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The Healthy for Life Taekwondo Pilot Study: A Preliminary Evaluation of Effects on Executive Function and BMI, Feasibility, and Acceptability

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Abstract

There is growing consensus that exercise improves cognitive functioning, but research is needed to identify exercise interventions that optimize effects on cognition. The objective of this pilot study was to evaluate Taekwondo implemented in public middle school physical education (PE). Two classes were randomly assigned to either: five sessions per week of PE or three sessions of PE and two sessions of Taekwondo. In PE sessions, evidence-based curriculum to address the Presidential Core Fitness Guidelines and California Physical Fitness Tests was implemented. Taekwondo sessions included traditional techniques and forms taught in an environment emphasizing respect and self-control. Sixty students were evaluated at baseline and during the last week of the intervention (nine months later). Differences in mean residualized change scores for parent-rated inhibitory behavioral control yielded a significant, large effect size (d =.95, p =.00), reflecting greater improvement among Taekwondo students. Results from an executive function computer-administered task revealed greater accuracy on the congruent trial (d = 2.00, p = .02) for Taekwondo students. Differences in mean residualized change scores for BMI z scores yielded a moderate, non-significant effect size (d = − .51, p = .16). The majority of Taekwondo students reported positive perceptions of Taekwondo and perceived self-improvement in self-control and physical fitness. Results suggest that Taekwondo is an exercise program that improves cognitive functioning and is both feasible and acceptable to implement in a public school setting.

Keywords

Taekwondo; martial arts; exercise; executive function; self-control; self-regulation; attention

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Among the many benefits of exercise, cognitive benefits are receiving increasing attention among scientists and society at large. Davidson, Amso, Anderson, and Diamond's (2006) definition of executive function describes critical cognitive abilities, which could be potential targets in studies of the impact of exercise on cognitive functioning. These include holding information in mind and manipulating it to inform actions (working memory), exercising self-control (inhibition), and adapting behavior to meet situational demands (cognitive flexibility). These executive functions may be among the major human capacities that contribute to positive outcomes. In an observational study of 1,000 children recruited at birth and followed for 32 years, Moffit et al. (2011) found that measures of self-control in early childhood predicted physical health, substance dependence, personal wealth, and criminal outcomes in adulthood. They concluded that success depends largely on self-control, making it an important target for measurement and intervention. Moreover, they documented a robust self-control gradient that suggests that universal interventions are warranted.

Universal school-based interventions have tremendous potential to reach large numbers of children. Given growing concerns about children's fitness and the rise of childhood overweight and obesity, school-based interventions that address physical fitness and executive functions simultaneously may provide a timely, efficient response that could change the trajectories of children at risk for health (overweight and obesity), academic, and behavior problems, which are interrelated and affected by executive functioning (Moffit et al., 2011; Diamond & Lee, 2011). There is growing evidence that moderate to vigorous (aerobic) exercise promotes enhanced cognitive functioning (e.g., Davis et al. 2007; Tomporowski, Miller, Davis, Miller, & Naglieri, 2008). A meta-analysis documented an effect size of .32 on cognitive outcomes following exercise interventions, with middle school students showing the greatest improvements (Sibley & Etnier, 2003). Cognitively-engaging aerobic physical activity that incorporates planning, problem-solving, responding and adjusting to novel stimuli (set-shifting), and complex motor movements appears to have stronger effects on executive function processes than physical activity consisting of primarily repetitive movements, such as distance running and swimming, which require limited cognitive demands (Best, 2010). Prior research suggests that increased oxygen saturation, angiogenesis, and levels of neurotrophins in the brain may account for exercise-induced improvements in cognitive performance, and benefits associated with changes in neural activity may be further enhanced by goal-directed physical activity that involves effortful mental engagement (Hillman et al., 2008; Tomporowski et al., 2008). Reviews of the effects of exercise on cognition note that an important priority should be the study of specific exercise interventions that optimize effects on cognition (Best, 2010; Hillman, Erikson, & Kramer, 2008; Diamond & Lee, 2011). Exercise interventions that may optimize effects on cognition include certain forms of dance, gymnastics, and martial arts, which share a focus on choreographed, complex physical movements.

An exemplar martial art is Taekwondo, a globally popular Korean martial art that is recognized as an Olympic sport. Traditional Taekwondo is an art refined over generations that engages students in a process whereby they work to improve themselves cognitively (e.g. building capacity to focus), physically (e.g., building physical flexibility, fitness, strength, and precision in motor movements), emotionally (e.g., learning to meditate, controlling negative emotions), and socially (e.g., practicing respect toward others and individual responsibility). Embedded in Taekwondo is a mature philosophy of behavior that emphasizes self-control, respect, integrity, perseverance, goal-setting, and focus. At the core of Taekwondo is an approach to exercise built on complex physical activity that involves planning, problem solving, and set shifting. The cognitive complexity of physical activity in Taekwondo practice is illustrated in *poomse ("forms")*, which are a series of choreographed physical movements performed with technical precision in a particular order. At the

