior.

Together, this body of literature suggests that by improving child behavior, it may be possible to improve a number of parent behavior, as well. Potential areas of change could include intimate partner violence and child maltreatment given their associations with child behavior. To our knowledge, however, no experimental study of nutrition supplementation has examined whether improvements in child

behavior are associated with improvements in parent's use of violence toward either one another or the child.

1.3 | The current study

The current study is a secondary analysis of a previously published randomized controlled trial (Raine et al., 2015). The main aim of the primary analysis was to examine the effect of omega-3 supplementation in children on child externalizing and internalizing behavior. Children who received omega-3 supplementation showed reductions in externalizing and internalizing behavior (as measured by the Child Behavior Checklist; Achenbach & Rescorla, 2001) 6 months post-treatment. In addition, caregivers of children who received supplementation experienced reductions in psychopathic personality (as measured by the Psychopathic Personality Inventory; Lilienfeld & Andrews, 1996) and caregiver reactive aggression (as measured by the Reactive Proactive Questionnaire; Raine et al., 2006) 6-months post-treatment. The current study builds upon the primary analysis by evaluating whether intimate partner violence and child maltreatment were also reduced among adult caregivers when their children were randomized to receive omega-3 supplements or placebo.

There are important reasons to investigate the distinct effects of prevention programs on general externalizing behavior versus intimate partner violence. Although intimate partner violence and general externalizing behavior are modestly correlated, research has shown that crime and intimate partner violence are distinct constructs that together do not reflect an underlying antisocial propensity (Moffitt, Krueger, Caspi, & Fagan, 2000). Females arrested for intimate partner violence often specialize in only this type of offense (Bouffard, Wright, Muftić, & Bouffard, 2008). While some research has found that intimate partner violence and violence in general have similar correlates (Felson & Lane, 2010), studies of intimate partner violence often focus on distinct correlates, including relationship conflict (Jewkes, 2002). Treatments for intimate partner violence are also often specialized. The most popular (and often state-mandated) treatment for intimate partner violence is feminist psychoeducational group therapy using the Duluth method, which focuses on feminist concepts of male power and control (Babcock, Green, & Robie, 2004; Pence & Paymar, 1993; Stover, Meadows, & Kaufman, 2009). Experimental research, however, has found that this method has limited effects on re-offending (Stover et al., 2009). Research is therefore needed that examines whether a treatment that is effective in reducing externalizing behavior in general is also effective in promoting reductions in family violence. We predicted that the adults caring for children who were randomized to receive omega-3 supplementation would be more likely to report reduced intimate partner violence and maltreatment of their children.

2 | METHOD

2.1 | Trial design

The design consisted of a randomized, double-blind, placebo-controlled, stratified, parallel-group trial (1:1 ratio) of representative children in the community. After a treatment period of 6 months, supplementation was stopped and participants completed a follow-up visit (6 months visit). Participants were followed up again at 12 months. This treatment duration was chosen because prior treatment studies have usually been 2–4 months (Sinn, Milte, & Howe, 2010) and a somewhat longer treatment period may be more effective in producing longer-term brain and behavioral change. The omega-3 drink was administered by the caregivers to their children each day at a suitable time.

Trial design remained unchanged throughout the study.

2.2 | Study setting

The study was conducted from the Joint Child Health Project headquarters in Quatre Bornes, Mauritius, from November 2009 to December 2011. Further details of this country and past research can be found in Raine et al. (2010). Further details about the randomized controlled trial can be found in Raine et al. (2015). The study was registered in ClinicalTrials.gov under the title "Effect of Omega-3 Supplementation on Child Behavior Problems" at https://clinicaltrials.gov/ct2/show/NCT02016079?term=mauritius&rank=2.

