THE EFFECTS OF MOVEMENT-BASED INTERVENTIONS FOR CHILDREN

THE EFFECTS OF MOVEMENT-BASED INTERVENTIONS FOR CHILDREN: A SERIES OF EVALUATIONS OF MOVEMENT-BASED INTERVENTIONS FOR YOUNG CHILDREN

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LAY ABSTRACT

Movement and physical activity (PA) play important roles in children's development and health. However, children across the world are engaging in less PA leading to higher rates of physical and mental illness and poor school readiness. There is a need to develop programs designed to enhance the health and development of children over time. This thesis tests the effects of various movement-based interventions on aspects of health and development in children. Results of study 1 provided preliminary evidence in support of a movement- and pre-literacy program called Move 2 Learn (M2L). Study 2 used more rigorous methods to test M2L and found that the program had unexpected positive outcomes for parents. Finally, study 3 findings pointed to the value in ensuring children find joy in PA and are not overly exerting themselves. Overall, this thesis highlights the importance of movement in child development and encourages several new avenues of research.

ABSTRACT

Participation in physical activity (PA) has been linked to positive health and developmental outcomes particularly for children; however, global estimates of physical inactivity range from 67-80% of children. Physical inactivity is also related to increased rates of unhealthy weight, poor school readiness, and mental health concerns among children. Urgent prevention strategies are required to enhance the health and development of children. This thesis explored the use of three study designs to investigate the effects of various movement-based interventions on aspects of health and development in children.

A quasi-experimental study was first conducted to test the effects of a movement- and pre-literacy program among 3- to 4-year-old children. This study found significantly positive improvements in movement skill and pre-literacy skills. Subsequently, a mixed method study was designed to expand the evaluation of the program. A randomized waitlist controlled trial with an embedded qualitative study revealed statistically significant intervention effects, while the qualitative data revealed that the program positively contributed to various aspects of children's movement and pre-literacy abilities and overall confidence, and enhanced quality of at-home practice. The final study used a randomized controlled trial to test the acute effects of a bout of activity that varied in physical and cognitive demands on executive function. Key findings did not support the hypotheses that a cognitively engaging bout of PA enhances cognitive performance over non-cognitively engaging PA or sedentary activities, and this may have been due to overexertion during the activity and/or depletion of positive affect.

Overall, the thesis findings demonstrated promise of a movement-based intervention for children, elucidated important design considerations of cognitively engaging physical activities, and suggested several new avenues of research. Moreover, the thesis has demonstrated the utility of using multiple designs and highlights the unique methodological considerations of conducting research with young children.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANCOVA	Analysis of Covariance
ANOVA	Analysis of Variance
BMI	Body Mass Index
bpm	Beats per minute
BRIEF	Behavior Rating Inventory for Executive Functions
cm	Centimeter
df	Degrees of Freedom
d_z	Standardized Difference Score
EF	Executive Function
EM	Experimental Manipulation
FMS	Fundamental Movement Skills
FS	Feeling Scale
h	Hour
HR	Heartrate
HRV	Heart Rate Variability
IMI	Intrinsic Motivation Inventory
IOTF	International Obesity Task Force
IQR	Interquartile Range
kg	Kilogram
LSD	Least significant difference
m	Meters
M2L	Move 2 Learn
min	Minutes
MPK	Master of Professional Kinesiology
ms	Milliseconds
MVPA	Moderate to Vigorous Physical Activity
n	Sample size
ORBIT	Obesity-Related Behavioural Intervention Trials
PA	Physical Activity
PALS-PK	Phonological Awareness Literary Screening-Preschool
PDMS-2	Peabody Developmental Motor Scales-Second Edition
PPC	Perceived Physical Competence
PSCS-PK	Perceived Competence and Social Acceptance for Young Children-Preschool-Kindergarten version
PWAP	Preschool Word and Print Awareness
RCT	Randomized Controlled Trial
RPE	Ratings of Perceived Exertion
RPME	Ratings of Perceived Mental Exertion
RT	Response time

SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
TGMD-2	Test of Gross Motor Development 2
WL	Waitlist
η^2	Eta Squared
ω_p^2	Partial Omega Squared

PREFACE

This thesis has been conducted as a “sandwich thesis” and consists of four individual manuscripts/papers at various stages of publication. These are:

1. Chapter 1: Introduction of the thesis
2. Chapter 2: A Quasi-Experimental Study of a Movement and Preliteracy Program for 3- and 4-Year-Old Children; published manuscript
3. Chapter 3: Evaluation of a Direct-Instruction Intervention to Improve Movement and Preliteracy Skills among Young Children: A Within-Subject Repeated-Measures Design; published manuscript
4. Chapter 4: Move 2 Learn: A mixed method evaluation of a movement and pre-literacy program for young children; manuscript prepared for submission
5. Chapter 5: Examining the effects of acute cognitively engaging physical activity on cognition in children; manuscript prepared for resubmission
6. Chapter 6: General Discussion

At the time of writing (March 2020-September 2020), two of the three manuscripts (chapters 2 and 3) have been published in peer reviewed journals; the remaining manuscripts (chapter 4 and 5) have been written and prepared for submission to journals for publication.

Ms. Bedard was the lead contributor to the conception and design of each study, with the aid of her supervisor Dr. Cairney. Such a lead entailed developing the research questions, the writing of the respective protocols, working with various academic and research content experts for feedback and guidance, selecting all measurement tools and assessors, coordinating training efforts and implementation of each intervention, performing all study tasks (e.g., submission of ethics applications, recruitment, data collection, performing the qualitative study interviews, conducting all data cleaning and analyses, writing up of drafts of all manuscripts, submitting the manuscripts to her coauthors and supervisor for guidance, and final submission of manuscripts for publication). This also involved editing the submitted manuscripts to allow for full acceptance and publications. This work is principally the undertaking of Ms. Bedard, with guidance from Dr. Cairney and collaborative input from the larger research team at the INfant and Child Health (INCH) Lab.

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Study 1 (Chapters 2 and 3)

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Author Contributions: CB designed the study, coordinated recruitment and data collection, designed the preliteracy component of the intervention and assisted with weekly implementation of the intervention, carried on the data analyses, and was the primary author of the manuscript. EB assisted with data collection, design of the motor component of the intervention and weekly implementation of the intervention, and revised and approved the final manuscript as submitted. WC assisted with design of the intervention, selection and design of outcome measurements, and reviewed and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted.

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<u>Author Contributions:</u> CB designed the study, coordinated recruitment and data collection, trained and coordinated intervention leaders and volunteers, conducted qualitative data collection, carried out the quantitative and qualitative analyses, and was the primary author of the manuscript. EB assisted with training of the intervention leaders, data collection, and revised and approved the final manuscript as submitted. WC assisted with design of the study and reviewed and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted.

<u>**Study 3 (Chapter 5)**</u>

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assisted with data collection, and revised and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted.

DECLARATION OF ACADEMIC ACHIEVEMENT

Ms. Bedard was the main contributor and first author of all the manuscripts/documents contained in this thesis. The details of the contributions of coauthors are described in the preface and at the beginning of each manuscript.

CHAPTER 1: INTRODUCTION

The central interest of this dissertation is the study of the influence and interrelationships between movement, physical activity (PA), cognition, and confidence during early childhood. These constructs are dynamically and reciprocally interconnected and the study of these complex relationships in early childhood requires rigorous, adaptive, and diverse study designs, grounded in strong research methodology and theory. This thesis explores the use of three study designs, specifically a non-randomized trial, a mixed method study, and an acute randomized between-within experimental study, to investigate the effects of various movement-based interventions on aspects of health and development in children in early childhood. The focus on movement-based interventions in early childhood is particularly advantageous because of the pervasive and important role it plays in overall child development, both in relation to physical and mental health and in other areas such as cognitive development. The progression of movement skills inherently promotes physical development as well as enables effective interactions with the environment subsequently allowing children to become aware of their own capabilities to develop a secure and positive self-concept while simultaneously building cognitive capacities such as reason, perception, and attainment of general knowledge. Furthermore, movement-based games and activities are inherently enjoyable to children and may present an effective medium to make impactful gains in other areas of development through intentional design of interventions. Given the growing literature on the importance of movement to positive and healthy development during childhood, movement takes a prominent role in each of the studies contained within this dissertation.

Movement is defined broadly as "observable change in the position of any part of the body" (1). Motor development describes changes in motor behaviours over the lifespan and results from interactions among the individual, the environment, and the task demands (2). The development of motor skills begins in early infancy and continues into late childhood; rates of development are quite variable among children (3). Motor skills may be categorized into gross and fine motor skills, distinguished by the magnitude of the muscle movements and associated muscle groups. Fine motor skills include picking up small objects, writing, using scissors, et cetera, and thus involve coordination of smaller muscle groups to perform finer movements (3). Gross motor skills involve whole body movements coordinated by large muscle groups; these skills include walking, running, jumping, hopping, galloping, throwing, and catching, which are also referred to as fundamental movement skills (FMS). The attainment of FMS is critical to a child's overall development (4). FMS are the foundational building blocks that allow children to learn more complex movements that facilitate independent participation in activities of daily living, sports, games, and recreational physical activities (5). However, increasing evidence from neuroscience and early childhood education research suggests strengthening motor skills may go beyond simply laying the foundation for an active lifestyle later in life. Increasingly, motor skills in childhood are viewed as inextricably linked to other core aspects of development, including self-perceptions and cognition (6–8). Therefore, targeting motor skills in the context of a primary intervention may have the capability to impact development more broadly by affecting self-perceptions and cognition, in addition to directly improving motor development.

Motor Skills and Self-Perceptions

Self-perceptions refer to an individual's beliefs and knowledge about their capabilities, attributes, and qualities (9). Positive self-perceptions act as buffers to protect against internal or external insults and act to promote healthy functioning. Harter and Cole discuss self-esteem through a competence-based approach, indicating there are several domains of competence that contribute to one's self-esteem (9,10). Domains of competence include cognitive, physical, scholastic, athletic, etc. Feelings of low levels competence in these domains can lead to internalizing symptoms, such as depression (10). The relative contribution of each domain changes across the life course; however, athletic and physical competence remains a relevant and important domain of self-concept from early childhood through to middle adulthood (9). The relationship between motor skills and self-perceptions is relevant for two reasons: firstly, extant research has demonstrated that higher motor skills relates to higher self-perceptions; secondly, the nature of this relationship in early childhood fosters a critical window of time to intervene to ensure maximal interest and participation of the child.

Wrotniak et al. (11) conducted a cross-sectional study measuring motor proficiency and perceptions of adequacy of physical skills and found a significantly positive correlation of 0.39. Similarly, LeGear et al. (12) found a significant correlation of 0.26 between perceived physical competence and total motor skills. These correlations suggest that there is a relationship between actual motor skill proficiency and how children perceive their own movement abilities. However, it is difficult to obtain information about the causal relationship as there is limited methodologically sound research conducted longitudinally or experimentally. It may be possible that actual motor skill directly causes perceptions of motor ability to improve, or that positive perceptions of motor ability encourages participation in motor skill building activities which then improves actual motor skill. One longitudinal study found positive associations between motor proficiency at age 6 and perceived motor competency in their teenage years; however, it is still uncertain if actual motor skill directly improved perceptions, as perceptions were not measured at age 6 (13). An intervention study measured perceived sports competence six years post their intervention, “Move it Groove it” and reported a similar relationship between motor competence and perceived motor competence (14). Regardless of the directionality of this relationship, it is evident that these two constructs are related and there is potential to impact self-perceptions through movement-based interventions.

Interestingly, in early childhood, perceptions of competence are often inflated as children lack the cognitive skills required to make accurate judgements about their own abilities. Young children often equate perceptions of motor proficiency with effort expended in the activity (9). Self-perception of motor competence begins to align with actual motor skill over time, and this may begin to occur as early as kindergarten (9,12). Therefore, it is possible that high self-perceptions of motor competence in young children may drive participation in motor skill building activities. This evidence suggests that early childhood is a critical time to capitalize on this inflated perception and create learning opportunities for building actual motor skill when children are more interested and inclined to participate.

Motor Skills and Cognition

Historically, cognitive and motor development have been studied independently, in part owing to incomplete understanding of brain development. Cognitive development is characterised by a relatively protracted developmental period extending into adolescence corresponding with a slower rate of development of the prefrontal cortex compared to motor development, which has been viewed as occurring earlier in development with a more rapid development of the cerebellum. Evidence in support of this developmental sequence was provided by observations of developmental milestone events: notably with Piaget remarking that a child learns to crawl before language happens (15). Through interactions with the environment and skillful and efficient movements, children can develop the ability to express themselves and simultaneously build cognitive capacities such as reason, perception, and attainment of general knowledge. Movement affords greater opportunities to interact with the environment, stimulating the need for rapid development in other domains (16). Previously, this led to an overly simplistic categorization of motor separate from cognition development; however, a growing body of modern neurobiological and behavioural evidence posits these two developmental domains are inextricably related (7). Specific motor abilities such as fine motor control, bimanual coordination, and visuomotor skills develop concurrently with complex cognitive abilities as an individual progresses from childhood through adolescence. There is also co-activation of the brain areas typically associated with cognitive and motor skills, the dorsolateral prefrontal cortex and the contralateral neocerebellum, respectively, in several non-motor, cognitive tasks. The cerebellum is particularly active when the cognitive task is difficult, novel, requires a quick response, or when the conditions are changing. This pattern of co-activation has led to the generation of several novel hypotheses of how cerebellar function can facilitate the functioning of other neural domains: possibly through error detection, modifiable pattern detection, improving the efficiency of other areas of the brain, or improving sensitivity to anticipated stimuli in the presence of noise. Furthermore, since the performance of a motor skill requires executive functions such as the ability to plan and regulate behaviours, maintain attention, problem solve, et cetera (17), skill building activities for motor development can simultaneously strengthen executive functioning. Conversely, cognitive skills also facilitate motor skill development. Functions of the dorsolateral prefrontal cortex, holding and manipulating information in our mind, staying focused on a task, inhibiting inappropriate first responses and delaying premature reactions, known collectively as executive functions, are critical in motor learning and mastery of motor skills (7).

In support of these of neurobiological studies, there is epidemiological research that demonstrates the predictive ability of motor functioning during infancy and young childhood of later cognitive ability. Piek et al. (18) showed that gross motor trajectory information collected at 4 to 48 months of age significantly predicted cognitive ability at 6 to 12 years of age, specifically working memory and processing speed. Wijnroks and van Veldhoven (19) used postural control as a motor performance indicator to show its prediction of experiencing difficulty during a problem reduction task in 6-month-old infants. Burns and colleagues (20) found that motor ability classifications (i.e., normal motor function, minimal motor problems, mild motor problems, moderate-to-severe motor problems) at 12 months could predict cognitive ability at four years of age.

Collectively, the evidence suggests a much closer relationship between motor and cognitive development than previously assumed. In consideration of this interrelationship between motor and cognitive development, it is posited that movement-based interventions may be able to simultaneously impact motor and cognitive skills. Furthermore, it appears that certain intervention elements may be intentionally designed to capitalize on this relationship to promote coactivation by including activities that are developmentally challenging and novel.

Primary Intervention in Early Childhood

Optimal development of motor and cognitive domains will not necessarily occur naturally. Access to and participation in quality early childhood education programs that directly attend to these domains will facilitate a strong foundation in both developmental areas and enhance growth (21,22). Extant research has targeted children who have developmental delays framed as secondary or tertiary prevention studies or have implemented interventions for children who are of school age, leaving a critical gap in the literature for younger children without clinical diagnoses (23). Estimates of any delay in young children ranges from 16- 20%, meaning most children are considered to be developing typically (24,25). However, the profiles of children who appear to be developing typically include alarming rates of inactivity, overweight/obesity, and poor school readiness. There is value in attending to this large part of the population as it is unknown what proportion of children will go on to be part of the 93% of children who are insufficiently active, 27% of youth who are considered overweight or obese, or 28% not ready for school (26–28). Therefore, among children considered to be developing typically, there is still concern for their risk of developing physical and mental illnesses, due in part to physical inactivity and unhealthy body weight (and their health sequalae), and learning difficulties and underachievement owing to poor school readiness. Intervening early may serve as an effective primary prevention strategy by guiding children towards a healthy lifestyle as they reap the physical, cognitive, and mental health benefits.

Methodological Approach

Generally, motor development is quantitatively studied using observational methods such as cross-sectional or longitudinal designs. These observational designs are incredibly useful for describing developmental trends over time and examining differences between children. Methodologically, observational studies often stimulate innovative research questions, new areas of study, and generate hypotheses that require testing or further inquiry. The foundational knowledge of motor development is indeed based upon rigorous longitudinal observational studies such as the Medford Boys Growth Study (29) and the Amsterdam Growth and Health Longitudinal Study (30). When conducted properly, observational studies can provide strong evidence of developmental patterns and trends; however, given the naturalistic and unobtrusive nature of the design, it is less well suited to investigations of dynamic and reciprocal relationships between developmental or health constructs. There is often temporal ambiguity that exists in observational designs which precludes determination of causality; furthermore, the presence of confounding factors will always be a limiting factor despite statistical adjustments. For example, there is an established positive relationship between movement competence and PA, such that higher motor skills relate to higher levels of PA. However, a large proportion of the research is cross-sectional, and therefore it is unclear whether better motor competence leads to more PA or if higher levels of PA leads to greater motor competence (23). Furthermore, there may be other variables confounding the association, such as socioeconomic status, whereby the advantages conferred by a high socioeconomic status also yield higher motor competence and more opportunities to be physically active.

Therefore, in the pursuit of understanding the complex influence of and relationships among movement and other areas of development in children, a different methodological approach is required. Specifically, to study the effects of movement or PA on various aspects of development, multiple methodologies must be employed that can measure the effectiveness of an intervention, the impact of a program on unobservable or unintended constructs (e.g., self-perceptions/confidence and parental learning), and the subjective experience of participating in an intervention. Clearly contained within the overarching research objective are a series of research questions, each of which necessitates a specific study design. Certain methodologies are more suited to answer specific research questions; therefore, employing a singular study design will provide only an incomplete understanding of the research phenomena. Applying multiple methodologies, however, will facilitate comprehensively investigating the research questions, thereby providing a stronger and more robust evidence base. Experimental studies can begin to evaluate causation and sequence; however, they are more complicated to design and are more resource intensive. There are several variants of experimental design, two of which are acute and long-term studies, which diverge in their suitability to answer specific research questions. The former is well-suited to test the effect of small changes on development or short-term effects of experimental manipulations. Acute studies are particularly useful to test the effect of intentionality within short-term interventions; that is, to answer the question, what is the effect on ‘x’ of an intervention that specially targets ‘x’? Long-term trials, however, can answer questions of effectiveness and efficacy of behavioural interventions. Translational models from behavioural fields of research, such as the Obesity-Related Behavioural Intervention Trials (ORBIT) model, recommend that long-term trials are piloted first using an uncontrolled designs (that is, a within-in group, single-arm trial) as a 'proof of concept' (31). The dual functions of these Phase IIa trials are to establish the potential clinical or practical effect of the intervention and to evaluate feasibility outcomes. Single-arm trials are relatively simple to execute, both in terms of cost and planning, and it is for this reason the ORBIT model suggests they precede the relatively more ambitious controlled trials. Uncontrolled studies are particularly difficult to conduct during early childhood because this is a period of time where rapid development takes place (3,32). Observed changes throughout the trial cannot be exclusively attributed to the intervention since maturational development will also be captured in the measurements across time in children. Therefore, successful pilot studies are typically followed by a controlled trial, Phase IIb, introducing a second arm with either no intervention or a comparison intervention to determine whether a significant treatment effect can be observed beyond changes occurring due to the passage of time. These designs allow for more certainty in attributing changes in outcomes to the intervention; however, the level of certainty depends on how assignment to the groups was performed. Quasi-experimental studies are more flexible in assigning group allocation to individuals, often allowing participants to self-select into their preferred group. However, quasi-experimental studies are at risk of selection bias because certain factors driving group allocation decisions may simultaneously affect changes to measured outcomes (also referred to as confounding). Random assignment reduces this risk substantially by providing participants with an equal probability of entering either group, thereby balancing the distribution of confounding factors between study arms. However, there remains the barrier of conducting these trials during this period of rapid development, making it difficult to detect intervention effects that are larger than maturational changes that take place over the study cycle. Therefore, precise estimates of intervention effects are difficult to obtain with small sample sizes and large developmental variability between and within children. Nonetheless, the most objective and rigorous methodology to assess quantitative changes resulting from a behavioural intervention is a randomized controlled trial (RCT). This systematic series of progressive quantitative studies helps generate a robust evidence base to support further study and application of behavioural interventions in children (31). While these early phase studies may be small, they each provide valuable information that contributes to the foundational knowledge on the intervention as well as informs future Phase III efficacy trials.

Quantitative studies, however, are still limited in their ability to comprehensively evaluate all intended and unintended effects of behavioural interventions in children. Mixed methods are uniquely situated to appraise behavioural interventions because they can harness the power of quantitative analysis to establish the frequency and magnitude of intervention effects and simultaneously capture the contextual meaning of the intervention under study. Given challenges in collecting objective data, the diversity of developmental trajectories in children, and the range of manifest intervention effects, both quantitative and qualitative approaches are necessary to fully understand the effects of interventions in children. Specifically, qualitative studies can complement the knowledge generated from quantitative studies in several ways. Firstly, qualitative studies can evaluate additional dimensions of constructs of interest beyond their quantitative attributes. Often quantitative instruments can capture only frequency indices or competency evaluations against a standard schema; however, there are other dimensions that may be of interest to researchers. For example, in the measurement of motor development in children, instruments such as the Test of Gross Motor Development (33) or Peabody Developmental Motor Scales (34), typically focus on product- or process-based assessments of movement proficiency through observation of standard tasks such as throwing a ball towards at a target within a fixed number of attempts with proper form; however, these instruments do not capture the child's enjoyment of these skills nor their propensity to engage in these movement skills of their own volition. Secondly, there are limitations to both quantitative data collection methods of parent-reported surveys and lab-based child assessments: for example, response options on parent-report surveys tend to overly restrict parent's true evaluation of their child and direct observations of children are frequently impacted by behavioural regulation issues or fatigue. Qualitative inquiry may allow parents to report in richer detail their honest reflections of their child's skill level, behaviours, or engagement as well as circumvent assessor observational biases due to poor behavioural regulation or fatigue by providing a report of their child's skill level, behaviour, or engagement as witnessed in their daily lives outside the context of a single visit to the lab. Thirdly, qualitative studies can also supplement measurement of constructs that cannot be easily captured through exclusively quantitative means. For example, confidence or perceptions of self among children are constructs that are difficult to assess validly or reliably through surveys administered to either the child or parent. Qualitative methods of data collection such as observations, focus groups, and interviews can address this limitation of quantitative estimation by providing more pieces of data and information across multiple contexts, and thus, can contribute to a deeper level of understanding of the construct. Fourthly, qualitative studies can provide insight into unexpected or unintended outcomes that were not planned a priori. Behavioural interventions are frequently comprised of multiple components, which while designed to cause a specific effect, often interact to produce unintended effects as well. Furthermore, despite efforts to provide standard training and instructions to intervention leaders and consistently adhere to a program curriculum, the delivery of behavioural interventions to young children cannot take place in tightly controlled settings exactly as intended; subsequently, unexpected outcomes may result. These unintended or unexpected outcomes are unlikely to be detected without qualitative investigation probing their possible existence.