beginner level of training, forms are relatively simple, having fewer and less technically difficult movements (for example, one lower-level form has 36 individual movements, including blocks and kicks, that follow a directional pattern requiring the student to turn multiple times in four different directions). In a serious of scaffolded steps, over a period of several months, a student practices his or her new form, practicing inhibitory control and exercising working memory. Practicing poomse (Figure 1) exercises working memory by requiring the student to keep a series of steps and movements in mind and to execute them with precision in a particular order. For example, when a student first learns a form, the instructor may demonstrate the first six movements (e.g., performing a particular block while in a specific stance), practice those six movements alongside the student so she can follow, and then watch the student perform the six movements, providing prompts only when needed. The student will need to memorize the movements, keeping in mind not only the series of steps, but also the precise manner in which each is executed. While executing each step, she is also practicing inhibitory control by focusing her attention on her actions and evaluating and correcting herself when needed. When she has mastered these first six movements, the instructor will add another number of movements, continuing the process until the student can execute the entire form correctly. At each stage of progression (recognized by moving to higher levels that are noted by different belt colors), forms become more challenging (increasing both the number of steps or movements and the complexity and physical difficulty of the movements), and the Taekwondo student is expected to be able to perform all previously learned forms as well as new forms. The culmination of the experience of learning new forms and techniques is a ceremony where accomplishments are recognized among a community of instructors, peers, and family with a promotion accompanied by a certificate and new color belt.

Prior research (Ainsworth et al., 2000) has classified Taekwondo as a physical activity of vigorous intensity based on its rate of energy expenditure, with a metabolic equivalent (MET) intensity level of 10 (expressed as the ratio of its work metabolic rate to a standard resting metabolic rate of one unit/MET). Although the numerous functional benefits associated with martial arts, particularly Taekwondo, have received more empirical attention among adults, there is growing systematic evidence for the physical (Kim, Stebbins, Chai, & Song, 2011), motor (Fong, Tsang, & Ng, 2012), and cognitive and behavioral (Lakes & Hoyt, 2004) benefits of Taekwondo for children and adolescents. Lakes & Hoyt demonstrated a positive impact of a school-based Taekwondo intervention on executive functions in elementary school students. They randomly assigned half of the homeroom classes in an elementary school (207 students) to a Taekwondo intervention, and the other half served as a control. The intervention group participated in traditional Taekwondo during 2 of their 3 weekly physical education (PE) sessions; their third session was standard PE. The control group participated in standard PE for all 3 of their weekly PE sessions. Lakes & Hoyt used multi-method, multi-informant pre and post intervention assessments to evaluate outcomes. The Taekwondo group showed significant improvements in the areas of observer-rated cognitive, affective, and motor regulation; children in the Taekwondo group also improved more on an executive function task and were rated by their teachers as demonstrating more improvement in prosocial behavior. Gains were greater for those with poorer executive function pre-intervention and for older (5^{th} and 6^{th} grade) children. The intervention was brief – three months long – and was conducted in a private school in an affluent community where children's baseline scores indicated very few problem behaviors. Thus, it was notable that improvements were found given the limitations of the sample.

The Present Study

This study was developed as a community-based participatory research project. The lead researcher had worked with a successful community-based intervention program, Healthy

for Life, as a part of the community engagement efforts of the Institute for Clinical and Translational Science at UC Irvine. Healthy for Life was formed as a community initiative to enhance public nutrition and physical education in schools where obesity and overweight rates were the highest. Healthy for Life had successfully provided training for PE teachers as well as nutrition education (providing educational information to parents and students) for eight years. In addition to training PE teachers, Healthy for Life also provided equipment as well as guest kickboxing instructors to enhance PE classes. Initially, the researcher worked with Healthy for Life to help evaluate program outcomes and examine potential areas to increase the program's impact. Their positive experiences with kickboxing led to an interesting research question – if kickboxing were replaced with traditional Taekwondo training, could students improve their executive function and behavior as well as their physical fitness?

Together, academic and community partners developed the current pilot study to address the feasibility and acceptability of implementing Taekwondo into PE in a public, low-income middle school as well as to investigate the effects of Taekwondo in a Title 1 (low-income) middle school over a full academic year. In addition, the study was designed to test and evaluate the use of a research assessment protocol in a school setting and to examine preliminary outcomes. This extends the research of Lakes & Hoyt (2004) by examining executive function and health outcomes in a diverse population of students (older children from low-income and ethnic minority backgrounds), over a longer period of time (nine months instead of three months), in larger PE classes (close to 50 students instead of 16), and in a different Taekwondo system (i.e., the intervention would be taught by different instructors than those in the prior study). In addition, a direct measure of executive function (Davidson, Amso, Anderson, & Diamond, 2006) and physical measures were added to the assessment protocol.

Predicted outcomes were based on two hypotheses. *Hypothesis 1:* Students in the Taekwondo group would demonstrate greater improvement in executive functions than children in the PE control group. *Hypothesis 2:* Students in both groups would demonstrate equivalent improvements in physical fitness. During the community planning process, community members asked if Taekwondo, because of its inclusion of activities perceived to be less aerobic and more cognitive (e.g., learning a form), might have a weaker effect on overweight and obesity. Researchers and Taekwondo instructors expected that this would not be the case as Taekwondo includes intervals of high aerobic activity and, thus, hypothesized that physical outcomes would be equivalent to those obtained through PE.

Method

Participants and Randomization Design

The study was implemented at a public middle school in Southern California. The participating middle school had two grade levels (7^{th} and 8^{th}) and more than 600 students. The school's 2011 accountability report indicated that among its 7^{th} grade students, only 32.6% met all six of six fitness standards established by the state of California (in the areas of aerobic capacity, body composition, abdominal strength, trunk extension strength, upper body strength, and flexibility), based on a health-related fitness assessment tool (FITNESSGRAM).