2.3 | Participants

Participants consisted of $n = 139$ adult caregivers of the $n = 200$ children who all had participated in the Mauritius Child Health Project (Raine, Liu, Venables, Mednick, & Dalais, 2010). Fifty-two parents had more than one child participating in the study ($M = 1.44$ children in study/caregiver, Range = 1–3 children/caregiver). Caregivers were included if they had children aged between 6 and 16 years old, were willing to participate in an RCT, and were residing in the community. Exclusion criteria consisted of: (1) child allergy to fish or fish products, (2) child use of fish oil supplementation in the past 6 months, and (3) child intellectual disability. Written informed consent was obtained from the caregivers, while assent was obtained from the child. During consenting, participants were informed of the study hypothesis that omega-3 may help improve child behavior. Ethical approval was obtained from Institutional Review Boards in Mauritius (Ministry of Health) and the US (University of Pennsylvania).

2.4 | Omega-3 intervention

Omega-3 supplementation consisted of a 200 ml drink (Smartfish Recharge). The base drink in both treatment and control conditions consisted of fruit juice from apple, pear, pomegranate, aronia, and passion fruit. It also contained vitamin D (0.85 μg) and antioxidants (ferric reducing ability of plasma value of 0.71 mmol/100 g). For the treatment condition only, a total of 1000 mg of omega-3 (300 mg of DHA, 200 mg of EPA, 400 mg of alpha-linolenic acid, and 100 mg of DPA) was added to the base drink. Placebo drinks were matched exactly with the fish-oil drink in terms of size, appearance, and flavor.

This drink was chosen because: (i) it contains an appreciably higher dosage of omega-3 than standard capsules in a relatively small liquid

quantity (60.6% of the size of a standard can of cola) suitable for child consumption; and (ii) the fruit-flavored drink may be better tolerated and result in higher compliance with children than standard capsules.

2.5 | Outcome measures

The physical assault and psychological aggression sub-scales of the Conflict Tactics Scales (Straus, 1979; Straus et al.,1998) were used to measure intimate partner violence and child maltreatment at each time-point. The psychological aggression sub-scale consists of six items measuring nonviolent aggression (e.g., "insult or swear at him or her"). The physical assault sub-scale consists of nine items ranging from minor assault (e.g., "threw something at him/her") to severe assault (e.g., "beat him/her up"). Caregivers reported on their behavior toward their child (child maltreatment scores) and toward their partner (intimate partner violence scores). Scores for each item ranged from 0 (never) to 6 (always). Scores were summed for each sub-scale to create child maltreatment scores and intimate partner violence scores. The intimate partner physical assault sub-scale was not used in the current analyses due to very low prevalence of any inter-partner physical assault in this sample (9.1% at baseline). At the baseline assessment, the internal reliability (standardized Cronbach's alpha) for the intimate partner psychological aggression scale was 0.73. At baseline, the internal reliability (standardized Cronbach's alpha) for the child maltreatment scales were 0.61 for the psychological aggression sub-scale and 0.52 for the physical assault sub-scale. We used square root transformations of CTS variables in the repeated measures ANOVA analyses to help correct for skewness.

2.6 | Child behavior change

The Child Behavior Checklist (CBCL; caregiver-report) is a well-standardized, extensively used psychometric instrument with high reliability and validity in many countries (Achenbach & Rescorla, 2001). Measurement invariance of the CBCL has also been documented on this cohort in Mauritius (Yarnell et al., 2013). Change in child externalizing behavior was assessed by subtracting the score on the externalizing behavior scale of the CBCL at baseline from the externalizing behavior score at 12 months ($M = -2.17$, $SD = 7.16$). For caretakers with more than one child in the study, the average of the change scores for their children was used in correlational analyses.

In primary analyses of this RCT (Raine et al., 2015), there was a significant treatment group × time interaction for caregiver-reported child externalizing behavior. Externalizing behavior decreased in both the omega-3 group and the placebo group 6 months after treatment initiation. Reductions in child externalizing behavior were sustained at the 12 month visit in the omega-3 group only (41.6% reduction from baseline).