Despite the advantages afforded by using multiple and mixing methodologies in the study of child development, the prevailing research paradigm in the field is quantitative. Therefore, the extant literature remains limited in its understanding of the complex and dynamic influence of and interrelationships between movement, PA, cognition, and confidence during early childhood. In the absence of careful consideration of the appropriate progression of studies to generate a strong evidence base and without application of multiple methodologies, there is a risk that potentially clinically and practically effective interventions will be prematurely rejected. To study these constructs within a period of rapid developmental growth requires a more creative, flexible, and adaptive methodological approach. The following four chapters will outline the use of three methodological designs to study the effect of movement-based interventions in children. A discussion will follow on the knowledge gained from each study, the advantages and limitations of these studies designs, and the recommended direction of future research.

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CHAPTER 2: A QUASI-EXPERIMENTAL STUDY OF A MOVEMENT AND PRELITERACY PROGRAM FOR 3- AND 4- YEAR OLD CHILDREN

Preamble

A quasi-experimental study of a movement and preliteracy program for 3- and 4- year old children is the first study in the dissertation. It is the pilot study to test the effectiveness of the Move 2 Learn program in children with typical development ages 3-4 years.

The following manuscript has been published in *Frontiers in Pediatrics*. The published version of the manuscript is included in the dissertation.

Author Contributions: CB designed the study, coordinated recruitment and data collection, designed the preliteracy component of the intervention and assisted with weekly implementation of the intervention, carried on the data analyses, and was the primary author of the manuscript. EB assisted with data collection, design of the motor component of the intervention and weekly implementation of the intervention, and revised and approved the final manuscript as submitted. WC assisted with design of the intervention, selection and design of outcome measurements, and reviewed and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted.

Contribution of Study 1 to overall dissertation:

Study 1 provided 'proof of concept' that Move 2 Learn could significantly impact movement and pre-literacy skills, relative to a control group, in children with typical development as delivered by researchers in a community setting. The results of this study prompted the design of the more rigorous follow-up investigation described in Chapter 3.

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CLINICAL TRIAL
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A Quasi-Experimental Study of a Movement and Preliteracy Program for 3- and 4-Year-Old Children

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Objective: Approximately 28% of children are not ready for kindergarten, 91% are inactive according to current guidelines, and 21% are overweight/obese. Early intervention to strengthen movement and preliteracy skills may help to curb the concerning rates of poor school readiness, inactivity, obesity, and subsequently positively impact health across the lifespan. The objective of this pilot study was to evaluate the effectiveness of a motor and preliteracy skill program for a community sample of 3- to 4-year-old children.

Methods: A quasi-experimental study design was used. The program was run for 1 h/week for 10 weeks and consisted of movement skill instruction, free play, and an interactive reading circle with care-giver involvement throughout each session. Movement and preliteracy skills were assessed in all children pre- and post-intervention using the Peabody Developmental Motor Scales-2nd edition, the Preschool Word and Print Awareness tool, and the Phonological Awareness Literacy Screening tool.

Results: Nineteen families (experimental group, $n = 8$; control group, $n = 11$) were recruited (mean age = 3 years, 8 m; 47% male). There was a significant effect of group on gross motor raw scores overall [$F(1, 16) = 4.67$, $p < 0.05$; $\omega_p^2 = 0.16$] and print-concept knowledge [$F(1, 16) = 11.9$, $p < 0.05$; $\omega_p^2 = 0.38$].

Conclusion: This study was one of the first to examine the impact of a community-based movement skill and preliteracy program with care-giver involvement in preschool children. Future research should continue to explore the effects of the program with larger and more diverse samples on multiple health and developmental outcomes.

Clinical Trial Registration: Play and Preliteracy among Young Children (PLAY) NCT02432443.

Keywords: early childhood, fundamental movement skills, preliteracy skills, early intervention, child development

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Abbreviations: PWPA, preschool word and print awareness; PALS-PK, phonological awareness literacy screening-preschool; PDMS-2, peabody developmental motor scales-2nd edition; ANCOVA, analysis of covariance.

INTRODUCTION

There is mounting evidence linking health status and behaviors in childhood to future health problems in adolescence, adulthood, and later adulthood (1, 2). For example, children who are overweight or obese are more likely to be overweight as adults and suffer from cardiovascular disease and poor mental health (3, 4). In response to this evidence, a great deal of research has focused on optimizing childhood development in order to improve health outcomes across the lifespan. However, in a Canadian population of children, 28% are not ready for school (5), 91% are insufficiently active according to current guidelines (6), and 21% are considered overweight or obese (7). Given the high prevalence of inactivity, overweight/obesity, and poor school readiness, we can conclude that significant improvements need to be made in order to enhance the health and development of children over time. Extant research has targeted children who have developmental delays or who are of school age, leaving a critical gap in the literature for younger, preschool-aged children with typical development (8). There is value in attending to this large part of the population as the potential impact of intervening in this population is large.

Underlying the rise in physical inactivity, poor school readiness, and obesity rates is hypothesized to be poorly developed motor and cognitive skills, particularly gross motor and preliteracy skills. This hypothesis emerges from the literature relating motor proficiency with physical, psychosocial, and cognitive development as well as evidence linking the development of preliteracy skills with psychosocial and cognitive domains (9–11). With respect to motor development, it has been shown that the attainment of fundamental movement skills (FMS) such as throwing and catching allow children to learn more complex movements that facilitate independent participation in activities of daily living, athletic pursuits, and physical activity (PA) (12). Engagement in these types of activities improves physical development through increases in PA levels, physical fitness, and healthy body composition (8, 13). In addition, increasing evidence from neuroscience research suggests movement skills in childhood are inextricably linked to other core aspects of development including social, cognitive, and psychological domains (14–17). With respect to preliteracy skills, studies have demonstrated relationships between early language and literacy development and later socioemotional regulation (18), social behavior (9), and academic self-perceptions (10).

There is reasonable theoretical, empirical, and practical evidence to promote a component-based program that teaches movement and preliteracy skills. From an embodied cognition perspective, motor and cognitive developments are intrinsically linked as cognitive processes, in particular language, emerge as individuals interact with their physical and social environment (19). As children develop their movement skills and interact with their surroundings, they have more diverse opportunities to learn about their environment and develop their language and other cognitive abilities (20, 21). Early language and preliteracy skills are intimately linked through their role in communication (22) thus, by extension we may apply the embodied cognition perspective to a paired movement skill and preliteracy skill-learning paradigm, in which we may expect enhanced learning. Empirical evidence supports this relationship between movement and preliteracy skills. Callcott et al. (23) demonstrated the synergistic benefits of a blended learning program on both movement and preliteracy outcomes. When preliteracy skill-building activities were used as a medium to teach movement skills, children showed greater improvements compared to a group of children participating in a movement-only program (23). From a practical perspective, including both reading activities and movement skill-building activities in a single program will attend to both parental and kindergarten curricular interests. Parents and educators of young children are concerned with achievement of both motor milestones and school readiness indicators; therefore, by targeting both domains in a single program, we will appeal to various child care providers. Finally, skill-building activities for both movement and preliteracy development are fun and enjoyable for children and their families (24, 25). Learning how to jump and throw and sharing a book with their caregivers are intrinsically appealing to children, which is an important predictor of participation and engagement (26).

It is critical to consider the role of the parents in these programs. Parents act as a child's primary instructor in the early years when children are learning new skills and with effective strategies they can support their development in a number of domains (27–29). The involvement of parents in skill-building programs allows for skill learning to continue outside of the program setting. Systematic reviews have consistently supported the inclusion of parents throughout programs and the dissemination of parent materials to facilitate knowledge translation into the home in order to achieve sustained improvement in movement skill proficiency (27, 30).

In light of all of the aforementioned considerations, we designed an evidence-based intervention targeting movement and preliteracy skills in children 3–4 years of age. The objective of this study is to evaluate the effectiveness of the program.

METHODS

Design

A quasi-experimental study design was used to evaluate the program. All children were assessed twice approximately 10–12 weeks apart: children in the experimental group were assessed pre- and post-program; children in the control group were assessed at baseline and again following 10 weeks. Families had the option of participating in the experimental group or control group, depending on their preference for the start date (Summer or Fall). Families in the control group were able to participate in the program after their second appointment was completed.

Participants

A convenience sample of families was recruited through advertisements at Ontario Early Years Centres, Boys and Girls Clubs of Hamilton, various licensed daycares, and the Hamilton Public Libraries from May to July 2015. Children were eligible to participate if they were between the ages of 3 years, 0 months and 4 years, 11 months at baseline and must not have been diagnosed with any developmental delay or other health condition that would prohibit safe participation in the program.

Intervention

The program took place at the Boys and Girls Club of Hamilton and was led by two graduate students (Emily Bremer and Chloe Bedard under Dr. Cairney's supervision). The program ran for 60 min once per week for 10 consecutive weeks and consisted of three components: direct FMS instruction, unstructured exploratory free play, and a dialogic storybook reading activity. The first segment of the program focused each week on a specific movement skill through single-step skill acquisition strategies (i.e., introducing new skills one-by-one). The free-play segment of the program allowed children the opportunity to self-direct their own activities: children had access to various play items including both gross motor and fine motor equipment (e.g., playground balls and puzzle pieces). The curriculum and teaching strategies used for the first two segments of our intervention have been successfully implemented in previous research to improve the movement skills of preschool-aged children with autism (31, 32); these strategies have been adapted for use with our general population of children. The final segment of our program was a dialogic shared book reading circle with all the children and their parents. Each week used one book to develop one to two preliteracy skills. Specific strategies and books were selected from several evidence-based curricula (25, 33, 34). There was active involvement of at least one parent in the direct instruction and reading components.

Outcome Measures

Demographic and Engagement Survey

The demographic questionnaire was completed at baseline and included questions about the parent and the child on age, gender, ethnicity, parental education and occupation, and household income. A parent engagement questionnaire was administered at both assessments and was developed to assess the use and the frequency of use, of specific activities that were employed in our program to determine if parents use these activities at home.

Preliteracy Skills

Children were administered the Preschool Word and Print Awareness tool (PWPA) test and the Phonological Awareness Literacy Screening: preschool (PALS-PK)-uppercase alphabet recognition task at both assessments to measure print-concept knowledge and alphabet knowledge (35, 36), respectively. The PWPA tests children on their print-concept knowledge, such as print directionality and print function, using 14 items administered in an interactive storybook reading format (35). Raw scores are then transformed into standardized scores with a mean of 100 and SD of 15. The PWPA has strong validity, and the reliability is 0.74 in a sample of children aged 3–5 years (37). The PALS-PK uppercase alphabet recognition task involves children naming each of the 26 letters of the alphabet as they are presented in a random order. The inter-rater reliability coefficient of this task is 0.99 (36). These measurements together took approximately 15 min to complete and were administered by a trained graduate student.

Motor Skills

Children were administered the gross motor subtests of the Peabody Developmental Motor Scales-2nd edition (PDMS-2) (38) at both assessments. The PDMS-2 is a standardized instrument designed to measure the progress of development of gross and fine motor skills in children from birth to age 6. The three gross motor subtests—stationary, locomotion, and object manipulation—were administered by two trained graduate students. The sum of the raw scores of each of the three subtests was used as the dependent variable in the primary analysis. The assessment required approximately 30–45 min to conduct (39). The PDMS-2 has good validity and sensitivity to change as assessed previously in 4-year-old typically developing children and the inter-rater reliability is 0.89 (39, 40).

Attendance and Home Practice

Attendance at the program sessions and the frequency of weekly home practice was measured using attendance checklists and parent-reported questionnaires.

Procedure

The study received ethical approval from the Hamilton Integrated Research Ethics Board. All study appointments took place at the INfant and Child Health (INCH) Lab at McMaster University. After eligibility was confirmed over the telephone, parents were asked to select a time for their first study appointment. Informed written consent was obtained at the first study visit. At each appointment children were administered the PWPA, PALS-PK—uppercase alphabet recognition task to assess preliteracy skills, and the PDMS-2 to assess movement skills. Parents were asked to complete the demographic (at the first assessment only) and the engagement questionnaire. The duration of each appointment was approximately 1–1.5 h. After the first appointment, families were asked to select their group (experimental/summer start or control/fall start). Families in the experimental group began the program within 1–2 weeks of their baseline appointment. After the experimental group completed the program, all families were asked to come in for their second assessment in which they were administered the same tests. See **Figure 1** for the flow diagram depicting the study procedures.

Statistical Analyses

Basic descriptive statistics of the demographic characteristics of the sample and attendance and at-home practice rates were computed. Between-group differences in baseline characteristics were compared using independent *t*-tests for continuous variables and chi square (Fischer's exact test) for categorical variables. The primary analyses were three group by time analyses of covariance (ANCOVAs) to assess changes in the children's gross motor skills (raw scores), print-concept knowledge (standardized scores), and alphabet knowledge between the experimental and control groups at time 2 with time 1 scores entered as a covariate. *Post hoc* ANCOVAs were used to examine differences across time in each gross motor subtest between groups. Secondary analyses included two group by time ANCOVAs examining differences in changes in parental engagement in both movement and preliteracy skills.

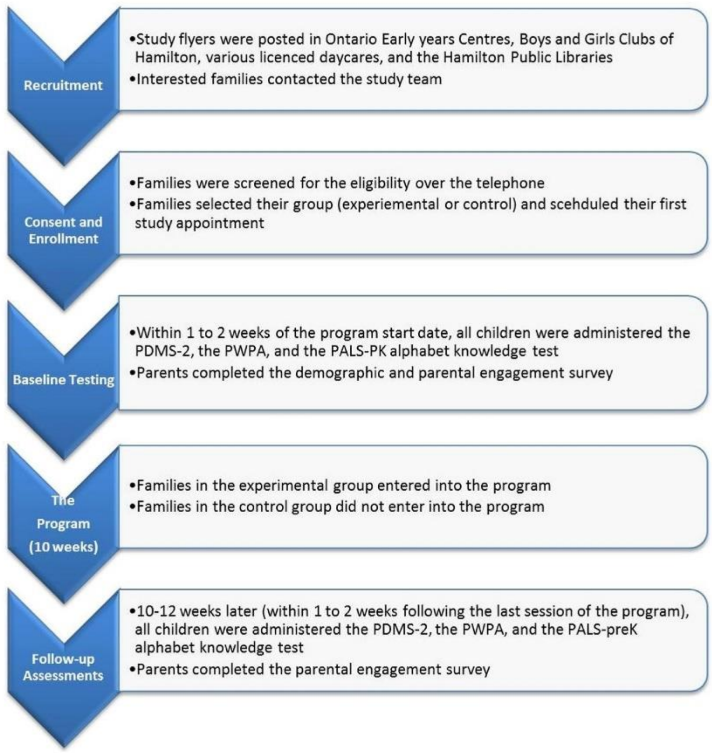

FIGURE 1 | Flow diagram for study procedures.

The partial omega squared will be used as a measure of effect size as it calculates the variance accounted for by group assignment controlling for the time 1 scores. This effect size is appropriate for analyses with more than one independent variable (i.e., an ANCOVA) (41). Effect sizes are interpreted as small for values over 0.01, medium for values over 0.06, and large for value over 0.14 (42). All analyses were conducted on a per-protocol basis. A two-tailed alpha value of 0.05 was used to determine statistical significance.

RESULTS

Descriptives

Twenty-one families were eligible and consented to participate in the first study appointment (see **Figure 2**). Of these 21 families, 19 completed the second study visit: 2 families discontinued the program and were lost to follow-up; 1 family withdrew from the intervention due to time constraints, however, attended the second study appointment. The final study sample included 19 children (10 boys) ranging from 3 years, 0 months to 4 years 11 months (mean = 3 years, 8 months, SD = 7.30 months).

Table 1 describes the demographic characteristics of the sample by group. There were no significant differences between the two groups for any demographic characteristic, with the exception of parental education (see **Table 1**). Baseline scores on raw and age-standardized gross motor skills, print-concept knowledge, and alphabet knowledge were not significantly different between groups (see **Table 2**). The median attendance level was 8 out of 10 program sessions (IQR: 7–9 sessions). The average rate of home practice was 45% (SD = 17%) and 52% (SD = 18%) for the movement and preliteracy activities, respectively.

Intervention Effects

Mean scores and SDs of the primary outcomes (movement and preliteracy skills) at each time point by group are presented in

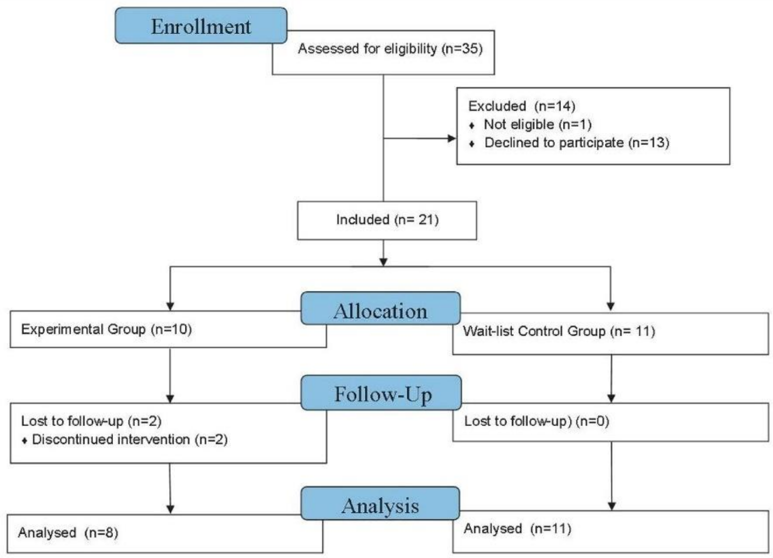

FIGURE 2 | **Flow diagram to indicate the included and excluded participants.**

TABLE 1 | **Sample demographic characteristics of the experimental and control groups.**

Variable	Experimental group (n = 8)	Control group (n = 11)	p-Value
Child's mean age in months (SD)			
	41.4 (6.99)	45.6 (7.30)	0.22
Child's gender %			
Male	51	55	>0.99
Child's ethnicity %			
Filipino	12	0	0.77
Black	0	9	
South Asian	0	9	
Chinese	12	0	
Mixed ethnicity	13	9	
White	63	73	
Parent age (years)			
	37.5	33.0	0.09
Parent education %			
College/technical training	0	45.5	0.04
University degree	100	54.5	
Parent income %			
Less than $50,000	12	36	0.27
Greater than $50,000	87	64	

n, sample size.

TABLE 2 | **Baseline scores of the experimental and control groups.**

Variable	Experimental group (n = 8)	Control group (n = 11)	p-Value
	Mean (SD)	Mean (SD)	
Gross motor skill (raw)			
Stationary (SD)	46.0 (6.63)	47.5 (5.47)	0.61
Locomotion (SD)	140.0 (22.42)	150.7 (12.20)	0.20
Object manipulation (SD)	28.4 (7.13)	33.8 (5.56)	0.08
Total	214.4 (35.38)	232.0 (19.57)	0.18
Preliteracy skill			
Print-concept awareness (SD)	87.5 (16.49)	93.9 (19.72)	0.47
Alphabet knowledge (SD)	10.6 (0.45)	11.3 (8.89)	0.89

n, sample size; SD, standard deviation.

Table 3. Overall, both group improved their movement and preliteracy skills over the 10 weeks (see **Table 3**). Parents showed small increases in their levels of engagement, with the exception of parents in the control group and their engagement in motor activities (see **Table 3**). Results of the ANCOVA on the primary outcomes are presented in **Table 4**. There was a significant group effect on gross motor raw scores measured at time 2, after controlling for time 1 scores [$F(1, 16) = 4.67$, $p < 0.05$; $\omega_p^2 = 0.16$]. There was also a significant effect of group on print-concept knowledge [$F(1, 16) = 11.9$, $p < 0.05$; $\omega_p^2 = 0.38$]; however, improvements in uppercase letter recognition did not differ significantly between groups [$F(1, 15) = 0.048$, $p = 0.83$; $\omega_p^2 < 0.001$]. *Post hoc* analyses reveal that there was a significant difference in the improvement of object manipulation skills in the experimental group, compared to the control group; improvements in scores on the stationary and locomotor domains were not significantly different between groups (see **Table 5**). The results of the secondary analyses

TABLE 3 | Scores for each assessment in the experimental and control groups for gross motor and preliteracy skills, and parent engagement scores.

Variable	Experimental (n = 8)		Control (n = 11)	
	Time 1	Time 2	Time 1	Time 2
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Gross motor skill—raw score	214.38 (35.37)	236.25 (26.11)	232.00 (19.57)	238.72 (23.20)
Print awareness—standardized score	87.50 (16.49)	114.90 (13.49)	93.91 (19.72)	100.10 (20.38)
Uppercase letter recognition	10.63 (10.69)	12.71 (11.74)	11.27 (8.90)	13.91 (9.68)
Parent engagement—motor	3.33 (1.06)	3.70 (0.94)	3.43 (0.64)	3.30 (0.91)
Parent engagement—preliteracy	3.43 (1.07)	4.50 (1.80)	4.14 (1.09)	4.36 (1.06)

n, sample size.

TABLE 4 | Analysis of covariance results for primary outcomes of motor and preliteracy skills.

Source	F-value	p-Value	ω_p^2
Total gross motor score			
Group	4.67	<0.05	0.16
Time 1 scores	66.74	<0.05	
Print-concept knowledge scores			
Group	12.66	<0.05	0.38
Time 1 scores	23.94	<0.05	
Uppercase letter recognition			
Group	0.048	0.83	<0.001
Time 1 scores	148.42	<0.05	

The dependent variables are the time 2 scores (df numerator = 1, denominator = 16). df, degrees of freedom; ω_p^2, partial omega squared.

TABLE 5 | *Post hoc* analysis of covariance results.