Each student at the participating school participated in daily PE (5 PE classes per week, each approximately 40-45 minutes in length). The school agreed to implement Taekwondo as a component of their PE curriculum (in two of the five PE sessions across the week) for one academic year for this study. Two PE classes were selected for the study based on the following criteria: 1) both classes were taught by the same PE teacher to ensure that their

weekly PE sessions (five for the control group and three for the Taekwondo group) contained the same curriculum with the same instructional style; 2) the classes occurred consecutively in the morning (about 10:15 and 11:00 a.m.) to minimize effects due to the time of day; 3) the classes were both in the participating grade level (7^{th} grade); and 4) assignment to either PE section was expected to be random and not dependent on other factors that might impact sample characteristics. The two selected classes were randomly assigned to either Taekwondo or an enhanced PE condition. Research participation was optional.

At the beginning of the school year, researchers asked parents of children in the two classes for permission to study the program effects by sending study information home for their review. Consent and all parent rating forms were provided in the three most common languages spoken by the parents of participating children: English, Vietnamese, and Spanish. Ninety-eight students were enrolled in the two classes at the beginning of the school year; 81 students (83% of the enrolled students) participated in the evaluation. Parents of 60 of these 81 students provided consent for their child's participation in individual assessments to measure outcomes, although some provided only partial consent (e.g., consent for physical measurements, but not psychological or vice versa). Parents of the unconsented students did not respond to information sent home; feedback from their teacher indicated that in some situations, parents were unable to respond (e.g., due to incarceration) and some students were living with friends or extended family. In addition, although recruitment materials and consent documents were provided in the three most common languages in the community, some parents needed materials in additional languages and because of resource limitations, translation was not available in those languages. After parental consent was obtained, students provided assent for their participation. Demographic characteristics of participants are summarized in Table 1.

Power Analysis

Power analysis was based on an anticipated effect size on behavioral outcome measures of $d = .40$ (Lakes & Hoyt, 2004). With an N of 75 per group, to detect an effect of this size, power would be 95% (Cohen, 1988). Therefore, this pilot study lacked sufficient power to measure effects with statistical significance, but was expected to be sufficient to note trends in improvements that could be studied in a subsequent larger study. Thus, the analytic plan focused on the computation of effect sizes and confidence intervals (Cummings, 2012) in addition to statistical significance testing.

Study Procedures

The PE group received standardized PE with activities that included stretching, running, and exposure to various sports and games. Students in this condition participated in these activities for all five of their weekly PE sessions. Prior to the start of the year, the PE teacher participated in training provided by the Healthy for Life program. A two and half hour training session with a PE Master Trainer provided the teacher with an evidence-based, age-appropriate physical activity curriculum and equipment to address the Presidential Core fitness Guidelines as well as the California Physical fitness Tests. As part of the Healthy for Life program, the Fitness for Life Curriculum (www.fitnessforlife.org) was provided to supplement the current district PE curriculum. The same teacher taught PE classes using this same Fitness for Life Curriculum in both the PE (5 sessions) and TKD (3 sessions) conditions. Contracted Taekwondo masters (i.e., instructors who had earned a fifth degree black belt) taught the two weekly Taekwondo sessions in the TKD condition. The Taekwondo instructors had extensive experience teaching Taekwondo to children, both in their private studios and in a local, private school where they had previously taught Taekwondo as physical education.

The Taekwondo group practiced traditional Taekwondo techniques (e.g., stances, blocks, strikes, and kicks) and poomse (forms) in a physically active setting with a focus on mindful practice. The environment was structured to emphasize respect, including bowing to the instructor as well as fellow students and reporting to class in a traditional uniform, which was provided to participants at no cost. Training was scaffolded and provided opportunities for mastery experiences and recognition of accomplishment. Learning Taekwondo involves: a) planning steps necessary to execute a movement or series of movements, b) self-monitoring movements, c) self-evaluating performance, and d) self-correcting by adjusting movements to mirror techniques demonstrated by the instructor. In traditional Taekwondo, sparring (one-on-one matches to practice self-defense) is not taught to students until they achieve a particular belt level and earn the instructor's trust in their capacity to use their training only for self-defense (versus aggression toward others). In the 9-month intervention, students would not achieve the necessary level to spar; therefore, the one-on-one sparring that many people think of when they think of martial arts was not part of the intervention. Over the nine-month period student progressed two levels (from white to orange belt and from orange to yellow belt) in Taekwondo (most Taekwondo systems have at least 10 color belt levels prior to earning a black belt).

Assessment Procedures and Instruments

The research design included a multimethod approach to measuring outcomes. Cognitive outcomes were measured using a computer test of executive function (at post-test only) as well as parent ratings of student's attention and behavior control (at both pre- and post-test). Physical outcomes were measured using a pediatrician's assessment (at both pre- and post-test), and program acceptability was measured using a participant questionnaire (at post-test only). At both time-points, parent questionnaires were delivered to parents in a stamped envelope with a request to return all forms within one week. Executive function computer task assessments and physical measurements were conducted during school hours at the school; the pediatrician and assistants were not made aware of group assignment. Students and parents received incentives ($5 each) for completing outcome measures at each time-point.