2.7 | Randomization and stratification

After providing informed consent, participants were randomized into treatment and placebo groups with blocking on a 1:1 ratio (Suresh, 2011). Prior to initial group assignment, matched pairs of participants were created from the computer data-base, with matching on age band (8–10, 11–13, 14–16), gender (male/female), and ethnicity (Indian/Creole). This stratification procedure aimed to balance groups on key demographic variables. Within each of the 100 pairs, restricted randomization to group was conducted using a computer-generated list of random numbers generated by SPSS. Children of the same caregiver were randomly assigned to the same treatment group. This procedure resulted in 100 children and 55 caregivers in the treatment group and 100 children and 84 caregivers in the placebo group.

2.8 | Adherence to protocol

Adherence to the treatment regimen was assessed at the end of treatment by asking caregivers how often the drink had been consumed (number of drinks/week). Adherence was also assessed by assays of omega-6 and omega-3 from finger-prick blood taken at baseline and 6 months (end of treatment). For detailed methods, see Lin, Loewke, Hyun, Leazer, and Hibbeln (2012).

2.9 | Statistical methods

In line with the intention-to-treat (ITT) design (Hollis & Campbell, 1999) endorsed by CONSORT to reduce bias, group membership was based on treatment allocated at initial randomization. Analyses focused on documenting group × time interactions and were conducted using repeated measures ANOVA. Violations of sphericity were handled using the Greenhouse-Geisser adjustment. Paired-samples *t*-tests were used to assess the significance of within-group change from 0 to 6, 6 to 12, and 0 to 12 months. There is no consensus as to how missing data should be handled in randomized controlled trials using the ITT design (Hollis & Campbell, 1999). While imputation of missing data respects initial treatment allocation at randomization, imputation may introduce bias (Hollis & Campbell, 1999). Therefore, analyses were conducted using complete case analysis, and sensitivity analyses were conducted by imputing missing data using the last observation carried forward strategy (White, Horton, & Pocock, 2011). Correlational analyses comparing changes in child externalizing behavior and adult caregiver behavior were conducted. All analyses were conducted using IBM SPSS Statistics 24 (Armonk, NY, 2016).

2.10 | Participant flow and recruitment

Nine hundred and thirty-eight children who had participated in the Mauritius Child Health Project were assessed for eligibility. Two hundred and fifty-eight were excluded for not meeting inclusion criteria, 230 could not be matched, 67 could not be traced, 1 declined to participate, and 188 exceeded the sample of 200. One hundred children were allocated to the omega-3 group and 100 were allocated to the placebo group. All child participants were randomized and received the allocated intervention. No participant loss was observed on baseline assessment after randomization. Of

the 200 child participants and 139 caregivers, 16 children (8%), and 13 caregivers (9.35%) were lost to follow-up at either 6 or 12 months (5 children from omega-3, 11 children from placebo). Reasons for attrition included discontinuing the intervention, conflict with school exams or inconvenient appointment times, unwillingness to answer interview questions, child dislike of assessments, and confinement in a detention center. Groups did not significantly differ in this attrition ($\chi^2 = 2.51$, df = 1, $p = 0.11$).

2.11 | Demographics and adherence to protocol

Demographic data are reported in Table 1. The omega-3 group was 48% female and the mean age was 11.07 years ($SD = 2.21$). No significant group differences were observed in children, documenting that stratification procedures were successful.

There was a significantly higher percentage of male caregivers in the placebo group than in the treatment group ($p < .05$). Caregiver marital status was assessed at the 12 month follow-up. 77.7% of caregivers in the sample were married (4.3% widowed, 2.2% separated, 2.2% divorced, 2.2% never married). There was a significantly higher percentage of married caregivers in the treatment group than in the control group ($p < .05$). Therefore, we include caregiver sex and caregiver marital status as covariates in the analyses that follow to deal with these baseline imbalances (Kahan, Jairath, Doré, & Morris, 2014). We also conducted sensitivity analyses in which we repeated the primary analysis among married caregivers only.