Source	F-value	p-Value	ω_p^2
Stationary			
Group	0.00	0.99	<0.001
Time 1 scores	58.74	<0.05	
Locomotion			
Group	2.40	0.14	0.07
Time 1 scores	35.00	<0.05	
Object manipulation			
Group	6.13	<0.05	0.21
Time 1 scores	36.38	<0.05	

The dependent variables are the time 2 scores (df numerator = 1, denominator = 16). df, degrees of freedom; ω_p^2, partial omega squared.

TABLE 6 | Analysis of covariance results for secondary outcomes.

Source	F-value	p-Value	ω_p^2
Parental engagement—motor			
Group	2.32	0.15	0.06
Time 1 scores	16.95	<0.01	
Parental engagement—preliteracy			
Group	3.45	0.08	0.11
Time 1 scores	23.69	<0.01	

The dependent variables are the time 2 scores (df numerator = 1, denominator = 16). df, degrees of freedom; ω_p^2, partial omega squared.

indicate non-significant differences between the experimental and control group on their level of engagement in both movement and preliteracy activities (see **Table 6**). **Figures 3A–H** show the change over time in the experimental and control group for each primary and secondary outcomes. **Figure 4** illustrates the change over time in the gross motor scores of the individual participants in the experimental group. There were no reported adverse effects of the intervention.

DISCUSSION

The aim of this study was to investigate the impact of a program designed to improve preschool-aged children's movement and preliteracy skills and the results show large significant effects between the experimental and control group in the improvement in both skill domains. This study is timely as evidence continues to accumulate supporting the critical importance of movement and preliteracy skills to several health and academic outcomes in preschool-aged children (43, 44). This alongside the growing number of children who are physically inactive (6), overweight or obese (7), and not ready for school (5) signals that targeted multicomponent interventions are necessary. An opportune time to intervene exists during the early years because children typically find enjoyment in learning new movement skills, such as jumping and throwing, and reading stories; thus, finding movement- and reading-based programs fun (24).

It is important to consider the results of this intervention within the context of the program structure. The positive improvements in gross motor skills suggest that programs consisting of direct movement skill instruction have the capacity to improve the movement skills of children with typical development. This aligns with the few intervention studies conducted in this age group showing positive gains in children participating in direct movement skill instruction (27). Furthermore, the significant gains in both gross motor and preliteracy skills despite the relatively low dose of the intervention (i.e., one time per week for 1 h) highlight the importance of both the combined learning environment and the parental component. As demonstrated by Callcott et al. (23), pairing motor and preliteracy learning in a single program has the capacity to produce synergistic gains in both domains. Although this synergistic hypothesis was not directly tested in this study, our results suggest that important gains in movement and preliteracy skills can be achieved in a

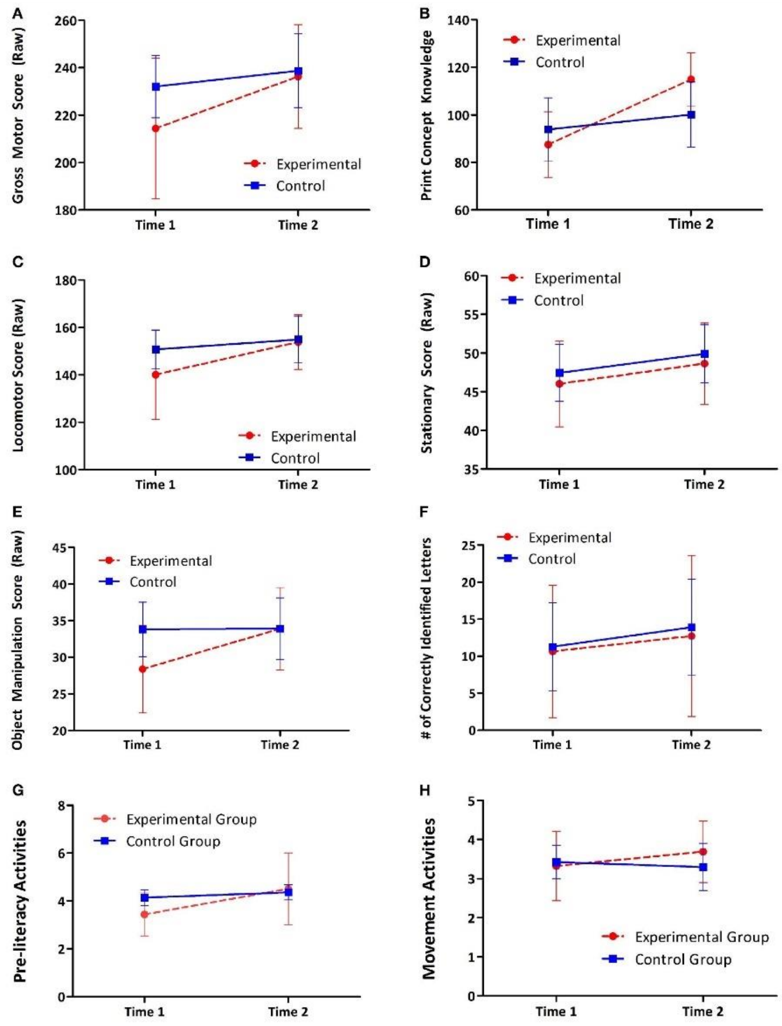

FIGURE 3 | Mean scores at time 1 and time 2 for both groups; error bars represent the 95% confidence intervals. **(A)** Gross motor skills; **(B)** print-concept knowledge; **(C)** locomotor skills; **(D)** stationary skills; **(E)** object manipulation skills; **(F)** alphabet knowledge; **(G)** parental preliteracy engagement scores; and **(H)** parental movement engagement scores.

dual program that capitalizes on this relationship. Additionally, parents were actively involved in the program and were provided with handouts outlining the weekly activities and encouraged to practice the activities at home. The rate of at-home practice for both the movement and reading activities ranged from 45 to 52%, indicating that activities were practiced on approximately half the days not spent in the program. The involvement of the parents was likely critical to expand their child's learning beyond the weekly session. One recommendation from Veldman et al. (27) suggests that programs should run at least twice a week; however,

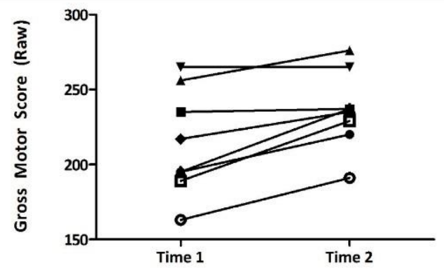

FIGURE 4 | Individual change over time in gross motor skills in the experimental group.

our results suggest that running one session a week and involving parents actively throughout the program may confer similar skill gains to a higher-dose program.

The results of the *post hoc* analyses on our primary motor outcomes indicate that the program seems to selectively improve object manipulation skills, not stationary or locomotor skills. However, there was a medium effect size observed for locomotor skills suggesting that non-significant findings for this domain may have been a power issue. The non-significant findings with respect to stationary and locomotor skills suggest that the movement skill component of the program should be modified to enhance skill development in these domains. We also found selective improvements in print-concept knowledge and not in alphabet knowledge. This may be explained through the organization of the program: print concepts were introduced during the first half of the intervention and alphabet concepts were introduced in the latter half. Thus, children were exposed to print concepts for a longer duration over the intervention period, compared to alphabet concepts, lending to the observed results. Finally, we also found non-significant findings with respect to levels of parental engagement of motor and preliteracy activities at home, and this may explained in consideration of the parental component of the intervention and measurement issues. The effect size for changes in parental engagement in motor and preliteracy activities at home are moderate and large, respectively; therefore, the analyses may be limited in their power to detect a statistical difference even when these fairly substantial increases exist. Furthermore, the measurement of engagement was through a self-reported survey, which may not be sufficiently sensitive to detect significant differences. Finally, the survey items asked about only the frequency of engagement, not the quality of practice. Therefore, while we could not detect changes in frequency of practice of activities at home, it may be that parents engaged in infrequent, but high-quality practice at home.

There are limitations that should be noted in conjunction with the results of the study. First, participants were not randomly assigned to the intervention and control group, thus there are some imbalances in baseline characteristics. The imbalances in baseline motor and preliteracy skills were non-significant and were accounted for in the analyses; the effect of the intervention remained significant after controlling for these differences in time 1 scores. However, it remains possible that our results reflect greater opportunity for improvement in the experimental group given their lower baseline scores. Thus, future research should ensure that baseline movement and preliteracy scores are equivalent in both groups. The imbalance in parental education levels may have impacted the results through differences in parental motivations (i.e., reasons underlying their decision to participate in the study), quality of activity practice at home (i.e., how closely home practice resembled the intervention activities), and the general quality of the child's surrounding environment (i.e., access to physical equipment and social support). However, as the imbalance in parental education was not accompanied by differences in household income levels, or baseline levels of parental engagement, it is difficult to determine the true effect of this statistical imbalance. Nonetheless, it should be considered a limitation of our sample. Second, our sample was small and relatively homogenous; therefore, the generalizability of the results is limited. Furthermore, the power of our analyses is limited by the small sample; the analyses of the effect of the intervention on the subdomains of motor skills and parental engagement levels were substantially underpowered, and this may explain their non-significance.

CONCLUSION

The results of this study show that participation in a direct instruction, community-based, parent-oriented movement and preliteracy program can significantly improve movement and preliteracy skill levels of preschool children with typical development. These novel results highlight the feasibility and importance of intervening during the preschool years and involving the parents throughout the intervention to maximize gains. Future research should begin to investigate the generalizability of the program in different community settings with larger more diverse samples.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Hamilton Integrated Research Ethics Board with written informed consent from all parents of participating children. All parents of participating children gave written informed consent in accordance with the Declaration of Helsinki.

AUTHOR CONTRIBUTIONS

CB designed the study, coordinated recruitment and data collection, designed the preliteracy component of the intervention and assisted with weekly implementation of the intervention, carried on the data analyses, and drafted the initial manuscript. EB assisted with study design, recruitment and data collection, design of the motor component of the intervention and weekly implementation of the intervention, and revised and approved the final manuscript as submitted. WC assisted with design of the intervention, selection and design of outcome measurements, and reviewed and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted. All the authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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CHAPTER 3: EVALUATION OF A DIRECT-INSTRUCTION INTERVENTION TO IMPROVE MOVEMENT AND PRELITERACY SKILLS AMONG YOUNG CHILDREN: A WITHIN-SUBJECT REPEATED MEASURES DESIGN

Preamble

Evaluation of a direct-instruction intervention to improve movement and preliteracy skills among young children: A within-subject repeated measures design is part of the first study in the dissertation. It reports on the follow-up of the wait-list control group in the pilot study designed to test the effectiveness of the Move 2 Learn program in children with typical development ages 3-4 years.

The following manuscript has been published in *Frontiers in Pediatrics*. The published version of the manuscript is included in the dissertation.

Author Contributions: CB designed the study, coordinated recruitment and data collection, designed the preliteracy component of the intervention and assisted with weekly implementation of the intervention, carried out the data analyses, and was the primary author of the manuscript. EB assisted with data collection, design of the motor component of the intervention and weekly implementation of the intervention, and revised and approved the final manuscript as submitted. WC assisted with design of the intervention, selection and design of outcome measurements, and reviewed and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted.

Contribution to overall dissertation:

This study provided evidence that the control group significantly improved their movement and pre-literacy skills following completion of M2L despite the imbalance in skills levels at baseline compared to the experimental group. This analysis attenuated concerns over the potential risk of selection bias in the quasi-experimental study and provided further evidence in support of an intervention effect of M2L.

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Evaluation of a Direct-Instruction Intervention to Improve Movement and Preliteracy Skills among Young Children: A Within-Subject Repeated-Measures Design

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Objective: School readiness involves the development of foundational skills such as emergent literacy and fundamental movement skills as well as the capacity to attentively engage in instructional situations. Children do not develop these skills naturally; therefore, they need the opportunity to develop these skills in their early years prior to entering school. The objective of the current study was to evaluate the effectiveness and feasibility of a direct-instruction movement and preliteracy intervention in children aged 3–4 years.

Methods: A within-subject repeated-measures design, embedded within a wait-list control study, was used to evaluate the intervention. The intervention was run across 10 weeks with 1 h weekly sessions. Each weekly session consisted of 30-min of movement skill instruction (e.g., through single-step acquisition strategies), 15-min of free play during which time children had access to a variety of equipment (e.g., balls, hula hoops, etc.) or toys (e.g., puzzles, building blocks), and a 15-min interactive reading circle during which children read a storybook and were taught 1–2 preliteracy skills (e.g., alphabet knowledge, narrative knowledge, etc.). A convenience sample of 11 children (mean age = 45.6 months, SD = 7.3) was recruited. All children were assessed four times: baseline (Time 1), pre-intervention (Time 2), post-intervention (Time 3), and 5-week follow-up (Time 4). Gross motor skills and preliteracy skills were assessed at each time point.

Results: There was a statistically significant effect of time on the change in gross motor skills (Wilks' lambda = 0.09, p = .002), print-concept skills (Wilks' lambda = 0.09, p = .001), and alphabet knowledge (Wilks' lambda = 0.29, p = .046). *Post hoc* analyses reveal non-significant changes between time 1 and 2 for motor and print-concept skills and significant changes in all three outcomes between time 2 and time 3.

Conclusion: Participation in a direct-instruction movement and preliteracy program led to positive improvements in gross motor skills, print-concept knowledge, and alphabet knowledge in 3- to 4-year-old children over time. Future research needs to evaluate the effectiveness of this movement and preliteracy skill intervention on various other indicators of child development and health.

Clinical Trial Registration: Play and Pre-Literacy among Young Children (PLAY) NCT02432443.

Keywords: direct-instruction, child development, school readiness, fundamental movement skills, emergent literacy, early intervention

INTRODUCTION

The definition of school readiness differs depending on one's theoretical perspective; however, contemporary developmentalists agree that it is multifaceted and involves readiness of both the child and their environment to receive all available benefits conferred in the school setting. Readiness skills at the level of the child include development in several areas, such as cognitive, socio-emotional, and motor domains. School readiness at the level of the environment includes, but is not limited to, provision of quality community-based programs, professional development of early childhood education teachers, and supporting parental capacity to help their children grow and develop (1). The degree of readiness is dependent on the proficiency level of children in a number of important intellectual and developmental domains, such as movement ability and emergent literacy skills, among others (2). It is critical that the foundations of these domains are laid before entering school to prepare children for further growth in these areas and facilitate their success in the development of new and complex skills (3).

Two important child-level school readiness skills are movement and preliteracy skills. The importance and relevancy of preliteracy skills for school readiness has been demonstrated extensively. Preliteracy skills include an understanding of print knowledge (e.g., being able to distinguish between print and picture), vocabulary, phonological awareness (e.g., knowledge about the individual sounds of spoken words), and narrative knowledge (e.g., understanding how stories are sequenced and described) (4). When explicit attention is drawn to developing these emergent literacy skills in early childhood, children are better prepared for later academic interactions in the classroom (5). With foundational emergent literacy skills, children can develop new knowledge about alphabet principles and skill in word recognition, reading fluency, and comprehension (4). Development of preliteracy skills not only facilitates these later literacy skills but has been shown to enhance social-behavioral and more general academic achievement (5).

Movement skills, specifically gross motor skills, involve whole body movements coordinated by large muscle groups; these skills include walking, running, jumping, hopping, galloping, throwing, and catching. Evidence from both experimental and observational studies show that attainment of these movement skills not only allows children to independently participate in physical activities (6) but also improves brain function (7, 8), social development (9, 10), self-concept (11), and academic achievement (12). Furthermore, children with motor skill deficits tend to demonstrate lower levels of physical activity (13), poorer self-esteem (14), lower levels of cognitive control (15), and poorer social function (16) compared to children with higher movement competence.

Beyond preparation for school entry, the development of movement skills is essential for long-term health and well-being *via* the influence of movement skills on life-long physical activity (6) and the subsequent physical and mental health benefits that accrue to individuals who lead an active lifestyle (17–19). According to the developmental model proposed by Stodden et al., movement skills are bi-directionally related to both perceived motor competence and health-related fitness (20). Through enhancement in actual and perceived movement skills, children will be more able and more motivated to engage in physical activity and thus maintain a healthy physical trajectory (20). There is strong theoretical and empirical support for the development of movement skills as the pivotal determinant that can set an individual on a positive health trajectory (6). Similarly, literacy skills in general are also essential for health, by ensuring individuals can make informed decisions about health care and healthy lifestyle choices (21). In children, early literacy and reading skills also have been positively related to self-regulation (22–24), which itself is related to positive mental and physical well-being later in life (25). In this sense, interventions designed to improve movement and preliteracy skills are foundational not only for school readiness but for long-term health and well-being as well.

Beyond possessing developmental skills (e.g., movement and preliteracy), school readiness includes being able to participate in classroom activities as well as attend and respond to instruction (26). While the strategy of direct and deliberate instruction is common in many preliteracy curricula [e.g., Justice and colleagues (27)—"experimental explicit intervention"], this is not always the case in movement skill programs. However, Robinson and Goodway (11) demonstrated that direct instruction, whether delivered in a low autonomy or a mastery motivational climate, improved the object control skills of preschoolers. Alhassan and colleagues (28) found significant gains in movement skills in preschool children following a direct-instruction movement-based intervention compared to a free-play program. These two experimental studies highlight the importance of using systematic and explicit instruction strategies to enhance skill levels because children do not inherently possess these skills. Furthermore, there is evidence to suggest that teaching both movement skills and

Abbreviations: PWPA, Preschool Word and Print Awareness; PALS-PK, Phonological Awareness Literacy Screening: Preschool, PDMS-2, Peabody Developmental Motor Scales—2nd edition; ANOVA, analysis of variance.

preliteracy skills in a single program may have synergistic effects on the gains achieved in both skill domains. For example, Callcott and colleagues (29) taught preschool children movement skills and preliteracy skills simultaneously in their intervention and found gains in movement skill above those achieved by a group of children learning movement skills in isolation. Additionally, an intervention that teaches both movement and preliteracy skills appeals to parents, educators, and children. Parents and teachers are interested in and attentive to ways to help their children and students meet these movement-related and academic goals and children are naturally drawn toward activities like jumping, skipping, and reading story books because they are inherently fun and enjoyable.

The readiness of a child to enter into school also is influenced by the capacity of parents to teach and support their child's development in these domains. Therefore, it is critical to include parents or caregivers in these direct-instruction programs to provide them with guidance on teaching strategies that can be implemented at home. In fact, this has been the recommendation from research for both movement and preliteracy skill interventions (30, 31). The systematic review by Veldman and colleagues (30) specifically noted the absence of parental or caregiver involvement in movement-based interventions for children beyond sending home educational handouts and subsequently recommended that parents should be actively engaged throughout the program and encouraged to practice the skills at home. Shared book preliteracy interventions have typically included and emphasized the role of parents and caregivers; however, these interventions do not use explicit instruction strategies for skill development (32). Interventions employing direct-instruction strategies are typically delivered by teachers (33) or trained researchers (34) without extension to parents. By excluding parents or caregivers in the delivery of effective preliteracy intervention the frequency and dose of the intervention is inherently limited to time spent with the interventionist; however, parents may have many opportunities to implement these lessons at home if they have been provided with the knowledge and tools to do so.

In summary, both emergent literacy and fundamental movement skills are important for school readiness, and confer long-term health and well-being benefits for children. However, there is a need for systematic evidence-based approaches that target children's movement and preliteracy skills. At present, best practice suggests that these approaches need to involve direct-instruction teaching strategies with explicit and active involvement with parents or caregivers. Thus, the purpose of this study was to evaluate the change in movement and preliteracy skills following a 10-week direct-instruction movement and preliteracy skill intervention for children aged 3–4 years.

MATERIALS AND METHODS

Design

A within-subject repeated-measures design was used to evaluate the program. The participants originally had been assigned to the wait-list control arm of a quasi-experimental study, the results of which have been published previously (35). However, by continuing to follow and offer these children the same intervention that the experimental group had received, we could assess change in motor skill and preliteracy using a within-subject design. We are unable to combine the results of the original quasi-experimental study with the current results because children in the wait-list control group serve as their own control; therefore, combining all children who receive the intervention and comparing them to the control period in which they did not receive the intervention, would violate the statistical assumption of independent observations.

All children were assessed four times: baseline (Time 1), pre-intervention (Time 2), post-intervention (Time 3), and 5-week follow-up (Time 4). While the results for time 1 and time 2 were previously reported in the study by Bedard et al. (35), time 3 and 4 results have not been reported.

Participants

A convenience sample of families was recruited through advertisements at local community centers (e.g., Early Years Centres, Boys and Girls Clubs, Public Libraries) from May to July 2015. Children were eligible to participate if they were between the ages of 3 years, 0 months, to 4 years, 11 months at baseline, and must not have been diagnosed with any developmental delay or health condition that would prohibit safe participation in the program.

Intervention

The program took place in the gymnasium of a local Early Years Centre and was led by two graduate students (EB and CB) with prior experience in implementing movement and preliteracy programs. The program ran once per week for 10 consecutive weeks and each 60-min session consisted of three components: direct movement skill instruction (30 min), unstructured exploratory free play (15 min), and an interactive storybook reading activity (15 min). Key teaching strategies employed throughout all aspects of the program included: an emphasis on the use of correct terminology; individual scaling of skill level; significant and active parent involvement for all aspects of the program other than free play; and the use of a large visual schedule to ease the transition between program activities.

The intervention and its teaching strategies were adapted from a movement skill intervention originally designed for young children with autism spectrum disorder (36, 37) and now used for children with typical development (35). The lesson plans and teaching strategies for the preliteracy component of this intervention were adapted from several evidence-based curricula (31, 38, 39).

Direct Instruction for Movement Skills

This first component of the intervention (direct teaching of movement skills) was further divided into four activities: warm-up, two blocks of skill instruction, and an obstacle course. Each week focused on teaching a different movement skill, with the skills progressing in difficulty over the 10-week program (see **Table 1** for the Weekly Skill List).

To start the program, the children and their parents formed a circle and participated in warm-up games (e.g., the hokey pokey) for approximately 5 min. This provided an opportunity for the

TABLE 1 | Weekly skill list.