Strengths and Weaknesses of ADHD and Normal Behavior (SWAN)—The SWAN (Lakes, Riggs, & Swanson, 2011) is a rating scale completed by parents or teachers to measure attentional and behavioral control (available at www.adhd.net). The SWAN has 18 items that load on two factors, each with 9 items: Attention and Hyperactivity/Behavioral Control. On each item, the child is rated on a 7-point scale (far below average, below average, slightly below average, average, slightly above average, above average, and far above average). Examples of attention items include: "Gives close attention to detail and avoids careless mistakes," "Sustains attention on tasks or play activities," "Listens when spoken to directly," "Organizes tasks and activities," "Engages in tasks that require sustained mental effort," and "Ignores extraneous stimuli." Behavioral control items include: "Modulates motor activity," "Modulates verbal activity," "Reflects on questions (control blurting out answers)," and "Sits still (controls movement of hands/feet or controls squirming)." In this study, the SWAN was scored so that higher scores indicated greater inhibitory control.

The SWAN was provided to parents in English, Spanish, and Vietnamese. The psychometric properties of scores derived from the English and Spanish versions of the SWAN have been studied in prior research (e.g., Swanson et al, 2012; Lakes, Riggs, & Swanson, 2011), but the Vietnamese version was translated specifically for this intervention study. In this sample, the internal consistency of scores obtained using the SWAN was strong: .97 and .95 for the Attention and Hyperactivity (Behavioral Control) scales, respectively.

Hearts & Flowers Executive Function Test—The Hearts & Flowers test (Davidson, Amso, Anderson, & Diamond, 2006; Diamond, Barnett, Thomas, & Munro, 2007) measures executive functions, including attention, inhibitory control, working memory, and cognitive flexibility. This measure was administered to students individually by a researcher using a touch-screen laptop computer in a private office at the school. All students completed the test on the same laptop computer and were instructed to place their hands in the same position in front of the screen in order to maintain equal distances from the screen for all students. Students wore noise-reducing headphones to block outside noise. Completion of the test (consisting of three blocks of trials) required about 8 minutes per student, including set-up, instructions, and practice. In the first block (Congruent), students were asked to press a button on the screen on the same side as the stimulus (heart). Following practice, there were 12 trials in which the heart appeared on either the left or right side of the screen. For the second block (Incongruent), students were asked to press the button on the opposite side of the stimulus (a flower). After practice, there were 12 trials. The final block (Mixed) consisted of 33 trials in which a student was presented with either a heart or flower; students were required to inhibit automatic responses, retain rules in working memory, and quickly shift between rules to press the correct button. Performance was evaluated using accuracy scores and median response time (in milliseconds) for each of the three blocks. The first trial of each block was omitted from analysis for both accuracy and response time scores. Accuracy scores were based on the percentage of correct responses in a given block (number of correct responses divided by the number of trials). To reduce the effects of outliers, a median response time was calculated for each block (Davidson et al., 2006); analysis was based on response times for correct responses only.

Physical Measurements—A pediatrician conducted a physical evaluation on each student. Standard, calibrated scales for weight and stadiometers for height were used to calculate Body Mass Index (BMI). BMI was determined using the Centers for Disease Control and Prevention (CDC) 2000 growth charts for ages 2-20 years and by gender. Height and weight were obtained from each participating student and their BMI was calculated. According to the CDC, students were identified as overweight with a BMI in the 85^{th} – 94^{th} percentile and students with a BMI ≥ 95^{th} percentile were identified as clinically obese. If a student was identified as clinically obese (BMI ≥ 95^{th} percentile), had elevated blood pressure for age, gender and height percentile, had acanthosis nigricans (physical sign of insulin resistance/prediabetes) or had other medical concerns, parents were informed by the pediatrician and encouraged to obtain further medical assessment by their physician or local clinic. Prior to analysis, standardized *z*-scores were computed for each student's BMI.

Acceptability Questionnaire—Acceptability of the intervention was evaluated by asking Taekwondo students to complete an evaluation developed for this study. Students responded to seven questions using a 6-point Likert scale (1=Strongly disagree, 2=Disagree, 3=Slightly disagree, 4=Slightly agree, 5=Agree, and 6=Strongly Agree). Items are listed in Table 3.

Analyses

Data were collected from multiple sources using a multimethodological approach (e.g., self-report questionnaire, computerized performance task, parent questionnaire, physical measurements), and were merged into a primary database to facilitate efficient data management. SPSS (version 20) was used for all analyses.

To test Hypothesis 1, exercise condition (group) served as the primary predictor variable with measures of executive function as dependent variables. BMI *z*-scores served as the outcome variable to test Hypothesis 2. For SWAN scores and BMI *z*-scores, ANCOVAs

were used to test for differences between groups, with pre-intervention scores included as covariates in the analyses. For all measures except the executive function computer task, post-test scores were regressed onto their corresponding measures of pre-test scores to obtain unstandardized residualized change scores. Effect sizes were computed by subtracting the mean residualized change score for the control group from the mean residualized change score for the intervention group and dividing by the average of the standard deviations for the intervention and control group means. Cummings' (2012) ESCI (Exploratory Software for Confidence Intervals: www.thenewstatistics.com) was used to compute 95% confidence intervals. Data obtained from the executive function computer test were analyzed using the two-group post-test only randomized design; these analyses were limited to students who had baseline data for parent-rated executive function (SWAN scores). ANCOVA was used to test for differences between groups, with SWAN total scores included as a covariate to adjust for baseline differences in executive function. A logarithmic transformation was used on congruent trial accuracy scores of the executive function computer task to reduce skewness. Effect sizes (Cohen's *d*) were computed by subtracting the control group mean from the intervention group mean and dividing by the pooled standard deviation. N's varied across measures (and are noted in the tables) due to partial consents and missing data (i.e., for some students residualized change scores could not be computed because they were absent during either the pre or post testing sessions). Nonsignificant results from ANCOVAs should be interpreted cautiously, as our power analysis indicated that it would be unlikely that we would detect significant differences given the sample size of this pilot study.

