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# The relationship between executive functioning and weight loss and maintenance in children and parents participating in family-based treatment for childhood obesity

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ABSTRACT

We examined the relationship between executive function and weight loss among children (8–12 years) and parents enrolled in a behavioral weight-loss program. 150 overweight/obese children and their parents participated in a 6-month family-based weight-loss intervention and completed baseline (month 0), post-treatment (month 6) and 18-month follow-up assessments (month 24), which included Digit Span (DS), Stop Signal Task (SST), and Wisconsin Card Sorting Test (WCST). Anthropometrics were additionally measured at mid-treatment (month 3) and 6-month follow-up (month 12). Children with more baseline WCST perseverative errors regained more weight ($p = .002$) at 18-month follow-up. Change in child BMIz was not associated with change in child executive function ($p > .05$) or parent executive function ($p > .05$). Among parents, baseline measure of DS-backward ($p < .001$) and post-treatment changes in WCST perseverative errors ($p < .001$) were associated with post-treatment changes in parent BMI. SST was not related to parent or child weight loss. Thus, children's baseline set-shifting was associated with weight regain during follow-up whereas changes in parent set-shifting was associated with changes in parent weight. Future research is needed to examine the relationship between executive function and weight loss and how this translates to intervention success for both overweight/obese children and participating parents.

## 1. Introduction

Approximately one-third of children in the United States have overweight or obesity (Ogden, Carroll, Kit, & Flegal, 2014) which is defined as having a BMI percentile ≥ 85th percentile (Kuczmarski et al., 2000). Children with overweight and obesity demonstrate deficits in neurocognitive functioning, particularly in executive functioning (Liang, Matheson, Kaye, & Boutelle, 2014; Reinert, Po'e, & Barkin, 2013). Broadly speaking, executive function is an umbrella term that refers to higher-level cognitive control processes that dictate goal-oriented behaviors (Miller & Cohen, 2001). Theoretical frameworks posit three core executive function domains: inhibitory control, working memory and cognitive flexibility (Diamond, 2013; Miyake et al., 2000). These three core domains interact to support higher-level functions involved in self-regulation of behavior like planning, problem solving and reasoning (Diamond, 2013; Munakata et al., 2011) and interact with automatic processes of attention and reward to determine ability to delay gratification (Appelhans, French, Pagoto, & Sherwood, 2016; Jansen, Houben, & Roefs, 2015).

Compared to healthy weight youth, youth with overweight or obesity may exhibit deficits in inhibition, set-shifting, delay of gratification, planning or decision making (Liang et al., 2014). Similar deficits in executive and higher level cognitive functions are observed among adults with overweight and obesity (Smith, Hay, Campbell, & Trollor, 2011). Among children, poorer executive function is linked to obesity-related behaviors such as high calorie snack consumption and sedentary behavior (Liang et al., 2014). Interventions to overcome executive functioning deficits with physical exercise show promise in improving executive functioning among children with overweight and obesity (Davis et al., 2011) and have demonstrated sustained effects among

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children up to 9-months following the exercise intervention (Hillman et al., 2014). While not targeting executive functioning skills directly, behavioral weight-loss treatments for pediatric obesity also may indirectly strengthen and enhance executive function in overweight children through a broad range of self-regulatory skills training (Hayes, Eichen, Barch, & Wilfley, 2017).

Weight-loss treatment success relies on self-regulatory skills and goal-directed actions benefiting from higher level executive functioning (Hayes et al., 2017). The most successful treatments to date for children with overweight or obesity are family-based programs (FBT) that deliver weekly group-based behavioral treatment to the parent and child separately over a 6-month period (Epstein & Wrotniak, 2010). A meta-analysis demonstrates that on average FBT programs result in reduction of BMI (Ho et al., 2012); however individual responses vary. Long-term follow-up suggests that only one-third of children who participate in FBT no longer have obesity in adulthood (Epstein, Valoski, Wing, & McCurley, 1990). FBT includes dietary and physical activity recommendations, parenting techniques, and behavior therapy skills. Moreover, the major tenets of FBT include self-monitoring of all food intake, inhibitory control of food intake to adhere to a calorie recommendation, scheduling physical activity, and planning for high-risk situations. These behaviors depend on executive functions as executive functions command behaviors needed for weight-directed goals to control eating and activity (Appelhans et al., 2016; Jansen et al., 2015). Deficits in executive function could impact the ability of parents and children to adhere to treatment recommendations and are likely to impact weight loss results. Since only one-third of children who participate in FBT are no longer obese in adulthood (Epstein et al., 1990), unaddressed mechanisms, such as executive functioning, may play a role in treatment success or failure. Successful weight-loss maintenance may be impacted by how parents and children utilize executive functioning skills to effectively respond to the obesogenic environment and make behavior changes that limit excess weight gain.