Week	movement skill	Preliteracy skill
1	Balancing	Pictures vs print
2	Underhand rolling	Characters
3	Leaping and galloping	Pictures vs print
4	Underhand throwing	Setting
5	Jumping	Directional tracking
6	Overhand throwing	Describing the plot
7	Catching	Directional tracking
8	Hopping	Sequencing events
9	Kicking	Alphabet knowledge
10	Striking	Alphabet knowledge

children to become comfortable with one another and ease into the start of the program. Next, two 7-min blocks of direct skill instruction occurred with the skill increasing in difficulty over the two blocks. For example, when teaching the overhand throw, the first block of skill instruction would focus on throwing a large ball overhand with two hands. The second block of skill instruction would then work on teaching the children how to throw a smaller ball overhand with one hand. During the blocks of direct instruction, the program leaders would first demonstrate the skill to the children and their parents, while emphasizing the correct form of the skill. The child-parent dyads were then instructed to spread out in the activity area to practice the skill. This ensured there were numerous repetitions of skill practice and opportunities for skill mastery. For example, while teaching the overhand throw, the child would be instructed to throw the ball to their parent. This would progress on an individual basis to throwing further distances, toward a target, etc. Throughout these activities, the program leaders worked their way around the activity space to check in on the child-parent dyads and provide suggestions for the child to scale the skill level up or down, based on individual need. For instance, a child struggling with the overhand throw would be given pointers on how to make it easier, such as using floor markers to indicate how to stand; likewise, a child who was excelling at throwing may be asked to throw further or at a moving target while still using proper form. As parents became more confident in their own teaching abilities, they were encouraged to help their child scale the skill level on their own. Throughout both blocks of direct skill instruction, an emphasis was placed on having children take their time and using correct processes to complete the task (e.g., to throw overhand, there is a wind-up of the ball up and back, a step with the opposite foot, and follow-through of the throwing arm toward the target), rather than rushing through the skill.

Following the two blocks of skill instruction, an obstacle course was set-up for the children to practice the skills that they learned that day, as well as review previously learned skills in a fun activity. The obstacle course each week consisted of 3–4 skill stations set-up in a square path so that the children started and ended in the same location. Parents completed the obstacle course with their child, either helping them through it, or completing it before or after their child to model or mimic the skills, respectively. Each child was given the opportunity to complete the course 3–4 times before transitioning to the second component of the intervention.

Free Play

The second component of the intervention consisted of 15-min of unstructured exploratory, child-directed free play. During this time, children were supervised by one of the program leaders and program volunteers, while the second program leader accompanied parents to a separate location to have them complete weekly questionnaires. Children had the option to play with a variety of equipment (e.g., balls, hula hoops, balance beams, etc.) or toys (e.g., puzzles, building blocks) and were given free choice in what they did for the 15 min. The program leader and volunteers engaged in the activities with the children but were instructed not to suggest or discourage the children's play, but rather to follow their lead in whatever game they chose. At the end of free play, children were instructed to put away whatever they were playing with and form a circle while the parents re-entered the activity space for the final component of the program.

Direct Instruction for Preliteracy Skills—Dialogic Shared Storybook Reading

The third component of the intervention was a 15-min interactive storybook reading circle with direct involvement of the parents. Each week, 1–2 preliteracy skills were introduced and developed using one storybook (see **Table 1** for the Weekly Skill List). Each book was read twice over the course of the 10 weeks. Parents and children sat in a circle and each pair were provided with the book. The program leader would begin the reading by first introducing the skill using proper terminology. For example, the leader would explain to the group that in today's story, "We will learn about characters and settings. Characters are who the story is about and the setting is where the story takes place." Each lesson would continue by reviewing the picture and words (i.e., title, author, and illustrator) on the front cover of the book. Next, the leader would encourage the parents to follow along during the book reading. Periodically, the leader would ask open-ended questions that helped develop the children's understanding of the particular preliteracy skill. For example, the leader might ask children "Where are they now?" to highlight how to describe the setting of the story. The leader would repeat and expand children's responses using appropriate narrative terminology to help strengthen understanding of the skill. Children were encouraged to raise their hands to answer a question and the leader ensured each child had an opportunity to respond to a question. Strategies to simplify the question included providing children with multiple response options, or modeling an appropriate response and asking the child to repeat back the model answer.

Take-Home Suggestions

At the end of each session, parents were provided with a 1-page handout outlining the movement and preliteracy skill learned that day. These handouts provided the parents with a description on correct execution of the skill, as well as ideas for games that could be played at home to practice the skill.

Outcome Measures

Demographic and Engagement Survey

A demographic questionnaire was completed at baseline by the child's parent and included questions about the parent and the child on age, gender, ethnicity, parental education and occupation, and household income. A parent engagement questionnaire was administered at each of the four assessments to assess how frequently the children were engaging in movement and preliteracy activities at home, and the parental uptake of the teaching strategies used in the program.

Movement Skills

Children were administered the gross motor subtests of the Peabody Developmental Motor Scales-2 (PDMS-2) (40) at each assessment. The PDMS-2 is a standardized assessment designed to measure the progress of development of gross and fine motor skills in children from birth to age 6. The gross motor subtests—stationary, locomotion, and object manipulation—were administered by two trained graduate students. The sum of the raw scores of each of the three subtests was used as the dependent variable in the primary analysis. The assessment required approximately 30–45 min to conduct (41). The validity and sensitivity to change of the test has been assessed previously in 4-year-old typically developing children and the inter-rater reliability is 0.89 (41, 42).

Preliteracy Skills

Children were administered the Preschool Word and Print Awareness (PWPA) test and the Phonological Awareness Literacy Screening: Preschool (PALS-PK) to measure print-concept knowledge and alphabet knowledge (43, 44). The PWPA tests children on their print-concept knowledge, such as print directionality and print function, using 14 items administered in an interactive storybook reading format (43). Raw scores are then transformed into standardized scores with a mean of 100 and SD of 15. The PWPA has strong validity; item reliability is 0.74 and inter-rater reliability is 0.94 in a sample of children aged 3–5 years (45, 46). The PALS-PK Upper-case Alphabet Recognition task involves children naming each of the 26 letters of the alphabet as they are presented in a random order. The inter-rater reliability coefficient of this task is 0.99 (44). These measurements together took approximately 15 min to complete and were administered by a trained graduate student.

Attendance and Home Practice

Weekly attendance was taken at the program and the frequency of weekly home practice was measured with a parent-reported questionnaire completed each week during the free-play component of the program.

Procedure

The study received ethical approval from the Hamilton Integrated Research Ethics Board at McMaster University. All study appointments took place in a research lab at the university, while the intervention took place at an Early Years Centre in the local community. Study eligibility was confirmed by telephone at which time parents scheduled their first study appointment. Informed written consent was obtained at the first appointment. At each appointment, children were assessed on their movement and preliteracy skills and parents were asked to complete the demographic (at baseline only) and engagement questionnaires. After the first appointment (time 1), families were asked to come back in for their second appointment (pre-intervention) approximately 10 weeks later where they were reassessed on all measures. Within 1–2 weeks of the second appointment, families began to participate in the 10-week intervention. Upon completion of the intervention, families came back to the lab for their third appointment (post-intervention), and subsequently 5–6-weeks later for their follow-up assessment. See **Figure 1** for the flow diagram depicting the study procedures.

Statistical Analyses

Descriptive statistics were computed on the demographic characteristics of the sample, attendance, and at-home practice rates. The primary analyses were three repeated-measures analyses of variance (ANOVA) to assess change in the children's gross motor skills (raw scores), print-concept knowledge (standardized scores), and alphabet knowledge across all four time points. Least significant difference (LSD) *post hoc* *t*-tests were applied to models that were statistically significant overall to determine significant changes between specific time points (e.g., T2 vs T3). Secondary analyses included two repeated-measures ANOVAs examining change in parental engagement in both movement and preliteracy activities. A two-tailed alpha value of 0.05 was used to determine statistical significance.

RESULTS

Descriptive Characteristics

Eleven families were eligible and consented to participate in the first study appointment. All 11 families participated in the second appointment and 9 (82%) entered into the intervention and completed the remainder of the study. The analytical sample includes 9 children (6 boys) ranging from 36 to 59 months (mean = 45.6,

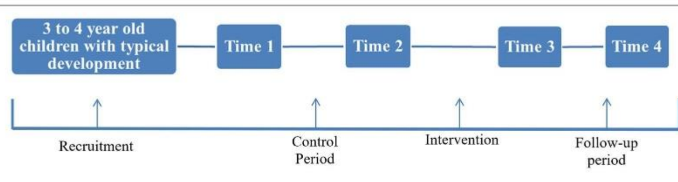

FIGURE 1 | Flow diagram of the study procedure.

SD = 7.3). **Table 2** describes the demographic characteristics of the sample.

Intervention Effects

The median attendance was 8 of 10 sessions, and the average rate of at-home practice was 48% and 46% for the movement skill and preliteracy activities, respectively. Mean scores and SDs of the primary outcomes (movement and preliteracy skills) at each time point are presented in **Table 3** and displayed graphically in **Figure 2**.

There was a statistically significant effect of time on the change in gross motor skills (Wilks' lambda = 0.09, p = .002), print-concept skills (Wilks' lambda = 0.09, p = .001), and alphabet knowledge (Wilks' lambda = 0.29, p = .046). For gross motor skills, LSD *post hoc* tests reveal no statistically significant changes between time 1 and 2 (during the control period) and 3 and 4 (follow-up period); however, there was a statistically significant change between time 2 and 3 (during the intervention period; mean difference = 14.8, p = .015). *Post hoc* LSD tests for print-concept knowledge revealed no statistically significant changes between time 1 and 2 (during the control period) or time 3 and 4 (follow-up period); but there was a statistically significant change between time 2 and 3 (during the intervention period; mean difference = 28.1, p < .001). Alphabet knowledge changed significantly between time 1 and 2 (during the control period; mean difference = 2.9, p = .048), time 2 and 3 (during the intervention period; mean difference = 2.7, p = .04), but there was no statistically significant changes between time 3 and 4 (follow-up period). The results of the secondary analyses revealed that there was no significant effect of time on parent engagement in movement or preliteracy skills. There were no reported adverse effects of the intervention.

TABLE 2 | Sample demographic characteristics.

Variable	*N* = 11
Child's mean age in months (SD)	45.6 (7.3)
Child's gender%	
Male	55
Child's ethnicity%	
Black	9
South Asian	9
Mixed ethnicity	9
White	73
Parent age (years)	33.9 (4.1)
Parent education%	
College/technical training	45
University degree	55
Parent income%	
Less than $50,000	36
Greater than $50,000	64

TABLE 3 | Scores over time on the primary outcomes.

Time	Gross motor skill (raw)	Print concept knowledge	Alphabet knowledge
1	230.7 (21.2)	93.8 (19.5)	13.1 (8.8)
2	236.0 (24.0)	102.6 (17.7)	16.0 (9.4)
3	250.8 (17.1)	121.9 (9.5)	18.7 (10.4)
4	256.6 (17.9)	130.3 (15.3)	19.1 (9.30)

DISCUSSION

Participation in our movement and preliteracy program led to positive improvements in gross motor skills, print-concept knowledge, and alphabet knowledge in 3- to 4-year-old children over time and these gains were sustained over a 5-week follow-up period. Participants in our study were measured four times to ensure a control, intervention, and follow-up period were captured; significant change occurred only after introduction of the intervention thus supporting the attribution of change to the intervention. Our results are consistent with the results of our quasi-experimental study published previously (35) as

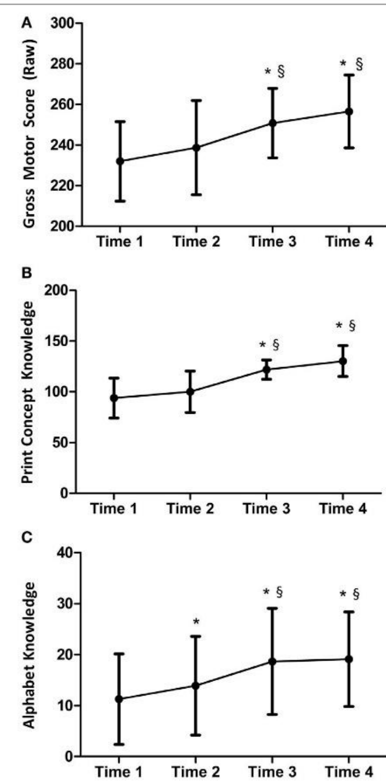

FIGURE 2 | Change over time in the primary outcome measures. **(A)** Gross motor skills; **(B)** print-concept knowledge; and **(C)** alphabet knowledge; *statistically significantly different from time 1; §statistically significantly different from time 2.

well as with the overall evidence supporting the effectiveness of interventions designed to improve movement skills in young children (30) as well as the wealth of evidence in favor of dialogic reading activities compared to passive reading strategies (27, 31, 33, 39, 43).

Furthermore, our results are consistent with extant literature supporting direct-instruction techniques compared to exclusive free-play in the development of movement skills or passive shared book reading activity in the development of preliteracy skills (11, 27, 28, 33, 34, 47). The current study demonstrated the feasibility and effectiveness of using direct-instruction techniques in a structured environment in combination with a short bout of free play to strengthen movement and preliteracy skills in young children. There is a large body of evidence supporting the use of free play in the development of important life skills including creativity, socio-emotional skills, and self-regulation (48, 49). However, free-play alone will not allow the maximal development of physical and academic skills because quality programs require planned instruction, clear goals, demonstrations of skill, opportunity for practice, and appropriate and timely feedback (11, 47, 50, 51). With respect to movement-based interventions, Robinson and colleagues acknowledged the critical need to provide explicit instruction to support the development of fundamental movement skills during early childhood and designed a study to test the effectiveness of such a program against a free-play recess intervention in preschoolers. Over a 9-week intervention period, children participating in the direct-instruction intervention demonstrated superior object manipulation skills compared to their peers in the recess group, and these skill gains were maintained at a 9-week follow-up (11). Within the preliteracy intervention research, there is also a wealth of evidence in support of explicit (direct-instruction) interventions as the best-practice approach as this is viewed as the most efficient method to improve preliteracy skills (27, 52). For example, Justice and colleagues (27) tested the effectiveness of an explicit preliteracy intervention against an adult-child shared book reading activity and re-telling activity and found that while both programs improved preliteracy skills, the direct-instruction program demonstrated larger gains in alphabet knowledge, print awareness, phonological segmentation, and rhyme production. Similarly, Hilbert and Eis (33) compared an explicit intervention developed by Laura Justice and Anita McGinty called *Read It Again Pre-K!* intervention against the usual curriculum in a Head Start program and found gains in picture naming ability. While our current study does not test the comparative effects of a direct-instruction intervention against a passive intervention, our results do provide evidence in support of the effectiveness of these explicit instruction techniques in both movement and preliteracy skill domains.

School readiness is about both the content of skill development as well as the process. Therefore, our intervention placed a large emphasis on teaching skills in a format reflective of a school day: that is, one in which children will need to attend to instructions, attempt the skill, self-regulate and learn from mistakes, persist with repetitions of skill execution, engage socially with teachers and peers, and creatively direct their own activities while being respectful and sensitive toward others. By placing children in this semi-structured environment they were not only able to improve their movement and preliteracy skills, but also were given the opportunity to develop self-regulation, pro-social skills, creativity, and a predilection toward learning—all of which define a child ready for school.

The results of this research have important implications on the promotion of health and well-being given the direct and indirect relationships with movement and emergent literacy skills. Improving the movement skill-set of preschool-aged children presumably enables participation in physical activities, which in turn, supports development of more complex movement abilities. Greater motor proficiency can lead to the strengthening of physical self-concept, which may positively reinforce children's motivation to engage in physical activities and promote cumulative physical and mental health benefits. A gain in preliteracy skills could plausibly lead to gains in specific aspects of executive function because the learning process itself places demands on specific executive functions (i.e., inhibition, cognitive flexibility) (24). Given the relationship between executive function and mental and physical health outcomes (53), long-term health benefits may possibly result from this indirect impact of a preliteracy intervention on executive functions. However, future research will need to formally evaluate both the short- and long-term impact of this intervention on measures of social skills, self-regulation, executive function, physical activity, self-concept, and other areas of health and development.

Limitations

Notably, this study is limited by a small sample size, few outcome measures, and lack of free-play control group. Analyses were underpowered to detect changes over time within specific gross motor domains (e.g., object control) or the effect of gender on intervention effectiveness. As well, we are limited by our measures to make definitive conclusions on the impact of our intervention on other aspects of school readiness. While movement and preliteracy skills are important components of school readiness, they are not comprehensive or direct measures of school readiness. The lack of control group implementing an exclusively free-play intervention limits our ability to make head-to-head comparisons between direct-instruction and free-play; however, the goal of the current study was not to evaluate the difference between these two approaches, but was to demonstrate the feasibility and effectiveness of direct-instruction in improving both movement and preliteracy skill levels. Lastly, our restricted outcome measures limit our ability to make conclusions about the effect of the intervention on broad measures of health and development (e.g., physical activity and executive function).

CONCLUSION

Future research needs to continue to evaluate the effectiveness of this movement and preliteracy skill intervention on various other indicators of child development, school readiness, and the long-term impact throughout childhood.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Hamilton Integrated Research Ethics Board at McMaster University with written informed consent from all subjects. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Hamilton Integrated Research Ethics Board at McMaster University.

AUTHOR CONTRIBUTIONS

CB designed the study, coordinated recruitment and data collection, designed the preliteracy component of the intervention and assisted with weekly implementation of the intervention, carried out the data analyses, and drafted the initial manuscript. EB assisted with study design, recruitment and data collection, design of the motor component of the intervention and weekly implementation of the intervention, and revised and approved the final manuscript as submitted. WC assisted with design of the intervention, selection and design of outcome measurements, and reviewed and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

CHAPTER 4: EVALUATION OF THE MOVE 2 LEARN (M2L) PROGRAM FOR YOUNG CHILDREN ON VARIOUS DOMAINS OF DEVELOPMENT

Preamble

Evaluation of the Move 2 Learn (M2L) program for young children on various domains of development is the second study in the dissertation. It presents the results of the mixed method study to re-evaluate the effectiveness of the Move 2 Learn program in children with typical development ages 3-4 years.

The following manuscript is currently in preparation for submission to *Child Development*. The manuscript has been formatted according to *Child Development* author guidelines.

Author Contributions:

CB designed the study, coordinated recruitment and data collection, trained and coordinated intervention leaders and volunteers, conducted qualitative data collection, carried out the quantitative and qualitative analyses, and was the primary author of the manuscript. EB assisted with training of the intervention leaders, data collection, and revised and approved the final manuscript as submitted. WC assisted with design of the study and reviewed and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted.

Contribution to overall dissertation:

This study did not provide evidence of a quantitative intervention effect on the primary outcomes; however, qualitative analyses revealed important benefits were conferred to children and parents participating in the program. The results of this study underscored the learning experience of M2L for parents and the potential of the program to enhance health and development in young children. Further, this study highlighted the importance of employing multiple methodologies to study the effect of interventions in young children in order to efficiently and comprehensively capture both expected and unexpected outcomes.

Move 2 Learn: A mixed method evaluation of a movement and pre-literacy program for young children

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Abstract

The Move 2 Learn (M2L) program is an intervention designed to improve fundamental movement skills (FMS) and pre-literacy skills in preschool children. A sample of 26 children (14 males; mean age = 47.85 months, SD = 7.51) were randomized to receive M2L immediately or be placed on a waitlist. FMS, pre-literacy skills, perceived physical competence, and rate of at-home practice were assessed in all children at baseline and following the intervention. Five parents participated in an embedded qualitative study to explore additional program outcomes. There were no statistically significant intervention effects; however, qualitative findings revealed that M2L positively contributed to various aspects of children's movement and pre-literacy abilities, children's confidence, as well as enhanced quality of parent-led at-home skill building activities.

Introduction

The attainment of fundamental movement skills (FMS) during the early years is critical to overall child development. These skills include stationary (e.g., balance), locomotor (e.g., running, jumping), and object control (e.g., catching, throwing, and kicking) skills. A strong evidence base of both observational and experimental studies support the relationship between proficient movement skills and engagement in physical activity (PA), enhanced executive function (EF), and positive self-concept (Diamond, 2000, 2015; Robinson, Rudisill, & Goodway, 2009; Robinson et al., 2015). Furthermore, a strong foundation in movement skills indirectly promotes both physical and mental health through its influence on PA. Theoretical support of this relationship emerges from the model proposed by Stodden positing that the development of FMS enables and encourages participation in PA, which in turn strengthens both actual and perceived movement competence resulting in higher levels of PA and health-related fitness; subsequently, both physical and mental health benefits are gained (Biddle & Asare, 2011; Robinson et al., 2015; Stodden et al., 2008; Timmons et al., 2012).

At present, however, there is an unacceptably low rate of children meeting recommended levels of PA (Aubert et al., 2018). Furthermore, there is evidence of declining health-related fitness and alarming rates of mental disorders among children (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015; Tomkinson & Olds, 2007), which may be attributed, at least in part, to the growing PA deficit. There are few studies that survey or track FMS competency trends; however, an analysis of Australian children and adolescents showed that self-reported FMS competency was low with prevalence rarely surpassing 50% (Hardy, Barnett, Espinel, & Okely, 2013). Given the interrelationships between movement skills, PA, and mental health, it is likely that underdeveloped FMS are contributing to concerning rates of PA, low physical fitness, and mental disorder among children.

The development of FMS in early childhood is a learned process such that children need to be taught these skills through structured and developmentally appropriate activities. Children will not master these skills naturally through free-play alone; direct instruction teaching strategies have been evidenced as the most efficient and effective approach to the development of FMS in early childhood (Alhassan et al., 2012; Robinson & Goodway, 2009; Robinson et al., 2009). Considering this evidence, the Move 2 Learn (M2L) program was developed to improve the FMS of 3-4-year-old children with the goal of improving overall physical, cognitive, and mental development. M2L is evidence-based and integrates best-practices from early childhood education and movement intervention research. Specifically, M2L consists of 10 one-hour/week sessions and uses direct instruction strategies and requires active parent/caregiver involvement throughout the sessions. Additionally, M2L has a curricular link with the inclusion of a pre-literacy component, the addition of which is supported by research demonstrating synergistic improvements in movement and reading outcomes as a result of a similarly structured multi-component program (Callcott, Hammond, & Hill, 2015). The pre-literacy component also functions practically as it attends to both parental and school curricular interests and is intrinsically enjoyable from a child's perspective which is an important predictor of participation and engagement (Chambers & Sugden, 2006; Zevenbergen & Whitehurst, 2003).

The feasibility and effectiveness of the M2L program was initially tested in a pilot study in 2015 using a quasi-experimental design (non-randomized waitlist control) in a sample of 3-to-4-year-old children with typical development. Results of the this study were favorable and showed significant improvements in movement and pre-literacy skills (Bedard, Bremer, Campbell, & Cairney, 2017a, 2017b). There was a significant effect of group on gross motor raw scores overall (F (1, 16)=4.67, $p<.05$; $\omega_p^2 = .16$) and print-concept knowledge (F (1, 16)=11.9, $p<.05$; $\omega_p^2 =.38$). Therefore, the purpose of the current proposed study is to re-evaluate the intervention using a more rigorous study design.