Frequencies were computed for demographic data and responses to the acceptability questionnaire. As the acceptability questionnaire yielded ordinal data, the median was selected as the most appropriate statistic to report (Clegg, 1998). Open-ended responses on the questionnaire were analyzed using qualitative thematic methods (King, 1998; Crabtree and Miller, 1999); researchers independently reviewed the qualitative data to identify themes as they emerged in the data. Researchers then met to review the data and discuss the themes. In accordance with qualitative procedures, supporting examples of themes are provided in the results.

Results

Hypothesis 1: Parent-Rated Inhibitory (Attentional and Behavioral) Control

Mean residualized change scores for attentional control and behavioral control are reported in Table 2. Differences in mean residualized change scores for attention and behavioral control yielded moderate to large effect sizes (*d*'s = .62 and .95 for the attention and behavior control scales, respectively). Differences between groups were statistically significant for the behavioral control scale ($p < .001$). These findings indicated greater improvement among students enrolled in Taekwondo compared to the PE control group (see Figure 2).

Hypothesis 1: Executive Function Task Performance (Inhibitory Control, Working Memory, Cognitive Flexibility)

Results for the Congruent, Incongruent, and Mixed trials (see Table 2, Figure 3) indicated greater accuracy among Taekwondo students (*d*'s = 2.0, 1.43, and 2.33), and the difference between groups was statistically significant for (log-transformed) accuracy on the congruent trial ($p = .02$). Differences in response times were not statistically significant; though not significant, the effect sizes indicated a small effect for faster response times on the congruent trial and moderate to large effects for slower response times on the incongruent and mixed trials among Taekwondo students.

Hypothesis 2: BMI *z*-scores

Differences in mean residualized change scores for BMI *z*-scores (Table 2) yielded a non-significant, negative, moderate effect size ($d = -.51$, $p = .16$), indicating a trend toward larger BMI reduction among students in the Taekwondo group.

Feasibility and Acceptability of the Program

School personnel remained supportive of and enthusiastic about Taekwondo throughout the academic year and expressed a willingness to continue the intervention contingent upon funding. There were no adverse events reported over the course of the intervention. The primary administrative challenge was that some students needed to change their course schedule and, as only one class at the school received Taekwondo, course schedule changes impacted their ability to participate. As a result, several students who completed an initial assessment did not complete the intervention. At the start of the second semester, administrators found it challenging when enrolling students in their second semester classes to keep all the Taekwondo students in one PE class. However, they managed to arrange schedules to accommodate the completion of the intervention and keep the students together for their Taekwondo intervention. In the second semester, control group students were placed in several different PE classes (i.e., were no longer in one combined class), but all had the same Fitness for Life PE curriculum throughout the year. In the future, school administrators noted that it would help if several classes in the same school at the same grade level were assigned to Taekwondo to allow for more flexibility in scheduling.

Acceptability of the intervention to students was evaluated by asking all students in the Taekwondo class (n=46) to complete a questionnaire. Results are presented in Table 2. There were no significant difference in responses between boys and girls. Two additional questions asked for open-ended feedback on what students enjoyed most and least about the program. Qualitative themes and supporting student comments are summarized in Table 3.

Discussion

Effects on Executive Function and Behavior

The first hypothesis of this pilot study was that students in the Taekwondo group would demonstrate greater improvement in executive functions than children in the PE control group. Improvements in parent-rated inhibitory behavioral control were noteworthy ($d = .95$, $p < .001$), indicating that improvements promoted in Taekwondo training generalized to other contexts. Similarly, improvements in parent-rated attention control were also observed ($d = .62$, $p = .23$), but were not significant, which is not surprising given the limited power in this pilot study. These effect sizes were larger than the effects on teacher-rated behavior and attention reported in prior Taekwondo research (d's = −.23 and −.20 for the whole sample, and d's = −.45 and −.24 for boys only, for teacher-rated conduct problems and hyperactivity/inattention, respectively; Lakes & Hoyt, 2004). Parent-rated improvements in executive function were confirmed by student performance on an executive function test; large effect sizes were observed for accuracy on all three tasks. Although this difference was statistically significant for only one of the three tasks, this was to be expected given the small sample size in this pilot study. Interestingly, response times for the three task suggested that Taekwondo students were slightly faster on the congruent trial, but slowed down (presumably to inhibit automatic responses and improve accuracy) on the incongruent and mixed trials. Differences in response times should be interpreted cautiously, though, as none were statistically significant.

Effects on BMI *z* scores

The second hypothesis of this study was that students in both groups would demonstrate equivalent improvements in physical fitness. Although there was no significant difference between groups, there was a moderate effect size suggesting greater physical benefits for the Taekwondo students ($d = -.51$ for BMI *z*-scores). This effect size was larger than the effect size reported in a prior study comparing Taekwondo to PE ($d = .28$, indicating greater improvement in physical fitness and coordination among Taekwondo students compared to PE students; Lakes & Hoyt, 2004). This is a noteworthy effect given that the control group also was engaged in evidence-based physical activity, including running and playing active games.