Parents are considered the major agents of change in reference to weight-related behaviors of children (Boutelle, Cafri, & Crow, 2011; Boutelle et al., 2017; Golan, 2006; Janicke et al., 2008). In FBT, parents are expected to participate with their children and model the recommended physical activity and eating behaviors. Research shows that parents on average lose weight when participating with their child in FBT (Epstein, Wing, Koeske, Andrasik, & Ossip, 1981) and that parent weight change is significantly related to child weight loss (Boutelle, Cafri, & Crow, 2012; Wrotniak, Epstein, Paluch, & Roemmich, 2004). Since parent executive function influences parent weight loss behaviors and facilitates parental management of the home environment (e.g., what foods enter the house), it is likely that parent executive function may be related to child weight loss.

To date, only one study examined executive function and weight loss in children participating in FBT (Best et al., 2012). This study found that 7-12-year-old children who demonstrated greater impairments in delay discounting (i.e., propensity to choose smaller immediate rewards vs. larger future rewards) had poorer weight-loss outcomes after FBT. Although interesting, this study focused on only one facet related to executive function (delay discounting) and did not examine the executive function skills of parents, the major agents of change in FBT (Boutelle et al., 2011, 2017; Golan, 2006; Janicke et al., 2008). Another study with 26 children ages 8–12 shows that children who were the most impulsive lost the least weight following weight-loss treatment (Nederkoorn, Jansen, Mulkens, & Jansen, 2007). Studies among older children and adolescents also show that baseline measures of executive function moderate weight loss such as those with the poorest executive function have less weight-loss success after intervention (Naar-King et al., 2016; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006). However, one study in children 7.5–15 years of age shows the opposite: more impulsivity predicted success in a 1-year weight-loss program, with age moderating the effect such that success was predicted by more impulsivity in older adolescents while there was no effect in younger children (Pauli-Pott, Albayrak, Hebebrand, & Pott, 2010). The proposed explanation for the contradictory findings provided by Pauli-Pott et al. (2010) is that older adolescents may benefit the most from the recommendation of stimulus control (i.e., keeping high calorie, tempting foods out of the house) provided in the program and thus were more successful (Pauli-Pott et al., 2010).

In adults, a few studies demonstrate that poorer executive function prior to treatment is related to poorer weight-loss outcomes following bariatric surgery and a medically-supervised lifestyle intervention (Galioto et al., 2016; Spitznagel et al., 2014; Spitznagel, Alosco, et al., 2013; Spitznagel, Garcia, et al., 2013). Two prospective studies suggest that impairments in executive function and related higher-level cognitive function like impaired delay of gratification predict higher weight at a later age (Groppe & Elsner, 2017; Seeyave et al., 2009). Further, cognitive trainings, targeting improving executive function, show there may be some benefits in aiding weight loss maintenance although effects do not always persist over time (Jones, Hardman, Lawrence, & Field, 2017; Verbeken, Braet, Goossens, & van der Oord, 2013). While this initial evidence supports the relationship of executive function and weight change, more studies are needed to fully evaluate the relationships between various executive function factors and weight-loss outcomes in youth and adults to better understand the underlying mechanisms in weight loss and maintenance.

Thus, the purpose of this study was to complete a secondary data analysis to examine the relationship between three key facets of executive function (working memory, inhibition, and flexible decision making) and weight-loss outcomes among children and parents participating in a FBT or FBT-based intervention with only parents attending treatment (PBT) (Boutelle et al., 2017). In particular, this study examined three questions about weight loss among children: 1) Was child baseline executive functioning related to child weight loss and weight-loss maintenance over time?; 2) Was parent baseline executive functioning related to child weight loss and maintenance over time?; 3) Were post-treatment changes in child executive functioning related to changes in child weight loss over time? We then addressed two additional questions regarding parent weight loss: 4) Was parent baseline executive functioning related to their own weight loss and maintenance over time?; and 5) Were post-treatment changes in parent executive functioning related to changes in their own weight over time? We hypothesized that both parent and child executive function would be related to weight loss outcomes in the child and that parent executive function would be related to parent weight loss. We also evaluated whether baseline executive function would be associated with weight loss and maintenance or whether executive function and weight appeared to change together over time. By elucidating these relationships, this study will contribute to the research base regarding the role of child and parent executive function on weight change in FBT-based programs and explore a potential mechanism by which parents serve as the agent of change in child weight loss.

## 2. Methods

### 2.1. Participants

One-hundred and fifty children with overweight and obesity (10.4 ± 1.3 years; 66.7% female; 43% non-Hispanic White, 31% Hispanic, 24% non-Hispanic other race; Body Mass Index (BMI): 26.4 ± 3.6 $kg/m^2$; BMI z-score: 2.0 ± 0.34) and their parents (42.9 ± 6.4 years; 87.3% female; 49% non-Hispanic White, 31% Hispanic, 20% non-Hispanic other race; BMI: 31.9 ± 6.3 $kg/m^2$) participated in a six-month Family-based Behavioral Treatment (FBT) weight-loss intervention. Children and parent dyads were enrolled in the study for 2 years and followed for 18-months after treatment [anthropometric assessment time points: 0 months (baseline), 3 months (mid-treatment), 6 months (post-treatment), 12 months (6-month follow-up) 24 months (18-month follow-up)]. Executive function was