The specific study objectives are:

1) To determine the effectiveness of the M2L program in improving primary outcomes: movement and pre-literacy skills.
2) To determine the effectiveness of the M2L program in improving secondary outcomes: perceptions of physical competence, and parental engagement in at-home practice.

3) To explore additional program outcomes and overall experience as perceived by parents participating in the M2L program.

Methods

Design

Situated within a post-positivist paradigm, a mixed methods study design was used to evaluate the M2L program. Specifically, a qualitative study was embedded within the framework of a quantitative study. A mixed method approach was selected for two reasons. First, study objectives 1 and 2 beget the use of quantitative methods to obtain an observable estimate of effect in children. The third study objective invites the use of qualitative methods and is situated within the context of the first two objectives. Second, there are limitations to both quantitative data collection methods of parent-reported surveys and lab-based child assessments; qualitative inquiry into the expected or unexpected outcomes of the program will provide a richer and deeper understanding of the impact of the program on families. Mixed methods are well suited to gain these insights and comprehensively address the posed research objectives (Plano Clark et al., 2013).

Quantitative Study

A randomized wait-list controlled trial (RCT) was used to quantitatively address the first and second study objectives. Based on the pilot study conducted in 2015, a sample size of 46 participants is required to detect a partial eta square of 0.226 with a power of 80% and alpha value set a 0.05, accounting for 20% attrition (Bedard et al., 2017). Children were randomized 1:1 to either enter the program immediately following baseline testing or be placed on a waitlist (WL) to receive the program following their second wave of testing. All children were evaluated twice: the first assessment took place at baseline and the second evaluation took place after the experimental group received the intervention, approximately 10-12 weeks later. Randomization was completed using an online random number generator (https://www.randomizer.org/). Random assignments were placed in sealed, opaque, and sequentially number envelopes to enable allocation concealment. Group assignment was revealed following the completion of the baseline testing for all children. Due to the nature of the intervention, the families could not be blinded to their group assignment; however, all outcome assessors were masked to the child's random assignment.

Participants

A convenience sample of children were recruited from across the Greater Toronto Area by posting study flyers in EarlyON centres, local licensed daycares, community centres, and university facilities, as well as social media advertisements. Children were eligible if they were between the ages of 3 years, 0 months to 4 years, 11 months and if they had not been diagnosed with any developmental delay or health condition that would prohibit safe participation in physical activity. The study was carried out in accordance with recommendations provided by the Human Research Ethics Program at the University of Toronto. Informed written consent was obtained from parents of all participating children in accordance with the Declaration of Helsinki.

Intervention

The program took place at the University of Toronto's Athletic Centre and was led by two Master of Professional Kinesiology (MPK) students. The program sessions were 60 minutes in duration and took place one time per week on Saturday mornings for 10 consecutive weeks. Each session was structured in the same format with the first 5 minutes reserved for warm-up activities, then 25 minutes of direct movement skill instruction, followed by 15 minutes of child-directed free play, finishing with 15 minutes of a dialogic reading activity. Each week focused on one of 10 FMS using single-step skills acquisition strategies. Direct movement skill instruction was provided over three 8-minute blocks of activities that progressed in skill difficulty. For example, week 9 focused on kicking and the first 8-minute block of activity instructed children kick the ball from a stationary position while the second 8-minute block of activity progressed children to kicking the ball while moving. The third 8-minute block of activity was an obstacle course which contained skill stations of the week's activity as well as skill stations from previous weeks. The next 15-minutes consisted of child-directed free play during which the children had access to a wide variety of toys and equipment (i.e., hula-hoops, balls, puzzles, and blocks). The final 15-

minutes of the program session implemented an interactive shared reading activity. Each week would use a storybook to teach children 1 of 5 pre-literacy skills; every other week the activity would focus on the same skill to enable repetition and deeper learning of the skill. For example, weeks 1 and 3 focused on print awareness, and weeks 2 and 4 discussed characters and settings. Parents were actively involved in each part of the program session except for free play. At the end of each session, families were able to take home the storybook used that week and were provided with a 1-page handout reviewing the session's activities and providing ideas on how to practice the activities at home. The curriculum and specific strategies used in this program are evidence based and have been shown to significantly improve movement and pre-literacy delivered separately (Bremer, 2015; Justice 2010) and together (Bedard 2017a, 2017b).

Intervention training. Two MPK students led the M2L program with assistance from 2 undergraduate kinesiology student volunteers. The MPK students participated in a 1.5-day training workshop lead by the researchers (CB and EB). The goals of the workshop were to: 1) familiarize the students with the M2L curriculum; 2) increase knowledge on how to teach young children FMS and pre-literacy skills; and 3) increase confidence to teach young children FMS and pre-literacy skills. The design of the workshop followed recommendations from continuing education research for professional learning such that it was interactive and practical (Makopoulou, 2017). The first day of the workshop included a simulation of the first session and demonstrations of each of the 10 FMS and 5 pre-literacy skills covered in the M2L program. The second day was dedicated to hands-on practice of each week; students were given opportunities to practice demonstrating, modifying, and instructing each FMS and pre-literacy skill through a role-playing activity. At the workshop, the leaders were provided with a 41-page manual, which contained detailed weekly instructions for each of the 10 sessions and skill modification charts to outline how each activity could be adapted to the varying skill levels of individual children. Undergraduate volunteers also received the 41-page manuals and attended a 2-hour training session to familiarize them with the M2L program.

Outcome Measures

Parent-reported assessments. Parents were asked to complete a basic demographic survey to collect information on their age, gender, ethnicity, education, and household income as well as their child's age and gender and whether he or she is enrolled in school or daycare. The parent engagement survey asked parents about various programming their child is involved in, the frequency and the extent to which they may engage in movement or pre-literacy activities at home with their child. In total, these questionnaires took approximately 5 minutes to complete.

Motor skills. Movement skills were assessed using the gross motor sub-scales of the Peabody Developmental Motor Scales – 2 (PDMS-2; Folio &

Fewell, 2000). The PDMS-2 is standardized instrument designed to measure the progress of development of gross and fine motor skills in children from birth to age 6. The gross motor subscales include stationary, locomotion, and object manipulation skills. Administration of these three subscales required approximately 30-45 minutes to conduct and a total score was computed as a sum of each subtest (Darrah, Magill-Evans, Volden, Hodge, & Kembhavi, 2007). The PDMS-2 was normed on over 2000 American and Canadian children. The psychometric properties of the test have been assessed previously in preschool age typically developing children. The inter-rater reliability was 0.89 for the gross motor (Darrah et al., 2007). The PDMS-2 has been shown to be valid when examining changes over time (Burton & Miller, 1998).

Pre-literacy skills. Pre-literacy skills were assessed using the Preschool Word and Print Awareness Test (PWPA; Justice & Ezell, 2002). The PWPA uses a storybook to test children on their knowledge of 14 print-knowledge concepts such as text directionality, letter recognition, and print function. The storybook activity took approximately 5-8 minutes to complete. Item scores are summed and transformed to a standard score that ranges from 46 to 161 with a mean of 100 and standard deviation of 15. The PWPA has good evidence of validity and reliability among children ages 3 to 5 years (Justice & Ezell, 2002).

Physical confidence. Perceptions of physical competence were assessed using the perceived physical competence (PPC) subscale of the Pictorial Scale of

Perceived Competence and Social Acceptance for Young Children-Preschool-Kindergarten version (PSCS-PK). This subscale consists of 6-items which ask children to consider their resemblance to a pictorial representation of a child with either high or low physical competence. In a two-stage question structure, children are first asked which child is most like him or her, then they are subsequently asked to indicate whether that child is a lot like him or her or just a little like him or her. The 6 skills assessed include running, hopping, swinging, climbing, tying shoelaces, and skipping. The subscale takes approximately 2 minutes to administer. The internal consistency of the subscale for preschool aged children is 0.86 (Harter & Pike, 1984).

Attendance, at-home practice, and intervention fidelity. Weekly attendance at each session was recorded. Parents were also asked to complete weekly surveys that asked about the frequency of use of the session activities at home. Items required parents to report whether they practiced the activities at home and response options ranged from ‘did not practice this activity this week’ to ‘practiced this activity more than once a day’. Each weekly survey only asked about the activities covered in previous sessions. Scores were averaged each week to create a total score ranging from 0 to 100 with higher scores indicating higher rates of at-home practice. MPK student leaders completed a 7-item checklist following each session which assessed the extent to which they were able to implement active parent involvement, active child participation, and skill-modifications during each segment of the session. Each item required the rater to judge the session on average and response options for each item included 0 ‘did not attempt’, 1 ‘tried to attempt, but was unsuccessful’, and 3 ‘attempted and was successful’. The average score for each week was summed to create a total score ranging from 0 to 14 with higher scores indicating higher implementation adherence.

Procedure

Prior to initiation of the trial, ethics approved was obtained from the University of Toronto Human Research Ethics Program. The trial was also registered at clinicaltrials.gov (NCT03999619) before data collection commenced. Interested parents contacted the study team and eligibility was assessed over the phone. Informed written parental consent was obtained at the baseline testing appointment. All study testing took place at the INfant and Child Health Lab at the University of Toronto and the duration of each study appointment was approximately 60 minutes. At each appointment, children were administered the same assessments in the same order: the PWPA, PPC, and the PDMS-2. The child assessments typically took place in a room separate from the parent unless the child required their parent’s presence. While the child was being assessed, parents completed the demographic questionnaire (baseline only) and engagement survey. Outcome assessors included two graduate students and one post-doctoral fellow; the post-doctoral fellow was highly experienced in administering each tool and the two graduate students received extensive training on each tool. After the baseline appointment was completed, parents were provided with an envelop containing their random assignment to be opened out of sight of the outcome assessors to maintain blinding.

Statistical Analysis

Basic descriptive statistics of participating children and parents were computed. Between group differences in demographic and time 1 scores were assessed using independent t-tests for continuous variables and chi quatre (Fisher's exact test) for categorical variables. The primary set of analyses were a group by time repeated measures analysis of covariance (ANCOVAs) to assess changes in the children's motor and pre-literacy skills between the experimental and WL control group across the time with baseline scores entered as covariates. Secondary analyses were planned, which included a group by time repeated measures ANCOVA to assess changes in perceived physical competence and the frequency of parental engagement in motor and pre-literacy skill strategies. Partial omega square was used as the measure of effect size for the between group difference in all ANCOVA analyses. The Cohen's d_z effect size was computed to describe the effect size over time within each group. All analyses were conducted on an intention to treat basis using complete cases.

Qualitative Methodology

The embedded qualitative study applied qualitative description methodology (Sullivan-Bolyai, Bova, & Harper, 2005). Two methods of data collection consistent with qualitative description were employed: focus groups and interviews. The sampling frame for the qualitative study was the convenience sample recruited for the RCT. All parents participating in the program were asked if they would also like to participate in a semi-structured focus group or individual interviews. A focus group and interview guide were created including open-ended questions surrounding parents' perceived effectiveness and outcomes as well as their overall experience in the program. One member of the research team (CB) conducted the focus group and interviews and each were audio recorded and transcribed verbatim.

Qualitative Analysis

A qualitative inductive content analysis of the transcripts was conducted (Sandelowski, 2000; Sullivan-Bolyai, Bova, & Harper, 2005). According to qualitative description methodology, the following 6 analytic strategies were used: 1) Coding of data from the focus group and interviews; 2) Recording insights and reflections on the data; 3) Sorting through the data to identify similar phrases, patterns, themes, sequences and important features; 4) Looking for commonalities and differences among the data and extracting them for further consideration and analysis; 5) Gradually deciding on a small group or generalizations that hold true for the data; and 6) Examining these generalizations in light of knowledge that is known.

Integration of Quantitative and Qualitative Data

The use of a post-positivist paradigm allowed for multiple dimensions of embedding, specifically at the level of the study objectives and data interpretation. The knowledge generated in the qualitative study to address the third study objective provides valuable information about the experience of families in the program. However, as its meaning is only understood in the context of the primary question, both research questions are inextricably linked. The other point of interface is at the level of data interpretation; qualitative results regarding perceived outcomes identified by parents during focus group interviews were used to explain and extend the quantitative results. To fully integrate the data and compare the qualitative and quantitative findings, the generalizations that emerged from the qualitative analysis were re-examined to better align with the outcomes of interest in the RCT. Through an iterative process of data integration, the outcomes of interest were conceptualized as multifaceted constructs and the qualitative and quantitative methods of measurement captured different dimensions of each outcome. The results of both the qualitative and quantitative results for each outcome of interest were examined concurrently to allow for a side-by-side comparison.

Results

Descriptives

There were 32 eligible families that were enrolled into the study, of whom 15 were randomized to the experimental group and 17 were randomized to the WL control. Of these 32 families, 6 withdrew from the study following their first study appointment (see Figure 1). Reasons for withdrawal were all due to schedule conflicts with other programming except for 1 parent who reported they were no longer interested in participating. The final sample included 26 children (14 males) with a mean age of 47.85 months (SD = 7.514). Table 1 describes the demographic characteristic of the sample by group. There were no significant differences between the experimental and the WL control group on any demographic variables or outcome variables measured at baseline (see Tables 1 and 2).

Attendance, at-home practice, and intervention fidelity

The median attendance was 8.5 sessions out of 10 (IQR: 6 – 9). The average rate of at-home practice was 25% (SD = 23%) and 44% (SD = 19%) for the motor and pre-literacy activities, respectively. Finally, the implementation checklist showed that the leaders scored an average of 12.2 (SD = 0.725) out of 14.

Quantitative Intervention Effects

Table 3 presents the scores over time for both the experimental and WL control group for each outcome. Results of the ANCOVA indicate that there was no significant effect of the intervention on any of the measured outcomes (see Table 4), with the exception of parental engagement in at-home movement activities ($F(1, 19) = 6.671$, $p = .018$, $\omega_p^2 < .01$) in favour of the experimental group.

Qualitative Intervention Effects

Qualitative data were collected from 5 parents (2 fathers and 3 mothers): the focus group was conducted with 3 parents and 2 individual interviews were conducted. Data coding of the transcripts from the focus group and interviews resulted in 40 codes which were then sorted into 8 generalizations (see supplementary Table 1), which centered around the overall perceived experience of the children during the program, changes in movement and pre-literacy skills and confidence, the learning experience for parents, the value of parental engagement, and pro-developmental healthy habit formation.

Integration of Qualitative and Quantitative Findings

This RCT aimed to evaluate the effect of M2L on outcomes of movement skills, pre-literacy skills, perceived physical competence, and parental engagement. The qualitative findings, however, have emerged to encompass and extend these measured outcomes within the larger context and experiences of each family. There is a somewhat divergent set of findings between the qualitive and quantitative findings, contrasting the mostly null quantitative results of the primary analyses with the largely positive qualitative findings described by parents in the experimental group. However, the results of the qualitative findings help explain and extend the results of the RCT and generally complements the within group trends of the experimental group. Table 6 describes both the qualitative and quantitative results for each outcome of interest.

The quantitative results demonstrated that while both the experimental and WL control groups improved their movement proficiency as measured by the PDMS-2, they did so at a similar rate. Therefore, improved motor proficiency cannot be exclusively attributed to the intervention. In focus group discussion and interviews, parents did not specifically comment on the quality or proficiency of their child's movement skills; rather, they described an increase in the variety of movements in which their child was engaging. A common example expressed by many parents was that they noticed their children engaging in different locomotor and object manipulation activities, more than they had prior to participating in M2L. One parent noted that, "When we're out, he's throwing overhand, underhand, balancing on one foot, hopping, skipping, way more than he did before." (P4) Therefore, it appears that while the intervention was unable to improve motor proficiency beyond maturational changes over 10 weeks, it did introduce children to a diversity of motor skill activities that they felt comfortable to add to their movement repertoire.

Similarly, while the quantitative results did not reveal statistically significant differences between groups with respect to improvements in pre-literacy skills as measured by the PWPA task, the qualitative findings suggested more active engagement in reading activities and a greater predilection to explore different elements of both the text and the story. All parents indicated that their child was much more participatory during their shared book reading, and often without prompting, their child pointed out the key information throughout the book (such as the illustrator or setting). Therefore, while quantitative improvements in pre-literacy skills were not detected, it appeared that children's motivation to actively participate in reading activities may have been increased over the 10-week intervention.

This study quantitatively measured children's perception of only physical competence using the PSCS-PK; however, parents spoke more broadly about their child's global confidence with a few specific references to their confidence in reading skills and enthusiasm to challenge their movement skills. Of note, scores on the PSCS-PK decreased in both groups (though non-significantly); this contrasts with the qualitative findings reported by parents, which showed that parents perceived increases in their child's confidence and a greater willingness to try new movements. This was expressed by one parent, stating, "he's very confident in himself, his movement and his reading, yeah he loves to brag to everyone that he knows, this is the author, this is the illustrator," (P3) and another parent noted, "she has much more confidence than previously before to do lots of different things."(P2) Therefore, it appears that while perceptions of physical competence may have decreased as reported by children, parents perceived that confidence in reading and global confidence increased.

The results of both the qualitative and quantitative assessment of parental engagement in movement activities at home converged, but both types of measurements still appear to capture different facets of this construct. Quantitatively, parents in the experimental group reported a significantly higher frequency of engaging in movement activities at home, compared with the WL control group. The qualitive findings extend these findings by revealing not only an increase in frequency but an increased awareness of the importance of engaging in these types of movement activities at home and the specific approach to practicing these activities at home using single-step skills acquisition strategies in a climate that encourages children to challenge their skills at their own pace to obtain developmentally appropriate levels of mastery. Many parents noted that they were unaware that movement skills must be taught and that their child was unable to perform certain skills. One parent noted, "there are things I assumed he could do, but I realized he couldn't do when we did the exercises, but I just assumed he could do them, and so that really forced us to go home and practice them and do them more.” (P4)

Quantitative assessments of parental engagement in reading activities showed increases in the frequency in which parents used the intervention-specific pre-literacy skill building strategies when reading to their child, in both the experimental and WL control group resulting in non-significant group difference. Qualitative data supported the increase in frequency of using these strategies during their daily reading activities with their child but also revealed that parents were spending more time reading and exploring the book to allow for active participation from their child (i.e., answering open-ended questions posed by the parent); this approach differed from the passive reading activities most parents described engaging in prior to their exposure to the intervention. Many parents expressed that they have changed the way they read to their child stating, “it added more points…like asking questions, talking about the author, things I've never thought of… I'm learning that approach, and just slow down and let them explore a little bit longer.” (P4) Therefore, the frequency of engaging in specific pre-literacy activities may not have increased because of the intervention; however, the quality of the shared book reading activities appears to have been enhanced.

Discussion

Principle Findings

This study sought to comprehensively evaluate the effectiveness of the Move 2 Learn program for 3-4-year-old children with typical development and their parents on the following outcomes of interest: movement skills, pre-literacy skills, perceptions of physical competence, and parental engagement in motor and pre-literacy activities. The results of the RCT did not show statistically significant gains in the experimental group compared with the WL control group on any measured outcome apart from parental engagement in motor activities, nor did results show any adverse effect from participating in M2L. However, the embedded qualitative study provided an additional lens to view the effectiveness of M2L by capturing improvements in different dimensions of the outcomes of interest. Integrated results revealed that while quantitative improvements in the measured outcomes do not exceed developmental changes observed in children not participating in the intervention, the qualitative evidence shows that M2L appears to have positively contributed to various aspects of children's movement and pre-literacy abilities and overall confidence, as well as enhanced quality of parent-led at-home skill building activities.

Comparison to Extant Literature

Movement skills. Existing literature on the effectiveness of movement-based interventions for preschool aged children is generally positive. Systematic reviews by both Veldman and colleagues (Veldman, Jones, & Okely, 2016) and Van Capelle (Van Capelle, Broderick, van Doorn, E.Ward, & Parmenter, 2017) report significant intervention effects in total gross motor skills, and specifically locomotor and object control skills. Furthermore, the pilot study conducted in 2015 to test M2L also demonstrated statistically significant improvements in total gross motor skills, including both object control and locomotor skills (Bedard et al., 2017a, 2017b). The qualitative results of the current study suggests that children in M2L are engaging in a wider range of movement activities and skills; however, it is unknown whether parents are simply more aware and therefore observant of these skills in their children or whether these are real changes. Additionally, the quantitative results do not support significant group differences in movement proficiency in children. However, there are key differences between M2L as implemented in the RCT compared with its implementation in the pilot study which may explain the discrepancy. The intervention was administered by the researchers in the pilot study and therefore its implementation fidelity was guaranteed. In the current RCT, however, M2L was delivered by trained MPK students and the results of the implementation assessment revealed an average implementation score of 12.2 (SD = 0.725) out of a possible 14. While this score represents adequate implementation it also suggests slight deviations from the intervention occurred therefore possibly diluting the intervention effects. Additionally, while the attendance rate is comparable between the current study and the pilot at 8.5 and 8 out of 10, respectively, the rate of at-home practice of movement skills was substantially lower in this RCT at only 25% compared to 45% in the pilot study (Bedard et al., 2017a). Therefore, despite enhanced quality of the at-home practice as indicated by the qualitative findings, the lower frequency of at-home practice of the movement activities between intervention sessions may be responsible for the discrepant findings between the pilot and the RCT. In comparison to other movement-based interventions, M2L is relatively short in duration taking place for 1 hour, once per week over 10 weeks. Veldman et al. (Veldman et al., 2016) reported that previously published movement-based interventions for preschool-aged children range in length from 2 to 10 months, take place 2 to 5 times per week, and session durations typically range from 15 to 40 minutes; the majority of these studies demonstrated superior gains in movement skills compared to a control group. Therefore, the discrepancies between previous studies and the current RCT may be a result of variations in intervention length, frequency, and duration with higher dosages more likely to result in significant intervention effect.

Another notable difference between the current RCT and previously reported trials on movement-based interventions is the assessment procedures used to track changes in children's motor skill. The current study employed blind assessors to measure motor proficiency using the PDMS-2; however, most other studies that demonstrated significant group differences used the Test of Gross Motor Development 2 (TGMD-2) and only half used assessors that were blinded to the group status, including the pilot study for M2L. The PDMS-2 assesses children's proficiency in 44 motor skills and includes skills beyond the FMS traditionally targeted in movement-based interventions, including M2L. Whereas the TGMD-2 only assesses 12 skills and is often used for intervention planning purposes. Therefore, trials utilizing the TGMD-2 may more likely to demonstrate significant findings given the obvious alignment between the targeted intervention skills and assessment skills. Also, since the PDMS-2 assesses more gross motor skills compared with the TGMD-2, scores of the former would contain more variability and subsequently differences between groups would more difficult to detect. Finally, given the subjectivity of assessing children's movement skills, the implementation of assessor blinding is critical to negate detection bias. Therefore, it is possible that non-blinded studies may have biased scores which favor the intervention group resulting in an inflated intervention effect.