Implementation of Taekwondo in Public School Physical Education

Acceptability results, based on direct student feedback about the Taekwondo intervention, should be interpreted in comparison to prior research on middle school attitudes toward PE. Carlson (1994) studied perceptions of PE among a large sample of junior high school students, and found that only 51% had positive attitudes toward PE. Results from students in this study indicate that more students held positive attitudes toward Taekwondo than students of similar age in prior research held regarding PE in general. Interestingly, themes identified in student comments about what they liked most about Taekwondo were consistent with hypotheses regarding the expected effects of Taekwondo training on students. Students identified perceived self-improvement in areas including self-discipline and physical fitness as examples of their favorite aspects of Taekwondo. Students also described enjoying learning challenging new tasks (e.g., obstacle courses, forms). In a review of interventions shown to improve executive functions, Diamond & Lee (2011) noted that a common theme across interventions that have positive effects on executive function was the introduction of incrementally challenging material. Taekwondo incorporates progressively more difficult techniques and forms, and instructors provide scaffolding while students are learning to ensure that appropriate supports are in place so that the student does not become overly discouraged. Some students reported enjoying this process and the sense of accomplishment they felt when they mastered a new skill or form, particularly when their accomplishment was recognized at a test and belt promotion ceremony.

Negative student comments included references to "*hard work*" and were often connected to the perception that students in other PE sections had it easier and were playing games that were less challenging. Overall, negative comments were not unlike those that could be expected with any physical activity intervention designed to promote physical and cognitive health – the exercises were physically and cognitively challenging. Most importantly, some of these comments came from students who had rated their enjoyment of the Taekwondo program highly; while they appreciated the intervention and perceived it as beneficial, they simultaneously disliked "*hard work*." Thus, many recognized that the training was difficult, but still indicated that they would like to continue and perceived it as beneficial. This is important, as one of the challenges in providing quality physical training is motivating students to participate in vigorous exercise. However, some students who commented on the difficulty indicated that they would not be interested in continuing Taekwondo training. In future research, it would be interesting to interview these students to identify whether or not there could be modifications to the Taekwondo intervention or alternative exercise interventions that might be more motivating and equally effective for them.

Limitations and Implications for Future Research

Results from this study and prior research (Lakes & Hoyt, 2004) suggest that Taekwondo is an example of a program of exercise that produces positive effects on executive function. The evidence supports the need for a large-scale, school-based randomized trial to evaluate

the effects of Taekwondo in a PE setting on cognitive, behavioral, and physical outcomes. Impact on emotion regulation, though not addressed in this study, should be studied as well, as prior research (Lakes & Hoyt) documented a significant effect of intervention on emotion regulation. It will be important to collect detailed information on the implementation of Taekwondo as well as a PE control to document the amount of time spent engaged in various activities as well as objective measures of physical activity (to monitor heart rate, etc.). Future research should include multiple measurements both during and following the intervention to measure change over time and study whether or not gains are maintained after the intervention has concluded. Limitations of this study included the sample size (which was both smaller than required for sufficient power and affected by recruitment issues related to partial consents and limitation of recruitment to families speaking one of three languages) and implementation in a single school, which were a function of both the nature of the study (pilot and feasibility research) and resources (e.g., limited funding for intervention, measurement, translation, and participant incentives). Moreover, future research should include additional measurements of physical fitness and body composition as well as measures of exercise intensity and rates of participation among individual students.

Conclusion

The implementation of a school-based Taekwondo intervention to strengthen executive functioning is feasible and worthy of consideration by school administrators. The long-term impact of simultaneously improving executive functions and BMI, particularly among students who are socioeconomically disadvantaged and at risk for poorer outcomes, could mitigate serious and costly societal and health burdens. This study is particularly timely as financial support and time for PE have been cut in many schools, and results of this research could impact administrator perceptions of the importance of PE and specific exercise approaches that could improve both academic and health outcomes.

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- Taekwondo students demonstrated improvements in parent-rated inhibitory control (attentional and behavioral control)
- Taekwondo students' performance on a computerized executive function task revealed greater accuracy in comparison to control group students
- Results suggest that Taekwondo is an exercise program that optimizes effects on cognitive functioning

Figure 1.
Child practicing a Taekwondo form. (Photo Credit: Haiou Yang)