Average number of drinks taken per week for each group are provided in Table 1. There was no significant group difference in compliance rates ($p = 0.73$). Adherence to the protocol was also assessed using whole blood omega-3 fatty acid levels (see Table 1). A

TABLE 1 Demographics and statistical comparisons for omega-3 and placebo groups

Child demographics				
	Placebo ($n = 100$)	**Omega-3 ($n = 100$)**	**Statistic**	***p***
Age (SD)	11.57 (2.12)	11.07 (2.21)	$t = 1.62$	0.11
IQ (SD)	99.94 (13.52)	101.23 (14.54)	$t = 0.65$	0.52
Sex				
Female	48%	48%	$\chi^2 = 0.0$	1.0
Male	52%	52%		
Ethnicity			$\chi^2 = 0.08$	0.77
Indian	59%	57%		0.77
Creole	41%	43%		
Religion				
Hindu	28%	28%	$\chi^2 = 0.11$	
Muslim	32%	30%		
Catholic	40%	42%		0.95
N Drinks/week	6.49 (1.04)	6.54 (0.88)	$t = 0.34$	0.73
Omega-3 blood level				
Before	21.49 (7.44)	22.73 (7.55)	$t = 1.16$	0.25
After	22.29 (7.12)	26.39 (9.33)	$t = 3.49$	0.001
Caregiver demographics				
	Placebo ($n = 84$)	**Omega-3 ($n = 55$)**	**Statistic**	***p***
Age (SD)	38.23 (3.42)	38.21 (2.99)	$t = -0.04$	0.97
Sex			$\chi^2 = 5.46$	0.02
Female	72.62%	89.09%		
Male	37.38%	10.91%		
Education			$\chi^2 = 0.20$	0.67
Less than 7th grade	30.95%	34.55%		
7th grade or higher	69.05%	65.45%		
Marital status			$\chi^2 = 5.28$	0.02
Married	82.2%	96%		
Not married	17.8%	4%		

TABLE 2 Means and standard deviations for placebo and omega-3 groups at 0, 6, and 12 months

	Placebo mean 0 months (SD)	Placebo mean 6 months (SD)	Placebo mean 12 months (SD)	Omega-3 mean 0 months (SD)	Omega-3 mean 6 months (SD)	Omega-3 mean 12 months (SD)	Group × time interaction F (df)
Caregiver outcomes							
Psychological aggression	4.81 (4.63) $n = 77$	3.51 (3.49)[a] $n = 72$	4.04 (4.20) $n = 70$	4.56 (4.91) $n = 55$	4.26 (4.00) $n = 50$	3.06 (3.33)[b,c] $n = 51$	5.18 (2)**
Child-directed outcomes							
Physical assault	1.97 (2.43) $n = 98$	2.77 (3.88)[a] $n = 92$	2.54 (3.48)[c] $n = 90$	2.67 (1.03) $n = 99$	2.28 (1.31)[a] $n = 94$	2.65 (1.80)[b] $n = 96$	0.45 (1)
Psychological aggression	4.18 (4.45) $n = 98$	2.70 (3.75)[a] $n = 92$	3.84 (5.25)[b] $n = 90$	3.08 (3.32) $n = 99$	3.26 (3.22) $n = 94$	3.09 (3.80) $n = 96$	4.48 (1)*

Physical assault and psychological aggression were measured using the Conflict Tactics Scales (CTS). CTS variables used in repeated measures ANOVA analyses were square root transformed and caregiver gender and marital status were included as covariates.
[a]Indicates within-group behavior change from 0 to 6 months was statistically significant.
[b]Indicates within-group behavior change from 6 to 12 months was statistically significant.
[c]Indicates within-group behavior change from 0 to 12 months was statistically significant.
*$p < 0.05$. **$p < 0.01$.

significant group × time interaction indicated that groups did not differ at baseline, but post treatment (6 months), the omega-3 group had significantly higher omega-3 levels than controls ($p < 0001$), indicating increased omega-3 levels over treatment.