Pre-literacy skills. With respect to the effect of the intervention on pre-literacy skills, the non-significant group differences are also discordant with the results of the pilot study and extant literature on direct instruction pre-literacy interventions. The use of direct instruction or "explicit intervention" is common within pre-literacy curricula and has empirical support as the most efficient approach to enhance pre-literacy skills of preschool aged children (Justice, Chow, Capellini, Flanigan, & Colton, 2003; Kaderavek & Justice, 2004), hence its use in Move 2 Learn. The results of the pilot study further supported its effectiveness as a researcher delivered curriculum within a movement-based intervention. However, in the current study the experimental group did not show superior gains beyond the WL control group and this may be due again to differences in the intervention implementation, rate of at-home practice, and testing procedures. Explicit instruction models of pre-literacy are more commonly implemented in a classroom setting by teachers, reading specialists, and/or speech-language pathologists and generally are administered at least twice per week (Justice et al., 2003; Kaderavek & Justice, 2004); this contrasts with single session per week administered by trained MPK students. It may be possible that the effectiveness of direct instruction strategies are moderated by the skill level of the teacher and frequency of intervention sessions; therefore, sessions delivered by researchers and literacy specialists multiple times per week may be more likely to produce gains in pre-literacy skills. Furthermore, the rate of at-home practice as reported by parents in the current study was slightly lower than that reported by parents in the pilot study (44% and 52%, respectively), which could contribute to a smaller intervention effect. Lastly, the quantitative assessment of pre-literacy skills only assessed one dimension of pre-literacy skills, print-concept knowledge, whereas qualitative findings from this study revealed that children participating in the intervention showed a greater interest in exploring the story (i.e., characters, settings, plot) and different elements of the text (i.e., table of contents, illustrator, page numbers). These qualitative observations reported by parents may not have been captured by the PWPA task given its limited scope; therefore, improvements in pre-literacy skills were not quantitatively detected. Finally, as mentioned above, blinded assessments are critical in the skill evaluations of children;

therefore, previous studies may have introduced bias through lack of blinding to the child's group status.

Perceived Physical Competence. The literature evaluating the effectiveness of movement-based interventions on perceived physical competence or overall confidence among preschool-aged children is scant, and this is likely due to the difficulty in assessing confidence in young children. Surprisingly, PPC scores decreased over time for the children participating in M2L and the WL control group, though this was not statistically significant. In a 2009 study by Robinson, Rudisill, and Goodway (Robinson et al., 2009), children participating in a mastery motivational climate movement intervention showed an increase in perceived physical competence compared to both a low-autonomy instructional intervention and control group (Robinson et al., 2009). However, children in this study were sampled from a socioeconomically disadvantaged neighbourhood and their baseline scores on the PPC subscale were lower than the scores of the children in the current sample, thereby possibly providing more opportunity for increasing their perceptions or regressing to the mean. Young children often have inflated perceptions of their competence as they lack the cognitive skills required to make accurate judgements about their own abilities, often equating perceptions of proficiency with effort expended in the activity (Harter, 1999). Self-perceptions of motor competence begin to align with actual motor skill with age, and this may begin to occur as early as kindergarten (Harter, 1999; LeGear et al., 2012).

Therefore, the current study may be detecting the normal developmental trend of decreasing perceived competence as their cognitive abilities develop and they begin to observe their own skills in comparison to their peers. However, given the results of the qualitative data and the limited validity of the 6-item PPC subscale, it is also possible that quantitative assessment was unable to comprehensively capture changes in perception of competence that occurred in the M2L participants. The PPC subscale asks children to report their perceived competence in only 6 physical skills and while these 6 items have face validity, they do not comprehensively encapsulate overall physical competence excluding both stationery and object manipulation skills. Furthermore, in early childhood, it has been noted that a sense of confidence does not emerge from performance of specific tasks but is rather manifested in behaviours such as taking initiative, exploring challenges, and displaying curiosity to engage in different activities (Haltiwanger & Harter, 1988; Harter, 1999). As children become older, task and domain-specific perceptions of competence will become more relevant to their self-esteem and overall confidence (Haltiwanger & Harter, 1988). Therefore, the PPC subscale may not be the most valid nor responsive instrument to measure meaningful changes in confidence resulting from movement-based interventions. Parents reported increases in overall confidence by observing their children trying new activities and activities they previously expressed fear towards (i.e., climbing play structures at the park, somersaults, etc.), exhibiting pride when successfully performing movement-activities at home, and discussing and demonstrating their newly learned skills for their classmates. Therefore, while M2L may not have specifically impacted perceptions of the 6 physical skills included in the PPC subscale, the intervention appeared to have increased positive perceptions of children's general movement ability and improved confidence overall.

Parental Engagement. There were larger gains in parental engagement scores for both movement and pre-literacy activities in the experimental group, which aligns with the results from the pilot study, though only the increase in frequency in movement activities was significantly larger for the experimental group. Parents participating in M2L consistently reported that they were able to embed the lessons they learned in the program into their daily lives at home and emphasized that the program was a highly valuable learning experience of them. Parents frequently mentioned that they believed they gained knowledge on the importance of teaching movement and pre-literacy skills to their children and on the developmentally and instructionally appropriate methods to teach their children these skills. Taken in consideration of parents' observed increase in their child's willingness and enthusiasm to be active and engage in different movement and reading activities, this is particularly illuminating as it may suggest that parental engagement beyond the 10 intervention sessions could stimulate improvements in skills level which may only be detectable over a longer period of time. A 10-week intervention may not have been sufficiently long to elicit quantitatively observable changes in skills in the measured domains, however, through sustained parental engagement in movement and pre-literacy activities at home, parents may be able to strengthen their children's actual movement and pre-literacy skills and promote positive perceptions of competence. However, the length of time required to produce these skill gains and the observational period required to detect meaningful changes is unknown. A meta-regression conducted by Logan, Robinson, Wilson, and Lucas in 2012 found no significant relationship between the duration of movement-based interventions and the magnitude of intervention effect; however, the authors noted that there may be a critical amount of instruction that is required to elicit changes and negligible improvements are made beyond this duration (Logan, Robinson, Wilson, & Lucas, 2012). Similarly, a study by Justice and colleagues (Justice, Logan, Kaderavek, & Dynia, 2015) suggested that there may be diminishing gains in pre-literacy skill beyond a dosage threshold as they found that skills gains in children participating in both an at-home and in-school intervention were similar to gains observed in children participating in an in-school intervention only. Long-term follow-up evaluations of preschool interventions is also limited as most studies include only a single assessment immediately following completion of the intervention. An exception is a study by Piek and colleagues (Piek et al., 2013) who administered a movement assessment both immediately following the intervention and 1-year later and found improvements in children's movement skills only at the 12-month follow-up. This suggests that some movement-based interventions may elicit their intervention effects over longer spans of time than are typical in most experimental designs and thus remain undetected in the short-term. However, it is difficult to make direct comparisons to the intervention used in Piek et al. (Piek et al., 2013) because their intervention was delivered in a school-setting by teachers. Nonetheless, more research is required to identify the critical instruction duration including time spent at-home and the length of observation period to quantitively detect meaningful improvements in development. On the other hand, given the positive response of parents to the intervention, it is possible that parents may continue to reinforce and practice the skills targeted in the intervention; if this occurs, we may see gains later on not yet detected.

Overall, the results of this study indicate that quantitative changes in the children's skills were not observable over 10 weeks, but qualitative findings show that changes in other facets of movement and pre-literacy skills, as well as motivation and general predilection towards movement and pre-literacy activities took place. These qualitative changes are relevant and may be instrumental in producing quantitative changes which may be observable over a longer period. It is plausible that through exposure to M2L parents have integrated movement and pre-literacy skill building activities into their daily routine and have created a family climate that promotes and supports these skill areas; sustained engagement in these activities by parents and continued interest and motivation to participate by children beyond the 10-week intervention may lead to superior improvements in movement and pre-literacy skills and self confidence compared with children not exposed to M2L.

Limitations

Nonetheless, neither the quantitative nor qualitative results can be exclusively attributed to the intervention given the presence of several study limitations. Primarily, the results are limited by a restricted sample size. The sample size calculated determined that 46 children would be required to power the primary outcome at 80%, however, the rate of recruitment in the current study was much slower than anticipated (based on the pilot recruitment rate), and the target sample size was not achieved. Prolonged recruitment efforts have both economic and ethical consequences (Gul & Ali, 2010). Therefore, recruitment was terminated and the intervention was commenced after only 32 participants were recruited to avoid negatively affecting the commitment of those families that had already been recruited into the study and to effectively manage the limited personal and financial resources allocated to the study. Further compounding the issue of power was a loss to follow-up rate of 19%. Therefore, all analyses were underpowered to detect any intervention effect. Additionally, the instruments used to quantitatively measure the outcomes of interest may not have been sufficiently sensitive to detect small changes over 10 weeks and child behavioural regulation issues may have introduced measurement error into the results; however, since the assessors were blinded, this would not have systematically influenced the results in favor of either group. Generalizability of the results is restricted to children from families of relatively high socioeconomic status living in a highly urbanized community. Finally, the methods of the embedded qualitative study were necessarily constrained by the design of the RCT; therefore, certain elements of qualitative methodology were compromised, specifically the use of convenience sampling over purposive sampling, using a fixed interview guide rather than changing the data collection procedure based on emergent findings, implementing data collection at single time following the intervention instead of multiple points of interaction with participants prohibiting data saturation. In particular, it should be noted that the transferability of the qualitative findings are similarly limited as the quantitative results because the sample size was small and was likely comprised of highly motivated parents who may have had particularly positive experiences in the program compared to those who did not participate in the focus group or interviews.

Conclusions

Overall, the results of this mixed methods study provide support for continued evaluation of the Move 2 Learn intervention. Quantitative results do not provide evidence of an effect on any of the measured outcomes over the 10-week intervention period, but limited statistical power also indicates that intervention effects cannot be ruled out. Qualitative findings reveal positive changes in children’s movement and pre-literacy skills and confidence, as well as increases in parental engagement in movement and reading activities at home and a strengthened relationship between parent and child following participation in M2L. This research highlights the importance of including parents and caregivers in the implementation of movement-based programs and the utility of employing a mixed methods study design to comprehensively evaluate such programs.

Future Directions

The results of this study show promise for the effectiveness of M2L. Future work should continue to evaluate the effect of M2L in larger samples to provide sufficiently powered analyses to estimate precise quantitative effects of the intervention on developmental and health outcomes. Additional work is required to understand the optimal length of instructional time including parent engagement at home and the ideal level of training and expertise required to deliver the program to produce maximal skill benefits. Questions regarding the long-term effect of movement-based interventions in children as they enter school and proceed into middle childhood also remain and should be investigated. Finally, the effectiveness of the program should be explored in other diverse samples of children, such as children with developmental delay or from low socioeconomic neighbourhoods, and a variety of settings such as community centres or virtual platforms.

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Tables

Table 1. *Sample Demographic Characteristics*

Variable	Experimental Group (n=15*)	Control Group (n=17)	*p*
Child's Age in months, mean (SD)	45.33	47.18	.502
Male; *n* (%)	8 (57)	10 (59)	.224
Child's Ethnicity; *n* (%)			.277
Black	1 (7)	0 (0)	
South Asian	2 (14)	3 (18)	
West Asian	0 (0)	1 (6)	
Chinese	3 (22)	2 (11)	
Mixed Ethnicity	7 (50)	3 (18)	
Latin American	0 (0)	1 (6)	
White	1 (7)	7 (41)	
Child in School; *n* (%)	4 (29)	5 (30)	.637
Child in Daycare; *n* (%)	8 (57)	11 (65)	.475
Parent Age, mean (SD)	39.43 (6.87)	37.77 (4.15)	.412
Parent Education; *n* (%)			.586
College/Technical training	1 (7)	3 (18)	
At least university degree	13 (93)	14 (82)	
Parent Income; *n* (%)			.341
Less than $50,000	4 (31)	3 (19)	
Greater than $50,000	9 (69)	13 (81)	

Note: *missing demographic information for 1 participant; *SD* = standard deviation, *n* = sample size

Table 2. *Baseline Scores of the Experimental and Wait-list control groups*

Variable	Experimental Group (n=15)	Control Group (n=17)	*p*
Gross Motor Skill Score (raw score); mean (SD)			
Stationary	45.27 (5.69)	45.88 (6.91)	.792
Locomotion	145.60 (15.68)	146.65 (15.87)	.853
Object Manipulation	33.53 (6.59)	32.12 (6.19)	.536
Total	224.40 (25.43)	225.63 (24.55)	.892
Pre-literacy Skill (standardized score); mean (SD)	89.73 (23.90)	98.06 (16.87)	.260
Perceived Physical Competence; mean (SD)	3.29 (0.59)	3.23 (0.70)	.824
Parent Motor Engagement; mean (SD)	3.34 (1.13)	3.47 (1.21)	.782
Parent Pre-literacy Strategy Use; mean (SD)	4.17 (0.97)	4.25 (1.12)	.843

Note: *SD* = standard deviation; n = sample size

Table 3. *Scores over time in the experimental and WL control groups for primary and secondary outcomes*

	Experimental (n=10)				Control (n=16)			
Variable	Time 1	Time 2	d_z	*p*	Time 1	Time 2	d_z	*p*
Gross Motor Skill Score (raw score); mean (SD)								
Stationary	45.27 (5.69)	49.50 (5.91)	1.022	*.010*	45.88 (6.91)	47.69 (6.10)	0.69	*.018*
Locomotion	145.60 (15.68)	152.00 (10.48)	0.12	*.718*	146.65 (15.87)	155.37 (14.76)	0.87	*.003*
Object Manipulation	33.53 (6.59)	36.40 (4.62)	0.51	*.882*	32.12 (6.19)	35.31 (4.77)	0.38	*.150*
Total	224.40 (25.43)	237.90 (17.43)	0.29	*.379*	225.63 (24.55)	238.38 (23.00)	1.00	*.002*
Print Concept Awareness (standardized score); mean (SD)	89.73 (23.90)	110.40 (16.46)	0.46	*.182*	98.06 (16.87)	112.00 (17.29)	1.26	*<.001*
Perceived Physical Competence	3.29 (0.59)	3.18 (0.45)	-0.51	*.143*	3.23 (0.70)	3.06 (0.58)	-0.11	*.686*
Parent Motor Engagement	3.34 (1.13)	4.07 (0.42)	0.50	*.172*	3.47 (1.21)	3.33 (0.97)	-0.12	*.677*
Parent Pre-literacy Strategy Use	4.17 (0.97)	4.84 (1.42)	0.45	*.214*	4.25 (1.12)	4.17 (0.98)	0.05	*.853*

Note: d_z = Cohen's effect size; *SD* = standard deviations; *n* = sample size.

Table 4. *Summary of ANCOVA Results. The dependent variable is the time 2 score*

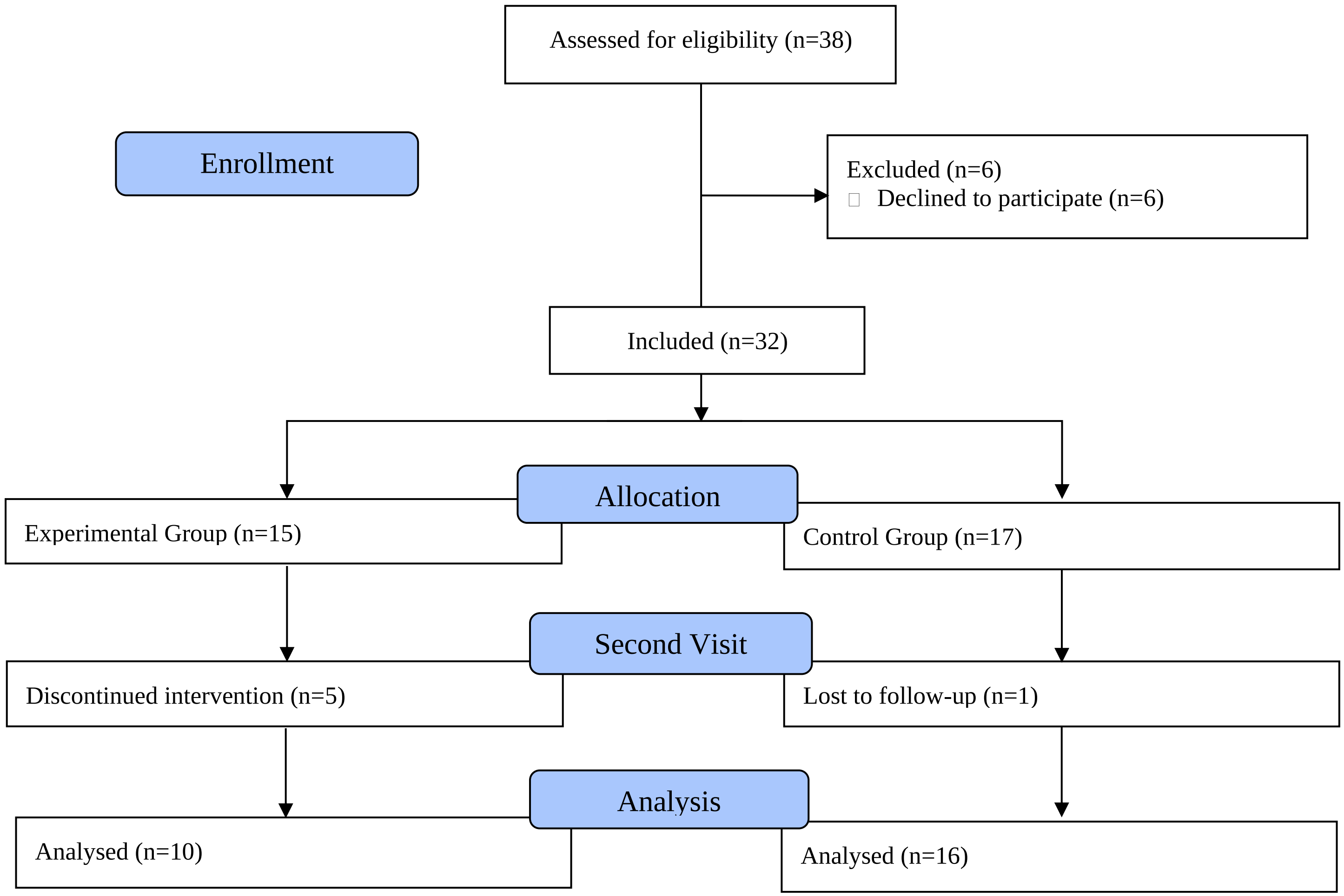
Source	F-value	*p*	ω_p^2
Gross Motor Skill Score (raw score)			
Stationary	3.165	*.09*	<.01
Locomotion	2.964	*.10*	<.01
Object Manipulation	0.030	*.86*	<.01
Total	2.458	*.13*	<.01
Print Concept Awareness	0.016	*.90*	<.01
Perceived Physical Competence	0.135	*.72*	<.01
Parent Motor Engagement	6.671	*.02*	<.01
Parent Pre-literacy Strategy Use	1.938	*.18*	<.01

Note: ω_p^2: partial omega squared.