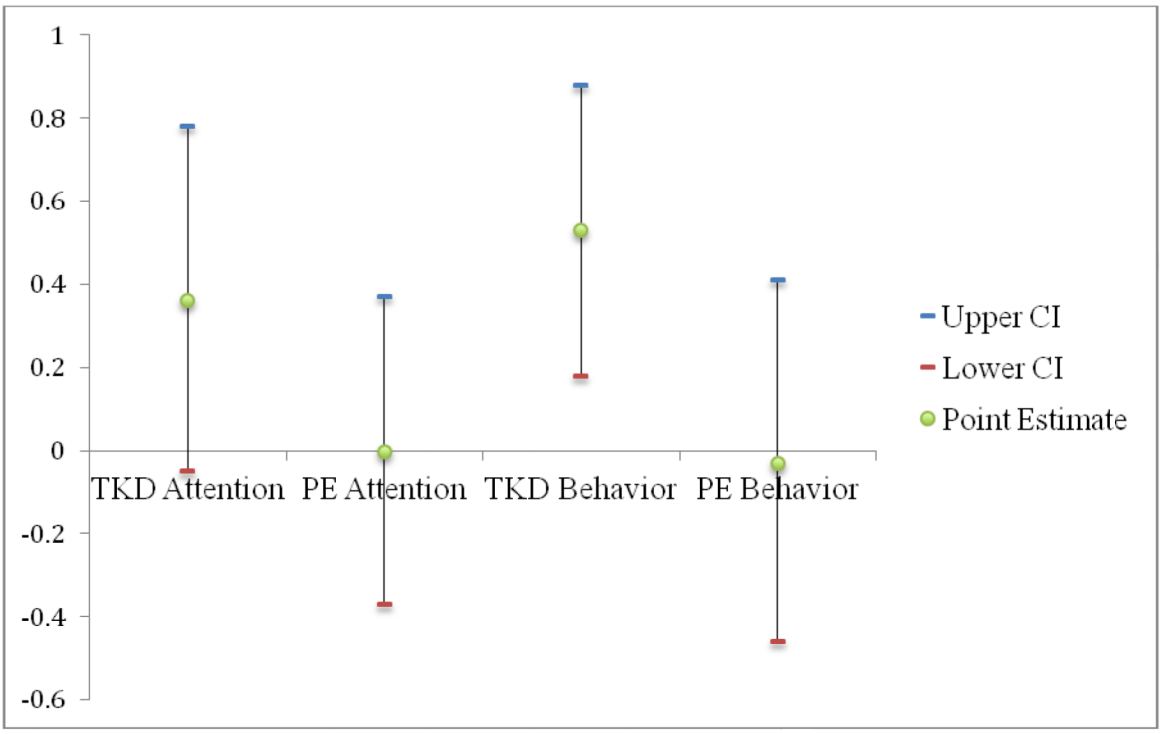

Figure 2.
Parent-Rated Attentional and Behavioral Control: 95% Confidence Intervals for Mean Residualized Change Scores. N=22 (n's = 9 and 13 for the TKD and PE groups, respectively). TKD = Taekwondo group. PE = Comparison group. Attentional and Behavioral Control were measured using SWAN Parent-Rated Attention and Hyperactivity/ Behavior Control subscale scores, respectively. Means are based on residualized change scores (residuals from regression of post-test scores on pre-test scores for each measure). CI = Confidence Interval.

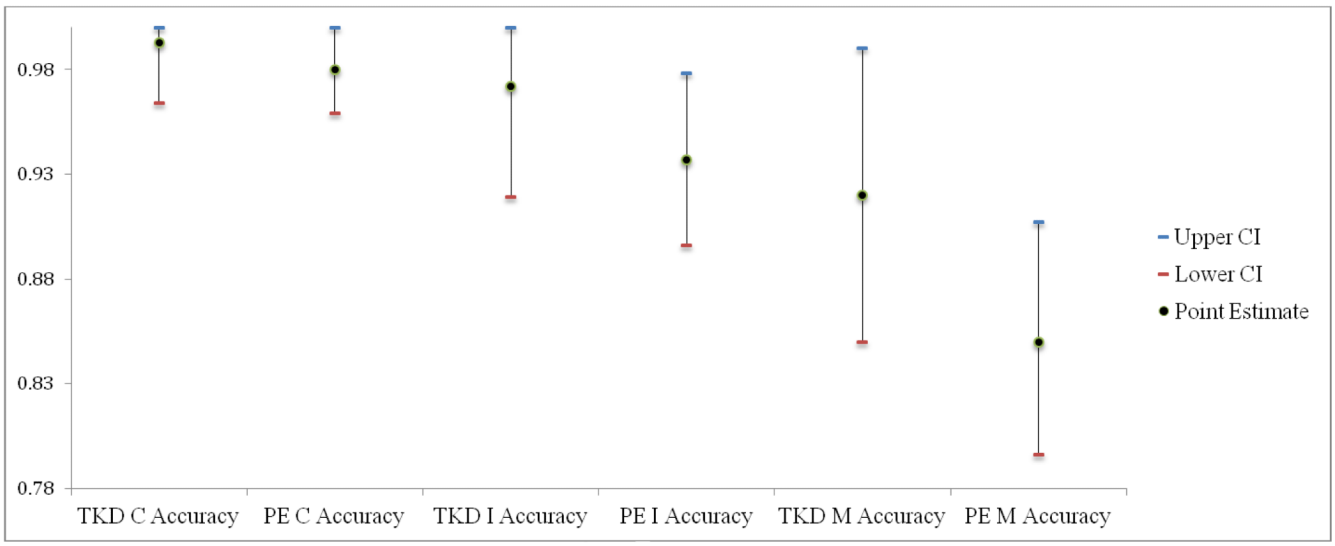

Figure 3.

Executive Function Task Performance: 95% Confidence Intervals for Mean Accuracy Scores by Group. N=27 (n's = 11 and 16 for the TKD and PE groups, respectively). TKD = Taekwondo group. PE = Comparison group. C = Congruent, I = Incongruent, and M=Mixed Trials from the Hearts and Flowers Executive Function Task. CI = Confidence Interval.

Table 1

Participant Characteristics

	Taekwondo Group	PE Control Group
Mean Age (in years)	12.2	12.3
Gender		
Female	52%	48%
Male	48%	52%
Racial/Ethnic Distribution		
Hispanic/Latino	52%	40%
White, Non-Hispanic	9%	8%
Vietnamese	35%	40%
Other Asian	4%	10%
African	-	2%
Baseline Mean BMI Percentile	59th	69th
Baseline Attention Mean (SD)	4.58 (.92)	5.70 (1.32)
Baseline Behavior Mean (SD)	4.59 (1.10)	5.73 (1.26)

Note. Attention and Behavior Control means at baseline were measured using the SWAN parent rating scale. Reported means are based on a 7-point scale, where 7 represents exceptional attention or behavior control and 1 represents severe impairment. Differences between groups at baseline were significant for baseline attention and behavior means (p = .04); therefore, baseline SWAN scores were used as covariates in all executive function analyses.