3 | RESULTS

3.1 | Caregiver outcomes

Treatment group means and standard deviations are shown in Table 2 and are illustrated in Figure 1. There was a significant group × time interaction for intimate partner psychological aggression, $F(2) = 5.18$ $p < .01$. Follow-up paired sample t-tests indicated that adult caregivers of children in the omega-3 group reported significant reductions in psychological aggression from 6 to 12 months ($p < 0.01$). In the omega-3 group, caregiver psychological aggression at 12 months was significantly lower than baseline (0 months, $p < 0.01$). In the placebo group there was a significant reduction in psychological violence comparing 6 months to baseline ($p < 0.01$). However, this difference did not persist, and at 12 months psychological aggression was no longer significantly different from baseline levels (0 months, $p < 0.05$). As shown in Table 3, change in child externalizing behavior scores from 0 to 12 months were correlated with changes in caregiver psychological aggression scores from 0 to 12 months ($r = 0.28$, $p < 0.001$).

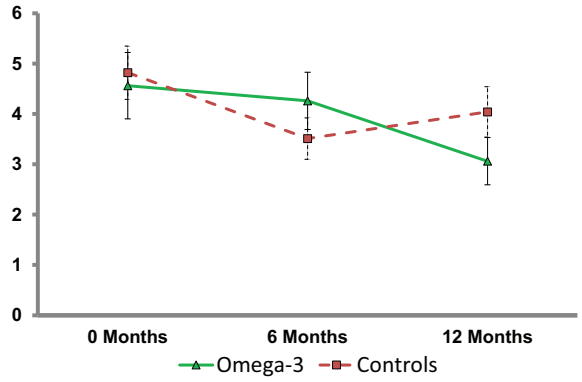

FIGURE 1 Caregiver intimate partner psychological aggression in omega-3 and placebo groups at baseline (0 months), end of treatment (6 months), and 6 months post-treatment (12 months). Error bars represent standard errors

3.2 | Outcomes of behavior directed toward the children

Treatment group means and standard deviations are shown in Table 2 and are illustrated in Figure 2. There were group differences at baseline in child-directed psychological aggression ($d = -0.28$, $p = 0.05$) and physical assault ($d = 0.38$, $p < 0.05$). Therefore, for analyses of child-directed outcomes, we included baseline psychological aggression or

TABLE 3 Correlations with change in child externalizing behavior for full sample, omega-3 group only, and placebo group only

	Full sample	Omega-3 group	Placebo group
Change in caregiver psychological aggression	0.28**	0.40**	0.13
Change in child psychological aggression	0.16	0.21	0.16
Change in child physical assault	0.22*	0.26	0.20

Physical assault and psychological aggression were measured using the Conflict Tactics Scales (CTS). Child externalizing behavior was measured using the Child Behavior Checklist.
*$p < 0.05$. **$p < 0.01$.