Table 5. *Summary of qualitative and quantitative results by outcome*

Outcome	Qualitative Finding	Quantitative Findings Between Group	 Experimental Group
Movement Skills	Increased movement repertoire	Small, negative, non-significant effect	Small, positive, non-significant effect
Reading Skills	Increased engagement in the different elements of the book and story	Small, negative, non-significant effect	Medium, positive, non-significant effect
Perceived Physical Competence/ Confidence	Increased global confidence; increased confidence in physical and reading abilities over time with practice; increased willingness to challenge their skills	Small, positive, non-significant effect	Medium, negative, non-significant effects
Parent Engagement in motor activities	Changed their approach to implementing movement activities at home (i.e. creating a mastery environment)	Small, positive, significant effect	Medium, positive, non-significant effect
Parent Engagement in pre-literacy activities	Changed their existing reading activities to include strategies learned in the program (i.e. to ask their child more questions about the words and the story)	Small, positive, non-significant effect	Small, positive, non-significant effect
Relationship with Child	Strengthened the bond between child and parent; parent was able to enhance their child's learning by providing comfort and sense of security	*Not measured*	*Not measured*
Parent learning	Learned the importance of teaching movement and pre-literacy skills at a young age; learned the skills of how to teach their children these skills; learned how to create an environment in which their child is motivated to engage in movement and pre-literacy activities	*Not measured*	*Not measured*

Figure 1. CONSORT 2010 Flow Diagram



Supplementary Material

Table 1. *List of the generalizations that emerged from the qualitative study*

Theme	Example Quote
Enjoyable experience for children	"she comes here all the time because she enjoys it." **(P1)** "I think in her mind it is like play, like a play date." **(P2)**
Increased variety of movements	"he'll do things where he will jump over the line, or he'll say, 'I'm going to jump 2 feet over this line onto the curb', or "put me up here so I can do a balance beam on this person's sidewalk.'" **(P3)** "they've expanded their abilities… when we're out, he's throwing overhand, underhand, balancing on one foot, hopping, skipping, way more than he did before." **(P4)**
Increased reading skills	"It added another level of understanding to literacy and reading, so now he is good at recognizing words." **(P4)** "They are more immersed in the reading, which I think keeps them more engaged and interested." **(P4)**
Increased confidence	"she has much more confidence than previously before to do lots of different things." **(P2)** "he's very confident in himself, his movement and his reading, yeah he loves to brag to everyone that he knows, this is the author, this is the illustrator." **(P3)**
Healthy habit formation	"And she loves to go to the library now." **(P5)** "so, if she come s home and she doesn't have recess at school then she has the recess at home… 'No, we didn't go out, we have to do now. We've [have] do some exercises at home now Mom'." **(P5)**
Parent-child bonding	"it was special for us." **(P5)** "Before, I think, especially my relationship with [my daughter] much better than before." **(P2)** "because I don't usually have the time to play with her like that." **(P5)**
Security to learn	"so, I feel like it being side by side…It instills that sense of security so the security to learn." **(P4)**

	"she has the confidence because she knows her mommy does it right behind her, whatever she's doing, I'm there, somebody's there to show her how." **(P5)**
Learning experience for parents	"it's not only their learning, it's also we are learning as well." **(P1)** "As much as the exercises are supposed to be teaching the children, I thought really they taught the parents more." **(P2)**

Qualitative Results

Overall perceived experience of the children during the program

Parents consistently spoke about their child's enjoyment of the program, indicating that they appeared to have fun during the sessions and always felt excited to come to the program each Saturday morning. For example, when asked if it was difficult to bring their child to the program each week, one parent responded, "no, not really…because I think in her mind it is like play, like a play date." **(P2)** This general sense of enjoyment was also evidenced by the children recognizing the program location when walking down the street on non-program days, "I think she enjoyed the program. She had a good time. Because sometimes when we pass through that site, she says "oh mommy we have been here before!" we went by the site today. I think she had a nice time enjoying the program." **(P5)** Some parents also noted that their child would be quite shy during the warm-up activities, however, once further into the session, would become more comfortable. For example, one parent noted, "the first few minutes, he takes just a little time." **(P3)** The variety of activities and equipment was also noted to enhance their child's enjoyment of the program, with one parent stating, "different games, playboards, books, yeah in her mind it's a playdate, very exciting." **(P2)**

Skill development of the children

The most evident changes parent noted in their children after participating in the program were enhanced reading abilities, increased range of movement skills, higher sense of confidence, and an improved motivation to engage in both reading and physical activities. All parents indicated that their child is much more engaged during their shared book activities, and often without prompting their child will point out the key information throughout the book. For example, one parented stated:

> Now when he reads, he is very much into the story, the plot, the characters…he will even describe what is going on in the scene, so I have noticed that… he knows this is the author, this is the illustrator. And some books he's like, 'this book doesn't have an illustrator.' Or even the table of contents, he loves to be like, 'I'm [going to] read this one, its page 46. And I'm going to find that page.' **(P3)**

Another parent said:

> It added another level of understanding to literacy and reading, so now he is good at recognizing words, and I'll ask him 'why do you think that word is, say "because"', and he says 'well "b" because it starts with a "b"', so even though he can't read it, he is recognizing, because we are following the words, he is recognizing what they look like, so that's added another element. **(P4)**

Parents also indicated that they observed more variety in their movements outside of the program. A common example expressed by many parents was that they noticed their children engaging in different locomotor and object manipulation activities, such as galloping, jumping, or throwing during outdoor activities than they had before their participation in the program. For example, one parent noted that, “she will look at the raised upper part, and will start to walk on it as a balancing exercise.” **(P1)** Another parent stated, “When we're out, he's throwing overhand, underhand, balancing on one foot, hopping, skipping, way more than he did before.” **(P4)**

Increased confidence in both reading and movement ability was also expressed as a major change observed by parents. For example, one parent said, “yeah he's very confident in himself, his movement and his reading, yeah he loves to brag to everyone that he knows, this is the author, this is the illustrator.” **(P3)** Another parent noted that their child’s confidence increased overtime with practice, “and so the more we practiced, the more comfortable he got.” **(P4)** This confidence appeared to facilitate a greater interest in engaging in more different physical activities and testing their abilities. This was expressed by one parent, stating, “she has much more confidence than previously before to do lots of different things.” **(P2)** and another parent said, “So let him go at his pace and then eventually he feels the confidence to go to the next level.” **(P4)** Furthermore, several parents noted they their child increased confidence was also demonstrated when they would try to teach their parents how to do the activities. For example, one parent described that he knew his daughter was gaining confidence because she tried to give him lessons that mimicked the program session:

> I noticed that she tried to teach me some of the activities. So, learning, to master something its not about whether you can remember, it's when you start to want to teach other people. That means it comes with them, becomes part of them. So, there are other things you can observe as they start to learn, is you want to see whether they want to teach other people. And those are the kind of things, some of the steps, jumping a lot, stuff like that, she's tried to ask me to do that with her, which is good. **(P1)**

Another parent experienced this with his daughter stating that she would often provide corrections to his instructions, "sometimes she would say 'no, no, that's not the right way, you should do this first and then do the other way.'" (P2)

A final observation noted by parents is an increase in their child's interest and motivation to read, go to the library, and engaging in physical activity. Many parents expressed that their child is excited to practice the activities at home and will often do so unprompted. One parent mentioned, "and those are the kind of things, some of the steps, jumping a lot, stuff like that, she's tried to ask me to do that with her, which is good." **(P1)** Another parent said, "yeah he was balancing when I was making dinner, he was hopping around on his own." **(P4)** One parent noted that if her child had an indoor recess at school, she insists on practicing the activities at home, "I ask her 'Did you have recess today?' 'No, we didn't go out – we have to do now. We've [must] do some exercises at home now Mom.'" **(P5)** Parents expressed that the program laid a good foundation to develop healthy habits and by embedding the activities into their daily lives, they children have become more engaged and excited to participate.

Value of parental engagement

Parents consistently articulated that they placed high value on the being actively engaged throughout each program session. Firstly, from a practical perspective, parents noted that being present in the session allowed them to learn from the instructors, understand the activities, and take the lessons home to practice with their children. To this point, one parent stated, “we also did most of the learning too. So, if were not in there, I'm not going to have any of those tools to implement at home.” **(P3)** Also, parents noted that since they were actively involved, they were able to help their child with the activity if the instructors were with another child, “that you need a parent there, I find. You need a parent or somebody there to help them.” **(P3)**

Secondly, parents believed that their presence gave their children a sense of security and comfort that facilitated a greater willingness and confidence to engage in the activities and subsequently a greater capacity to learn the skill. For example, one parent said, “So whenever we have the presence, the simple presence of being there provides them the kind of security to make them successful.” **(P1)** Another parent echoed this concept stating:

> I feel like it being side by side…. It instills that sense of security so the security to learn and the comfort and then you can take that home and practice it and it doesn't feel like learning because it becomes your everyday rapport… So, I feel like it gives him the security, lays a good strong foundation for them to launch on their own. **(P4)**

Thirdly, parents felt that their involvement throughout the program sessions strengthened their relationship with their child. Parents discussed that

that these one-hour sessions were protected time to play with each other and it allowed them to understand their child better. One parent said:

> [The program was] very useful, because I don't usually have the time to play with her like that. When we get there, and we get to play, she has the confidence because she knows her mommy does it right behind her, whatever she's doing, I'm there, somebody's there to show her how. So yeah, the one hour is very useful for us…it was special for us. **(P5)**

Another parent speaking about their relationship said:

> I think, especially my relationship with [her] is much better than before because before sometimes I pushed her too hard to tackle something. But right now, after those times, reading together so it's kind of in [her] eye I'm helping her doing this, doing that, and she's more appreciate what I did for her. **(P2)**

Learning experience for the parents

All parents emphasized that they believed that this program was an important learning experience for them in terms of the importance of teaching these skills and the strategies used to instruct these skills. Many parents noted that they were unaware that movement skills must be taught, and their child was unable to complete certain skills. One parent noted:

> There are things I assumed he could do, but I realized he couldn't do when we did the exercises, but I just assumed he could do them, and so that really forced us to go home and practice them and do them more. And sometimes there was resistance because he realized he couldn't do them, so he didn't want to do them. And so, the more we practiced, the more comfortable he got. **(P4)**

Many parents also expressed that they learned the importance of teaching movement skills for their child's overall development. For example, one parented state, "And also the physical exercises, those are quite important. I think that they will really help her to develop her brain, her body." **(P2)**

Parents also indicated that they learned specific strategies to enhance their child's skills as well as the general approach of creating a mastery environment for their child to learn. Many parents expressed that they have changed the way they read to their child stating, "it added more points of stuff like asking questions, talking about the author, things I've never thought of." **(P4)** Another parent noted, "I'm learning that approach, and just slow down and let them explore a little bit longer." **(P4)** These insights suggest that the lessons parents gained from the program extended beyond the specific movement and pre-literacy teaching strategies but also included lessons on how to create an environment in which their child is motivated to learn and engage in the activity.

Structure of the program

Parents expressed very positive feelings about the structure of the program sessions, the activities themselves, the instructors, and the take-home materials. Many parents noted that their child was receptive to the schedule of the session because while it was structured in terms of the order and type of activities, it also allowed for autonomy during free-play. For example, one parent noted, "I think it was the right balance. It wasn't so strict that there was still opportunity, and especially with the free play, they were open to do what they wanted." **(P4)** Parents also discussed that they liked the session structure of starting with physical activities and ending with a sedentary activity as one parent said, “premise of doing an activity first, kind of gets that extra energy out of them so then when they read they can focus.” **(P4)** Additionally, parents noted that each component of the program was relevant to their child’s overall development. For example, one parent states, “the whole program is um, curriculum planning, right? It touches all aspects of the child's life, the cognitive, the physical, the social part of everything to, the curriculum planning for the program fits in with the children's learning.” **(P5)**

Parent were also very happy with the instructors and volunteers leading the program. Parents expressed their satisfaction with the instructors’ professionalism and competency, their friendliness towards both them and their child, and the level of attention and instruction they were able to provide to their child. For example, one parent said “They were into it 100%. Every person there that came to volunteer was someone that I really wanted to work with or work with the kids and work with us parents.” **(P5)** Similarly, another parent stated, “They are very adept, energetic, loving, encouraging, which made a difference.” (P1)

Another program component highly valued by parents was the take-home materials including the paper handouts and children’s books. Parents noted that the “Do it at-home” handouts served as useful reminders to practice the activities as home and were simple enough for both parents and children to follow. For example, one parent said, “it signaled, ok let's read the book, follow the instruction. It provided a nice structure and framework to signal, ok let's go over our exercises.” **(P4)** Similarly, another parent stated, “So whenever we go home, we try to go through the handout and see what was done and I share with [my daughter].” **(P5)** Also, one parent noted that the physical pages were preferable to a digital copy since they were able to go through them with their child, “Its easier for the kids to look at too, it's not as easy to have to look at my phone, rather than having to look at my email. So that would be harder.” **(P3)** This parent also felt that the books they took home provided a useful reminder to practice the activities as well as motivated their child to read stating, “I think because we also got to take the books home, so anytime we would read the book I felt like I had to bring out my duo tang, like they went hand in hand.” **(P3)** Finally, this parent also noted that their child was excited to get a new book every other week expressing, “And it was nice to get a new book, because it's a new prize thing, look at this new thing I got.” **(P3)**

Parents also felt generally positive towards the timing, dose, duration of the program (Saturday mornings, once per week for 1 hour, for 10 weeks, respectively). Some parents indicated that the sessions could have been up to a half hour longer and that their child wanted to stay longer as well. For example, one parent said, “I wouldn't mind if it was longer, as long as they had a snack break,” **(P4)**, another stating, “[my daughter] said she wished it can be a little bit longer, maybe one hour and a half.” **(P2)** However, others noted that the one-hour length easily fit into their busy schedules and that longer sessions would be difficult to arrange into their weekend. Parents also said that coming once a week for ten weeks allowed for enough flexibility such that they felt they could still make travel plans and occasionally be absent for a week without missing too much content.

Finally, when parents were asked if they had any suggestions to improve the structure of content of the program, parents wished to see more focus on social interactions both between their children and between themselves throughout the program sessions and between program session. One parent stated that:

> I wish there was an element that integrated the children more together… Even just as simple as, trying to pass the ball to each other, one person is kicking the ball and one person is the receiver. I think the exact same activities we did with the parents, but flip it, maybe pair them with the kids. **(P4)**

Another parent suggested that the social interaction between parents could be enhanced, citing the value of communication between parents. For example, one parent said, "of course of how that could work, is to create a parent community in a way to share information, bounce ideas with each other…That will help them to be able to remember how to do certain things, or to remind them, stuff like that." **(P2)**

CHAPTER 5: EXAMINING THE EFFECTS OF ACUTE COGNITIVELY ENGAGING PHYSICAL ACTIVITY ON COGNITION IN CHILDREN

Preamble

Examining the effects of acute cognitively engaging physical activity on cognition in children is the third study in the dissertation. It presents the results of an acute RCT testing the effects of short bouts of activities with varying physical and cognitive demands on executive function in children ages 6-8 years.

The following manuscript is currently in preparation for submission to the *Journal of Sports Sciences*. The manuscript has been formatted according to *Journal of Sports Sciences* author guidelines.

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Author Contributions:

CB designed the study, coordinated recruitment and data collection, conducted data collection, carried out the data analyses, and was the primary author of the manuscript. EB, JDG, and DC advised on study design, assisted with data collection, and revised and approved the final manuscript as submitted. JC supervised the design and execution of all phases of the study and revised and approved the final manuscript as submitted.

Contribution to overall dissertation:

Given that movement skills can impact multiple areas of child development, study 3 was designed to explore the impact of movement on another critical area of development, that is executive function. This study also provided the opportunity to explore a different methodological paradigm in the study of movement in relation to child health and development. Ultimately, this research is meant to inform the design of longer-term interventions by exploring the effects of small changes to movement-based interventions, which may in turn lead to or support long-term outcomes.

This study did not provide evidence of a superior effect on executive function as a result of participating in a cognitively engaging bout of PA, compared with a non-cognitively engaging PA, or a cognitively engaging sedentary activity. The results showed no significant difference between group and this may be attributed to overexertion during the acute bout of PA and depletion of positive affect prior to performing the post-intervention EF tasks. This study illustrated the utility of an acute RCT and emphasized the importance of including assessment of affect and personal-motivation factors.

Examining the effects of acute cognitively engaging physical activity on cognition in children

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Abstract

Introduction: Research has generally shown that the effect of acute physical activity (PA) on cognitive outcomes is small to large across children and young adults. However, substantial heterogeneity in the results suggests that the type or quality of PA is important when characterizing the relationship. Cognitively engaging PA has been suggested to have superior effects on cognition compared to PA with low cognitive demands; however, there have been few studies directly comparing these different types of activities. The aim of this study was to compare the cognitive effects of a combined aerobically and cognitively engaging acute bout of PA to an aerobic or cognitive activity alone in children ages 6 to 8 years.

Methods: A randomized controlled trial was used to assess the effects of three 20-min conditions: (1) a cognitive sedentary activity; (2) a non-cognitively engaging bout of PA; and a (3) cognitively engaging bout of PA. Executive function (EF) was assessed using a modified Eriksen flanker task immediately before and 10-15 min following the experimental condition.

Results: Forty-eight children (M_{age} = 7.04, *SD* = 1.37; 40% girls) were included in the study. A repeated measures ANOVA found no significant difference between groups with respect to interference scores of accuracy, response time, or inverse efficiency scores on the flanker task.

Discussion: The results did not support the hypotheses that a combined cognitively engaging bout of PA enhances cognitive performance over non-cognitively engaging PA or sedentary activities. Possible explanations for our findings include overexertion during the acute bout of PA and depletion of positive affect prior to performing the post-intervention EF tasks.

Keywords: affect, exercise, executive function, cognitive engagement

Introduction

Executive functions (EFs) are the cognitive processes that allow us to mentally hold and manipulate information; ignore or supress cognitive, visual, verbal, and behavioural stimuli; and shift between tasks and perspectives (Diamond, 2013). Respectively, these EFs are termed working memory, inhibition, and cognitive flexibility, and together they form the foundations for higher-order functions such as planning, reasoning, and problem solving (Diamond, 2013). EFs begin to develop during early childhood and continue developing into adulthood (De Luca et al., 2003). The development of EFs are critical as they contribute to overall development in mental, physical, social, psychological, and academic domains (Diamond, 2013). Deficits in EFs at a young age are associated with poor health, poor economic success, and higher rates of delinquency in adulthood (Moffitt et al., 2011). There is increasing recognition that improvements in EFs in childhood can influence a wide range of developmental domains and have important benefits in adulthood, including better quality of life, increased abilities to obtain and retain a job, and increased likelihood of marital harmony (Diamond, 2013). Furthermore, there are short-term consequences of EFs that affect performance and success in school (Blair & Diamond, 2008). For example, poor EFs tend to associate with lower math and literacy skills in kindergarten (Blair & Razza, 2007) and attention at the age of school-entry is among the three strongest predictors of later academic achievement in elementary school (Duncan et al., 2007).

There is a growing interest in designing both acute and long-term interventions for children and youth that target EFs, such as computer training programs or various types of physical and exercise programs (Diamond & Lee, 2011). The cognitive effects of acute aerobic exercise among children has been studied extensively (Chang, Labban, Gapin, & Etnier, 2012; Verburgh, Königs, Scherder, & Oosterlaan, 2014). Two systematic reviews reported small to moderate effects of acute physical exercise on several measures of EFs, with the largest gains in inhibition in individuals ages 6 to 35 years of age (Chang et al., 2012; Verburgh et al., 2014). However, the results across studies vary substantially suggesting that the type and quality of aerobic activity may be important when characterizing this relationship. Chang and colleagues (Bandura, 1997; Chang et al., 2012) noted that duration and intensity of physical activity (PA) moderate this relationship such that activities of at least 11 minutes of moderate to vigorous intensity produces positive cognitive benefits following a slight delay after the PA bout. However, these systematic reviews were able to identify only a few studies examining these effects in young children (children less than 12 years of age). At present therefore, it is unclear if these findings are relevant to preadolescent children.

Emerging research has suggested that physical activities that require cognitive engagement are likely to produce superior cognitive benefits compared to non-cognitively engaging PA (Best, 2010; Diamond & Lee, 2011). One potential mechanism for this is that cognitively engaging PA directly recruits the same frontal-dependent neural networks used when EFs are activated. Increased activation of these neural networks during a bout of PA may lead to more efficient neural functioning during cognitive tasks that follow this exercise resulting in enhanced performance (Best, 2010; Diamond & Ling, 2016). Alternatively, or in addition, combining cognitive and physical activities may produce synergistic effects due to co-activation and inter-connectedness of the neural areas associated with cognition and movement (referring broadly to the prefrontal cortex and the cerebellum, respectively). This neural co-activation is strongest when the task is demanding, novel, requires concentration, and when the required response is unpredictable and quick (Diamond, 2000, p. 200). Therefore, cognitively engaging physical activities may stimulate the necessary contextual parameters to elicit co-activation resulting in enhanced cognitive performance.

Research to date has demonstrated inconsistent findings with respect to this hypothesis, with some studies showing a positive effect of cognitively-engaging PA (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008; Schmidt, Egger, & Conzelmann, 2015), and others showing no benefit (Best, 2012; Van den Berg et al., 2016) or even negative effects (Egger, Conzelmann, & Schmidt, 2018). These contradictory findings may be due to differences in intensity of either the cognitive or physical demands of the task (e.g., exergaming, gross motor stations, running), and/or the specific type of EF assessed (e.g., concentration, attentional inhibition). Variability in design and measurement renders comparisons across existing studies problematic.

Beyond design of the task and measurement issues related to EFs, there are other characteristics that may explain or enhance the promotive effect of cognitively engaging PA on EFs, including mood state or affect prior to or during a cognitive task, and personal-motivational factors such as perceived difficulty of the cognitive task, the level of motivation to perform a task, and self-efficacy to perform cognitive tasks. EFs are enhanced when an individual has a feeling of positive affect rather than negative feelings. There is substantial evidence from cognitive psychology that demonstrates improved creativity and cognitive flexibility in participants when a positive mood is induced (Hirt, Devers, & McCrea, 2008; Murray, Sujan, Hirt, & Sujan, 1990). Conversely, a depressed mood can impair the ability to focus attention (Desseilles et al., 2009). Given the relationship between mood and cognition, it follows that cognitively-engaging PA that induces a positive mood may produce larger benefits to EFs (Diamond & Ling, 2016). While there is very limited evidence that directly supports this hypothesis, Schmidt and colleagues (2016) demonstrated that increases in positive affect led to better and quicker performance on tests of attention (Schmidt, Benzing, & Kamer, 2016). Therefore, it is important to build in aspects of fun and joy and measure participants' affective states during these cognitively engaging physical activities. Lastly, the extent of intrinsic motivation, perceptions of task difficulty, and beliefs of self-efficacy are relevant personal-motivational factors that are thought to influence cognitive performance (Puustinen & Pulkkinen, 2001). According to metacognition models, personal-motivational states are highly influential during the performance of cognitive tasks (Borkowski, Chan, & Muthukrishna, 2000). Generally, children attribute their success or failures on cognitive tasks to factors such as their own ability, effort, attitude, task difficulty, assistance from others, physical factors, or luck. Depending on whether attributions have an internal or external locus, are stable or variable, are controllable or uncontrollable, children may display or feel specific psychological consequences. For example, children may have high feelings of self-efficacy if their attributions of success are internal (i.e., their effort), have expectations of success if attributions of success are stable (i.e., their ability), or have feelings of anger if attributions of failure are controllable (i.e., task difficulty). These affective reactions can affect future cognitive performance as they influence their persistence and willingness to try challenging tasks (Bandura, 1997; Borkowski et al., 2000). Therefore, assessment of motivation to complete cognitive tasks, perceptions of task difficulty, and feelings of task-related self-efficacy are all relevant variables to monitor in studies of interventions to improve cognition. However, there is no research currently relating acute bouts of PA to these personal-motivational factors among children.

These gaps are especially noteworthy in young children, who as we previously noted, are under-represented in studies of EFs and PA in general. EFs develop rapidly between the ages of 5 to 8 years, with slower gains thereafter (Best, Miller, & Naglieri, 2011; Diamond, 2013). Schmidt et al. (2015) suggest that developing EFs should be more sensitive to changes compared to EFs that are more fully developed in older children. Therefore, younger children under the age of 8 years may be more responsive to PA intervention.

Given the inter-study variations in effects of cognitively engaging PA previously mentioned, and the gap in literature investigating the influence of affective and personal-motivational factors, the objectives of the current study are as follows:

1) Primarily, to evaluate the effect of cognitively engaging PA compared to non-cognitively engaging PA, and cognitively engaging sedentary activity on an EF (inhibition) among 6 to 8-year-old children. We hypothesized that cognitively engaging PA would show larger effects on inhibition when compared to non-cognitively engaging PA and cognitively engaging sedentary activity
2) Secondarily, to evaluate the effect of cognitively engaging PA compared to non-cognitively engaging PA, and cognitively engaging sedentary activity on motivation to perform an EF task, perceptions of an EF task difficulty, and beliefs of self-efficacy to perform an EF task. Given the relative novelty of these measures within this research paradigm, we did not have specific hypotheses regarding this secondary objective.

Methods

Design

Three experimental conditions were compared using a randomized controlled trial. Children were randomized in pairs to one of three 20-minute experimental conditions that varied in their cognitive and physical demands. Simple randomization with a 1:1:1 ratio was completed using a computer algorithm after eligibility had been established and the participant was enrolled. All assessments were standardized in content and order across the groups. An EF task was administered to all children before and after the experimental manipulation to evaluate within-participant change.