Table 2

Effects on Executive Function and BMI Z-Scores: Standardized Mean Differences (d) Between Groups

		Taekwondo Group		*PE Control Group*			
		Mean (SD)	***95% CI for Mean***	***Mean (SD)***	***95% CI for Mean***	***p value***	***Cohen's d***
Parent-Rated Inhibitory Control	Attentional Control	.39 (.54)	[−05, .78]	.00 (.61)	[−.37, .37]	.23	.62
	Behavioral Control	.53 (.46)	[.18, .88]	−.03 (.95)	[−46, .41]	< .001	.95[1]
Inhibitory Control, Working Memory, Cognitive Flexibility (Executive Function Computer Task)							
Congruent Trial (Hearts)	Accuracy[1]	.99 (.01)	[.96, 1.02]	.98 (.01)	[.95, 1.00]	.02	2.00*
	Response Time	585 (30)	[524, 647]	592 (25)	[542, 643]	.86	−.26
Incongruent Trial (Flowers)	Accuracy	.97 (.03)	[.92, 1.03]	.94 (.02)	[.90, .98]	.59	1.43
	Response Time	653 (29)	[593, 713]	627 (24)	[578, 676]	.51	.98
Mixed Trial (Hearts and Flowers)	Accuracy	.92 (.03)	[.85, .99]	.85 (.03)	[80, .91]	.12	2.33
	Response Time	766 (21)	[723, 809]	749 (17)	[714, 785]	.56	.43
BMI Z-score	Change Scores	−.05 (.22)	[−.16, .06]	.06 (.21)	[−05, .17]	.16	−.51

Note. N's = 22 for parent ratings, 27 for the executive function computer task, and 32 for BMI z-scores. Attentional and Behavioral Control means and standard deviations (*SDs*) are based on residualized change scores (residuals from regression of post-test scores on pre-test scores). EF Task means and *SDs* are based on performance at post-test controlling for baseline Attentional and Behavioral Control Total Scores. d = (mean treatment group − mean comparison group)/sd_{pooled}. CI = Confidence Interval.

[1] Untransformed means and *SDs* are reported to facilitate interpretation; the reported *d* was calculated using log-transformed means and standard errors, which were .003 (.006) and .007 (.004) for the intervention and control groups, respectively.

** $p \leq .01$

* $p \leq .05$

Table 3
Student Perceptions of the Taekwondo Intervention

Program Evaluation Question	Median (SD) Girls (n=24)	Boys (n=22)	Total (n=46)	Percent who agreed [1]
1. My Taekwondo classes helped me improve my physical fitness.	5.00 (0.63)	5.00 (0.87)	5.00 (0.75)	98%
2. My Taekwondo classes helped me improve my self-control.	5.00 (0.63)	5.00 (1.35)	5.00 (1.24)	87%
3. My Taekwondo classes helped me improve my ability to concentrate and pay attention.	5.00 (0.97)	4.00 (1.20)	5.00 (1.11)	80%
4. When compared to regular PE classes, my Taekwondo classes were more challenging.	5.00 (1.47)	5.00 (1.25)	5.00 (1.33)	76%
5. When compared to regular PE classes, my Taekwondo classes were more fun.	4.00 (1.36)	4.00 (1.25)	4.00 (1.31)	74%
6. If I could, I would like to continue Taekwondo.	5.00 (1.42)	4.00 (1.64)	4.00 (1.52)	64%
7. I would like my school to offer PE choices like Taekwondo	5.00 (1.24)	5.00 (1.35)	5.00 (1.29)	79%

Note. Students responded using a 6-point Likert scale (1=Strongly disagree, 2=Disagree, 3=Slightly disagree, 4=Slightly agree, 5=Agree, and 6=Strongly Agree). The number reported is the median response, and the standard deviation (SD) is shown in parentheses.

[1] Reports the percentage of students who selected either “Strongly agree,” “Agree,” or “Slightly agree” in response to the question.

Table 4
Qualitative Themes and Supporting Quotations from Written Student Feedback

What I liked the most about Taekwondo was:	
Learning self-discipline	*"What I liked most was the discipline because I felt it was really necessary"* *"The discipline andfitness "*
Self-efficacy experiences	*"The accomplishment I felt when I got another belt"* *"How to learn new moves and passing test"*
Challenging and novel physical activities	*"I liked the obstacle courses and learning new techniques"* *"The forms that we got to learn and the practices"* *"I liked the obstacle courses the most out of Taekwondo. They were fun and challenging."* *"What I liked the most about Taekwondo was that we had many fun activities "*
Learning self-defense	*"Learning ways to defend ourselves"* *"I learned self-defense and how to protect myself"*
The instructors	*"How nice the masters were, they were kind and helpful"* *"I liked the instructors "*
Self-Improvement	*"It helped me improve in areas I couldn't do myself"*
What I liked the least about Taekwondo was:	
Intensity of physical exercises	*"The exercises…they were hard!"* *"Push-ups "* *"I least liked the hard work"* *"Running"*
Uniform	*"I least liked the outfit and the hard working out"*
Less time to participate in other PE activities	*"When it takes away our free play. Because the other classes get free play but we get Taekwondo."* *"I didn't like the fact that we were missing out on the things the other classes were doing."* *"It prevented us from playing something else like capture the flag"*