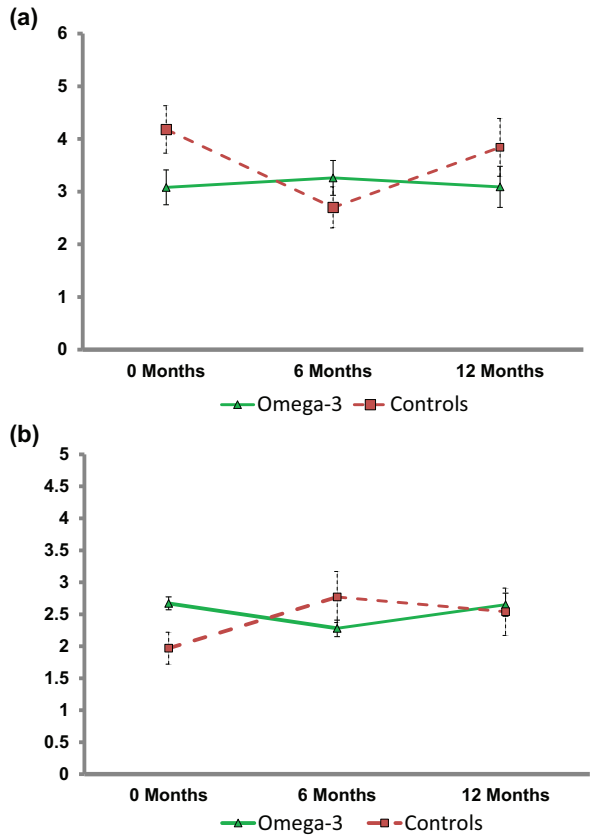

FIGURE 2 (a) Psychological aggression toward the child in omega-3 and placebo groups at baseline (0 months), end of treatment (6 months), and 6 months post-treatment (12 months). Error bars represent standard errors. (b) Physical assault toward the child in omega-3 and placebo groups at baseline (0 months), end of treatment (6 months), and 6 months post-treatment (12 months). Error bars represent standard errors

physical assault as covariates and used time of testing (6 and 12 month follow-ups) as a within-subject factor in the repeated measures ANOVA. There was a significant group × time interaction for child-directed psychological aggression, $F(1) = 3.77$, $p < 0.05$. Follow-up paired sample *t*-tests indicated that psychological aggression significantly decreased in the placebo group from 0 to 6 months, but this reduction did not persist and significantly increased from 6 to 12 months ($p < 0.05$). There was no significant change in the omega-3 group over time. The group × time interaction for child-directed physical assault was not significant, $F(1) = 0.45$, $p < 0.05$.

3.3 | Sensitivity analyses

In order to test for robustness of results, analyses were repeated using last observation carried forward to account for missing data. We also repeated analyses among only married caregivers. For both analyses, results were substantively unchanged. Detailed results can be found in Supplementary Tables S1 and S2.

4 | DISCUSSION

The purpose of this article was to examine whether omega-3 supplementation in children decreased levels of family violence. We found that omega-3 supplementation of children resulted in significant, long-term reductions in psychological aggression among their adult caregivers. These findings suggest that improving child behavior through omega-3 supplementation could reduce intimate partner violence. Results are consistent with reciprocal models of parent-child behavior, which treat the family as a dynamic system in which the behavior of parents and children have mutual effects on one another (Patterson et al., 1992). However, reductions were not observed in child maltreatment by adults in the omega-3 group. To our knowledge, only one other study has documented the efficacy of child omega-3 supplementation in improving caregiver psychopathology (Raine et al., 2015), and this is the first study to examine its effects on intimate partner violence.

4.1 | Preventing intimate partner violence

Studies have repeatedly shown that within the family, the quality of the marital relationship is closely associated with the quality of the parent-child relationship (Erel & Burman, 1994). Although child behavior problems predict martial dysfunction (Cui et al., 2007), few programs designed to prevent intimate partner violence focus on improving child behavior problems. Many existing intimate partner violence prevention programs focus on changing social norms and gender stereotypes that promote domestic violence (Murray & Graybeal, 2007). Little rigorous research has evaluated these programs, and a review of these studies found that none had utilized random assignment (Murray & Graybeal, 2007). Langhinrichsen-Rohling and Capaldi (2012) called for changes in the prevention of intimate partner violence. Suggestions included the need to focus on primary prevention and the development of early prevention programs that target broad risk factors and the family. The current study meets these needs; the findings here suggest that omega-3 supplementation in children may potentially be an effective primary prevention strategy for intimate violence by targeting family risk factors.

Our primary analysis in this sample showed that omega-3 supplementation in children reduced caregiver psychopathic personality and aggression. This analysis built on the prior findings by showing that omega-3 supplementation also reduced caregiver psychological aggression. This further suggests that specialized prevention programs may not always be necessary to reduce intimate partner violence, but rather prevention programs aimed at reducing antisocial behavior in general may also help to reduce intimate partner violence. However, we should note that the base rates of psychological aggression and physical assault in this sample were low. Therefore, findings may not generalize to samples with more extensive and severe intimate partner violence.

4.2 | Limitations, conclusions, and future directions

Although prospectively collected in a randomized trial, the initial design of the study did not include reduction in adult caregiver violence and aggression as a primary aim. This study was conducted in

Mauritius and given that the dynamics between family violence and child behavior may vary cross-culturally (Lansford et al., 2005), it is unknown how well these results will generalize to other populations and replication with a study design specifically optimized and powered to assess family violence is needed in a Western population. This study was also conducted in a community sample with relatively low levels of family violence; thus it is also unknown whether omega-3 supplementation could improve family violence in a sample with higher levels of violence. Additionally, researchers are increasingly focusing on developing interventions to prevent family violence *before* it occurs (Langhinrichsen-Rohling & Capaldi, 2012). The current study did not evaluate primary prevention, but may provide a promising strategy.

We should note that results for child maltreatment were unexpected. Child physical assault and psychological aggression did not significantly change in the omega-3 group from baseline to the 12-month follow-up. While it is unknown why child maltreatment was unchanged, it is possible that cultural norms could help to explain these findings. It could be the case that in countries in which physical discipline is more normative, the reciprocal links between child behavior and physical discipline are weakened. Consistent with this possibility, Lansford et al. (2005) found that physical discipline was less strongly associated with adverse child outcomes in countries with higher use of physical discipline. However, it remains to be seen whether normativeness of physical discipline moderates the effect of child behavior on parent's use of physical discipline. Research is needed on the perceptions and normativeness of child physical discipline in Mauritius to evaluate this explanation for the null results.

We should also note that within-group reductions from baseline were observed for intimate partner and child-directed psychological aggression at 6 months in the placebo-group. Similar placebo effects at 6 months were also observed in the primary trial for parent-reported child externalizing behavior (Raine et al., 2015). While expectation of improvement with treatment enrollment likely contributed to this effect, it is also conceivable that the antioxidants and vitamin D contained in the placebo drink may have contributed to these transient changes in caregiver and child behavior given some evidence suggesting the potential efficacy of micronutrient supplementation for lowering antisocial behavior (Benton, 2007).

The limitations of this study should be viewed in light of several strengths. This trial involved a longer treatment duration (6 months) than prior studies of omega-3 supplementation; prior studies have treatment durations as short as 1 month with a median of approximately 4 months (Sinn et al., 2010). The current study had low attrition at the 6 and 12 month follow-ups (8%). Caregiver-reported compliance data was supplemented with objective blood data documenting that children in the omega-3 group largely complied with treatment.

Although the current findings require replication, results suggest that omega-3 supplementation to disruptive children could be a promising candidate as a non-invasive treatment to help reduce intimate partner violence. In addition, existing family prevention programs, such as the Nurse-Family Partnership—which has already been found to result in reductions in intimate partner violence (Olds et al., 2004)—may see added benefits from incorporating omega-3 supplementation.

In the current study, caregivers did not receive omega-3 supplementation. Omega-3 supplementation directly among adult caregivers, in addition to their children, may also be a promising strategy for reducing intimate partner violence. It is possible that simultaneously supplementing both caregivers and their children could have synergistic effects that reduce behavior problems over and above the effects of supplementing each alone. This would be consistent with research into parenting and social skills training, which has found that providing training to both the caregiver and child is more effective than providing treatment to either one alone (Kazdin, Siegel, & Bass, 1992) An experiment is needed to that examines the effects of caregiver only supplementation, child only supplementation, and joint caregiver and child supplementation on family violence. In general, findings suggest that interventions designed to reduce child behavior problems may also have the added benefit of reducing family violence as a whole.

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CONFLICTS OF INTEREST

The authors have declared that they have no competing or potential conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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