Participants

A convenience sample of 50 participants was recruited from local youth clubs, community centres, and community events in Southwestern Ontario, Canada. Participants were eligible if they were between the ages of 6 to 8 years, 11 months and did not have any diagnosed developmental delays or conditions that would prohibit participation in PA. Two children did not complete the full experimental protocol and were therefore excluded from the analysis. Therefore, the final sample consisted of 48 children (mean age = 7.04, SD= 1.37; 40% girls). Informed written consent was obtained from all parents/guardians of the participants and children 7 years and older provided written informed assent. Ethical approval for the study was obtained from Hamilton Health Sciences at McMaster University.

The sample size is based on a previous study (Palmer, Miller, & Robinson, 2013) examining the effect of acute physical activity on sustained attention (one facet of EF), which produced an effect size of $f = 0.8$. Using a conservative estimate with a different intervention, we scaled down the effect to $f = 0.4$. The primary hypothesis relates to a repeated-measures analysis of variance (ANOVA) for which a sample size calculation was based, assuming 80% power and a two-tailed alpha of 0.05. This calculation indicated a total sample of 48 (16 in each group) would be sufficient for the analysis (G*Power3.1) (Faul, Erdfelder, Buchner, & Lang, 2009).

Procedures

Following enrollment, participants were scheduled to visit the lab with another participant. Participants were unaware of their random assignment until they arrived for their study appointment. After consent and assent were obtained, both participants were introduced to each other, and anthropometric assessments were completed. Standing height was measured without shoes to the nearest 0.1 cm using a calibrated stadiometer, and body mass was measured without shoes and the child wearing light clothing to the nearest 0.1 kilogram (kg). Children were then fitted with a Polar heart rate monitor and familiarized with the scales assessing perceived physical and mental exertion and feeling state. Children were then asked to sit quietly without moving for 10 minutes while monitoring their heart rate variability (these data will not be presented); during this time, children were shown a nature video to maintain attention without being over-stimulating. Next, the children were asked to complete a brief 2-minute questionnaire measuring their motivation to complete the cognitive tasks. The EF task was then administered; participants were each seated at a desk on opposite sides of an auditorium (approximately 20m apart) to minimize distractions. The EF task lasted approximately 15 minutes, followed by 20 minutes of their randomized experimental condition. Immediately after the experimental condition, children were once again seated at their respective ends of the auditorium and asked to again sit quietly without moving for 10 minutes while viewing the same nature video to reassess their heart rate variability (these data will not be presented). Then children were asked to complete the same questionnaire about motivation in addition to a task self-efficacy questionnaire; this took approximately 3 minutes. The post-test EF task was then administered, concluding the appointment. While the participant was completing the experiment, the parent (or guardian) was asked to complete a demographic questionnaire and the Behavior Rating Inventory for Executive Functions (BRIEF).

Experimental Conditions

Each condition lasted 20 minutes. The cognitively engaging sedentary activity condition (Cognitive Group; n=16) consisted of two children seated at opposite sides of a table playing the game Connect 4 (board dimensions: length 26 cm; height 20 cm). Once a game was won, the board would be re-set and the children would start a new game. The non-cognitively engaging PA condition (Exercise Group; n=16) consisted of children running to and from a pylon placed 13.7m in front of them, alternating turns. The cognitively engaging PA condition (Dual Group; n=16) consisted of children playing a large game of Connect 4 (board dimensions: length 121 cm; height 117 cm) which was placed 13.7m in front of them; children were asked to run to the board to play the game. Once a game was won, the board was re-set and a new game would begin.

Measures

Background variables. The demographic questionnaire included questions about the parent and the child on age, gender, race/ethnicity, parental education and occupation, and household income. Parents also completed the Behaviour Rating Inventory of Executive Functions (BRIEF) (Gioia, Isquith, Guy, & Kenworthy, 2000) to assess trait levels of EFs. This assessment is appropriate for parents of children ages 5 to 18 years and takes approximately 10-15 minutes to complete. The instrument assesses the following domains of EF: inhibition, shifting, emotional control, working memory, and planning/organizing. Scores are totaled to give the Global Executive Composite. Parent test-retest reliability scores from the normative sample of 1,419 parents of children aged 5 to 18 is 0.82. Anthropometric measurements of body mass and height were used to compute body mass index (BMI; kg/m^2) and International Obesity Task Force (IOTF) guidelines were used to determine the thresholds for thinness, overweight, and obesity by age and sex (Cole & Lobstein, 2012).

Manipulation check variables. Physical exertion was measured both objectively using heartrate (HR) data collected during the experimental condition and subjectively using the 12-point Borg RPE scale (Borg, 1982). HR was recorded every 60 seconds and perceived physical exertion was assessed every four minutes throughout the 20-minute conditions. HR in the age predicted zones of moderate to vigorous intensity (approximately 135-160 bpm) were intended to create conditions most likely to produce the largest gains in cognition (Chang et al., 2012). Cognitive exertion was also measured subjectively every four minutes during the 20-minute conditions using a modified Borg RPE scale which asks participants to provide their rating of perceived mental exertion (RPME) on the same RPE scale ranging from 1 to 12. Affect was assessed using the Feeling Scale (FS) (Hardy & Rejeski, 1989) which asks participants to rate their current affective (or feeling) state using a bipolar scale ranging from -5 (feeling very bad) to +5 (feeling very good). Ratings of RPE, RPME, and FS took approximately 10-20 seconds to complete.

EF task. A modified Eriksen Flanker task was used to assess attentional inhibition (Eriksen & Eriksen, 1974). The task was administered on an iPad (iPad Mini 2) and took approximately 15 minutes to complete. Children were presented with an image of five fish on a horizontal plane and the task required children to tap an arrow on either side of the screen indicating the direction of the middle fish. The four fish flanking the middle fish were either facing the same direction as the middle fish (congruent) or the opposite direction of the middle fish (incongruent). The image was presented for 200 milliseconds (ms) and participants were asked to respond as quickly as possible by tapping their right or left index finger (depending on the direction of their response) on the corresponding arrow on the screen. A response window was limited to 2000ms before presenting the next image. After making a response, children returned their index finger to "home base" which were two large black dots (one for each finger) taped on the desk, 4cm from the base of the iPad. Ten practice trials presented at 2000ms and 20 practice trials presented at 200ms were administered with appropriate feedback, then the children completed 4 blocks of 50 trials with no feedback; participants rested for 2-minutes between blocks (Chang, Tsai, Chen, & Hung, 2013). Each block contained a random sequence of congruent right, congruent left, incongruent right, incongruent left with 40% of trials congruent and 60% incongruent (maximum number of repeated trials was limited to five). Trials in which the reaction time was less than 150ms or greater than 3 SD from the child's mean were excluded from analysis. Interference effects (incongruent – congruent) were calculated for inverse efficiency, response time (RT), and accuracy and were used as the primary dependent variables. Inverse efficiency measures overall performance by combining both RT and accuracy rates in the following calculation: mean RT on correct trials/ proportion correct.

Personal-motivational variables. Motivation for performing the flanker task was assessed using the 5 items from the effort and importance subscale from the Intrinsic Motivation Inventory (IMI) which took approximately 2 minutes to complete [Ryan 1982]. The IMI was administered prior to completing the flanker task before and after the experimental conditions. To assess perceived task difficulty for performing the flanker task, children were asked to rate their RPME within the 2-minute rest periods; average ratings were computed for the pre- and post-experimental manipulation administrations of the flanker task. Task Self

Efficacy for completing the flanker task following the experimental manipulation was assessed using a 4-item scale adhering to recommendations from Bandura for assessing self-efficacy (1997; 2006). Each item reflected degrees of performance relative to the participant's performance on the first executive function task. The first item asked participants to rate their confidence that they would perform the executive function task "almost as good as last time", followed by "as good as last time", then "a little bit better than last time, " and finally "A lot better than last time". The participants rated their confidence on an 11-point Likert scale. The average score across these 4 items comprised the total self-efficacy score.

Statistical Analysis

All data analyses were performed using SPSS version 25 (*IBM SPSS Statistics*, 2010). Descriptive statistics were used to describe the participants (see Table 1). To test for imbalances across groups on demographic factors and baseline EF and motivation one-way ANOVAs were conducted with group as the independent variable.

To check assumptions of the manipulation, four separate one-way ANOVAs were run for the average RPME, RPE, HR, and FS measured during the experimental conditions.

The primary analyses were three repeated measures ANOVAs with group as the independent variable and the interference effects for the inverse efficiency score, response time, and accuracy as dependent variables, respectively. Only analyses that met statistical assumptions of repeated measures ANOVA are presented; if assumptions were violated the analysis was re-run using a dataset excluding participants in whom their change score on the dependent variable exceeded three standard deviations of their group mean. The statistical assumptions of homogeneity of the intercorrelations could not be met in the analysis examining the interference accuracy score with either a full dataset or one with removed outliers, therefore it will not be presented.

Secondary analyses were repeated measures ANOVA with group as the independent variable and personal-motivational variables as the dependent variable: intrinsic motivation and average RPME during the EF task. Since task-self efficacy was only measured once prior to the second EF task an ANOVA was completed to test the effect of group on this variable.

All significance thresholds were set to $p<.05$ and partial eta squared was used to describe the magnitude of the effects. Multiple comparisons were not adjusted for; therefore, inferences drawn from the results of the secondary and exploratory analyses might not be fully reproducible.

Results

There were no significant differences between groups on parental age or income, participant age, sex, ethnicity, global executive composite, BMI, baseline motivation, or EF scores (see Table 1).

Manipulation Checks

Significant differences were found for RPE, HR, and FS (see Table 2 and Figure 1a-c) between the experimental groups. Significantly higher RPE was present in the two PA groups (F (2, 45) = 10.98, $p < .001$, partial $\eta^2 = .33$) compared with the cognitive group (no significant difference between the exercise and dual groups, $p = .41$). Similarly, the average HR was significantly higher in the two PA groups (F (2, 45) = 124.24), $p<.001$, partial $\eta^2 = 0.85$) compared to the cognitive group (no significant difference between the exercise and dual groups, $p = .39$). Children in both PA groups performed at an average of 75% of their maximal heart rate using the formula, 220-age (Fox, Naughton & Haskell, 1971) which corresponds to a moderate to vigorous intensity. There was an overall significant difference in feeling state (F (2,45) = 3.50, $p < .05$, partial η^2= 0.13) with children in the dual group reporting significantly higher positive feelings compared to the exercise group (no significant differences between dual and cognitive groups, $p = .08$). Children in the cognitive and dual conditions reported higher levels of mental exertion when compared to the exercise group; however, this was not significant ($p = .30$). The results suggest that the experimental manipulations were successful in producing the expected difference in physical exertion and enjoyment. Despite non-significant differences in cognitive exertion, the pattern of group means demonstrate that the cognitive and dual groups elicited higher levels of perceived cognitive demands compared to the exercise group.

Primary Analyses

There were no significant differences between groups on either interference, inverse efficiency scores, or interference response time (see Table 3); however, the direction of effect favored the cognitive group over the PA groups.

Secondary Analyses

Secondary analyses showed no significant differences between groups for any of the personal-motivational variables (see Table 3).

Discussion

The primary objective of this study was to evaluate the effect of various cognitively and physically engaging activities on EF in 6 to 8-year-old children. It was hypothesized that cognitively engaging PA would have superior effects on cognition. Overall, however, the results do not support our hypothesis: we found no significant differences in any of the EF metrics between the dual, exercise, or cognitive group. Surprisingly, the cognitively engaging PA group appeared to perform worse, compared to the other two groups, and there was no advantage of the exercise group over the cognitive group. Furthermore, the results also showed non-significant differences in the effect of the activities on the personal-motivational factors. In general, these results are misaligned with other research in the field that supports the beneficial cognitive effect of acute PA on cognition [13,32,33]. However, our results are consistent with the few studies that show no or detrimental cognitive effects (Best, 2012; Egger et al., 2018). Neither PA group produced improvements in their scores on the EF task of inhibition, despite following the prescribed activity duration and intensity of 20 minutes of moderate to vigorous activity likely to produce cognitive benefits (Chang et al., 2012). Task constraints and procedural limitations may be responsible for the inconsistency between our results and previous research.

Task Constraints

Recommendations from the meta-analysis conducted by Chang and colleagues in 2012 (Chang et al., 2012), suggest that 20 minutes of moderate to vigorous physical activity (MVPA) will produce cognitive improvements. However, a duration of 20 minutes may have been too long for this young sample of 6 to 8-year-old children. The evidence upon which the recommendation of 11-20 minutes of MVPA are based are mainly derived from samples of young adults, with fewer studies conducted with younger samples. Therefore, the dose-response relationship between activity duration and cognitive effects may need to be shifted to shorter durations of activity. This hypothesis is supported by the results of Howie and colleagues in 2014 (Howie, Beets, & Pate, 2014), which showed significant improvement in academic outcomes in a classroom-based PA session of 15 minutes, and no improvement after 20 minutes. Egger et al. (2018) also argued for a shorter duration of activity as their 20-minute classroom-based cognitively engaging PA session also showed no significant effect on inhibition and actually led to worse performance on a shifting task (Egger et al., 2018).

An additional task constraint that may have affected our results is the intensity of the PA. Chang et al. (2012) found that when the cognitive task is performed following a delay after exercise, higher intensities produced the largest effect on cognition. However, this finding once again may not be applicable to a younger sample. In the current study, children in both PA groups were performing at an estimated 75% of their age-predicated max heartrate; while still in a moderate-to-vigorous intensity range, this may have overexerted the young sample. Budde and colleagues (2008) reported an average HR of 120 bpm in a sample of 13-to-16-year-old participants and demonstrated positive effects of their cognitively engaging PA session on cognition (Budde et al., 2008). Best (2012), however, had participants performing between 70-80% of their maximum HR and they also were not able to produce superior cognitive effects following cognitively engaging exergaming compared to non-cognitively engaging exergaming among 6-10 year old children (Best, 2012). Therefore, it is plausible that PA of lower intensity may be more likely to elicit cognitive benefits than more vigorous activities among younger children. This is consistent with the strength model of self-control, which posits that individuals have a finite reserve of mental resources to draw upon when performing cognitive tasks. This reserve can be spent when we engage in activities that require self control or activation of EFs, such as intense exercise (Audiffren & André, 2015; Baumeister, Bratslavsky, Muraven, & Tice, 1998). Children participating in both PA groups reported high levels of both physical and mental exertion, thus suggesting that high levels of self-control were required to continue to engage in the 20-minute activity. It is possible that the flanker task performance was impaired by overexertion during both PA conditions; therefore, the participants' mental capacity was drained and consequently they could not perform the task efficiently. Although not significant, the cognitive group appeared to have a better performance on the flanker task following their activity, possibly because they had not depleted their cognitive resources during the seated cognitive game and could therefore utilize their cognitive reserve.

Procedural Constraints

Beyond the activity itself, the non-significant findings of this study may be explained through procedural limitations, specifically with respect to the choice of EF task, timing of EF task administration, and activities that preceded the EF task. In general, acute interventions that produce the largest cognitive effects are those that specifically train the EF to be tested; in other words, EF transfer is narrow (Diamond & Ling, 2016). Improvements in inhibition are most likely found after completing an activity that directly trains inhibition. Therefore, it is possible that the assessment of inhibition used in the current study may not have been sufficiently specific to the EF training that the dual activity may have elicited. The goals of the game are to connect four of your pieces in a row before your opponent. It is critical to be able to visualize your opponents' options to block their opportunity to connect four; while this certainly demands inhibition to focus on the task, ignore distractions in the environment, and inhibit the impulse to follow a planned strategy when the opponent can connect four pieces in their next turn, it also requires a high degree of cognitive flexibility, to be able to shift perspectives and change priorities (i.e., from winning to blocking). Therefore, Connect 4 may train cognitive flexibility in addition to inhibition, so the flanker task of inhibition may not have been sensitive or responsive to any enhanced training effects. Future research should consider the specific training that is occurring throughout the intervention and accordingly administer the relevant EF task to assess training effects. Alternatively, multiple facets of EFs could be assessed following an intervention to evaluate the extent of transfer of EF training during cognitively engaging PA.

An additional consideration of the current study is the timing of the EF testing, such that it followed a 13-minute delay after the activity. The meta-analysis from Chang et al. (2012) showed the largest effects when the cognitive task was administered between 1 and 15 minutes. Therefore, administration following a 13-minute delay may have been too long to detect any positive gains in the EF possibly elicited from the activity. However, given the divergent results from Chang et al. (2012) with respect to duration and intensity among young children, it is unclear if the same effects of immediate testing would hold true in a younger sample. For example, Egger et al. (2018) administered EF tasks immediately following the intervention sessions and did not find a positive benefit to cognition among a sample of 7- to 9-year-old children. More research is necessary among younger children to ascertain relationships between timing of EF task administration following a bout of PA.

Finally, an important influencing factor involves consideration of the events that immediately preceded the second test of inhibition in the current study.

Immediately after the experimental manipulation was complete, the children were asked to sit still to return their heartrate to resting state and reassess heartrate variability; during this 10-minute break, they viewed the same nature video. Repeated assessment of feeling state revealed that across all groups there was a significant decrease in positive affect during this 10-minute break (see Figure 3). Therefore, gains in affect produced by the 20-minute dual activity were depleted prior to completing the second test of EF, possibly contributing to lowered performance on the flanker task. The ‘mood as facilitator’ theory states that a positive feeling state stimulates other positive reflections and thoughts, which results in more efficient EFs (Dalgleish & Power, 2000; Isen & Reeve, 2005). In a study of the cognitive effect of classroom-based PA, Schmidt et al. (2016) found support in the ‘mood as a facilitator’ theory such that change in positive affect during the intervention led to improved scores of attention and processing speed (Schmidt et al., 2016). Given this relationship between positive affect and cognitive performance, it is possible that if the positive affect levels of the cognitively engaging PA group had been maintained, cognitive gains may have been observed. However, the reduction of positive affect following the activity may have disabled mood as a potential facilitator of an enhanced performance on the EF task.

Absence of an Effect on Personal-Motivational Factors

Given the relative novelty of including measures of task self-efficacy, perceptions of task difficulty, and motivation to perform the EF task in trials investigating the effects of cognitively engaging PA, we did not enter into the secondary objective of the study with any specific hypotheses. Nonetheless, given the non-significant group differences in inhibition and the reduction in positive affect following the 20-minute intervention activities (alongside previous research from Schmidt et al., 2016), it is not surprising that the results also show no differences between groups in any of the measured personal-motivational factors. It is plausible that the reduction in positive affect influenced the personal-motivational factors in a similar manner. Perhaps if the positive gains in affect were maintained throughout the 13-minute delay after the activity, the personal-motivational status would have been enhanced, and this may have subsequently improved the EF performance. Indeed, positive affect is associated with higher perceptions of self-efficacy and, in turn, performance (Bandura, 1997). Alternatively, Schmidt et al. (2016) suggest that positive affect related to high motivational intensity, that is positive affect which results in the motivation to improve performance, may be more relevant than generalized positive affect associated with low motivational intensity (Schmidt et al., 2016). It is possible that the positive affect gained throughout the cognitively engaging PA in the current study was related to a low motivational intensity and thus changes in motivation and inhibition were not observed. Given the drastic drop in positive affect following the intervention, it is unknown how specifically motivation and affect were related. Despite non-significant findings, personal-motivational variables are still relevant factors that should continue to be considered and measured.

Limitations and Future Directions

Beyond the aforementioned limitations, there are several others in this study that should be identified. First, the validity and reliability of the measurements of perceived physical and mental exertion and feeling state among young children is unknown. To ensure adequate comprehension of the scales, the children received a thorough explanation of each of the exertion and feeling state scales prior to the start of the protocol. Additionally, each of these scales have been used successfully in other studies within this research team in samples of children of similar age. The results of the manipulation checks provide some confidence in their validity; however, their sensitivity to small changes and reliability is still undetermined. Additionally, the assessment of internal motivation and self-efficacy are also not formally validated in samples of young children. Therefore, inferences based on these assessments should be cautioned and replicated. These measurement limitations reflect generalized shortcomings of this field since research still lacks an appropriate measure of these constructs in young children.

Conclusions

Overall, the results of this study contradict our hypotheses and suggest that a bout of cognitively engaging PA may not produce superior effects on cognition; however, this may be a result of overexertion during PA and a reduction in positive depletion following the experimental manipulation. Future research should be directed towards investigating the optimal physical and cognitive load during activities to produce cognitive benefits, and the role of affect and personal-motivational factors in this relationship.

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Tables

Table 1. *Demographic and Baseline Characteristics by Condition*

Variable	Cognitive Group	Exercise Group	Dual Group	*p*
Age, mean (SD)	7.33 (1.35)	7.04 (0.54)	6.74 (1.86)	.48
Female; *n* (%)	5 (31.25)	8 (50.00)	6 (37.50)	.56
BMI IOTF				.21
Thinness; *n* (%)	0 (0)	1 (6.25)	0 (0)	
Normal weight; *n* (%)	15 (93.75)	14 (87.50)	13 (81.25)	
Overweight; *n* (%)	1 (6.25)	0 (0)	2 (12.50)	
Obese; *n* (%)	0 (0)	1 (6.25)	1 (6.25)	
Child Ethnicity*				.73
Latin American	0 (0)	1 (6.67)	0 (0)	
White	15 (93.75)	13 (86.67)	13 (86.67)	
Mixed Race	0 (0)	1 (6.67)	0 (0)	
South Asian	1 (6.25)	0 (0)	1 (6.67)	
Southeast Asian	0 (0)	0 (0)	1 (6.67)	
Caregiver Age	39.87 (5.04)	38.20 (4.41)	40.50 (7.33)	.54
Global Executive Composite Score	46.13 (9.87)	49.13 (7.86)	49.27 (6.53)	.49
Baseline Motivation	5.80 (1.09)	5.61 (0.96)	5.94 (1.11)	.68
Baseline Executive Function				
Interference Accuracy	-0.10 (0.20)	-0.11 (0.13)	-0.07 (0.06)	.78
Interference Response Time	71.79 (70.09)	56.72 (65.82)	96.60 (37.80)	.17
Interference Inverse Efficiency	526.30 (1397.79)	336.58 (475.52)	206.80 (125.10)	.57

Note: *Exercise and dual groups missing 1 for ethnicity; *SD* = standard deviation, *n* = sample size; BMI = body mass index; IOTF = International Obesity Task Force.

Table 2. *Manipulation Checks by Condition*

Variable	Cognitive Group	Exercise Group	Dual Group	*p*-value
HR	88.37 (9.76)	164.66 (22.11)	159.92 (11.04)	< .001
RPE	4.69 (2.46)	7.65 (2.55)	8.34 (1.96)	< .001
RPME	7.30 (2.90)	6.38 (3.11)	7.94 (2.34)	.29
FS	3.62 (1.48)	3.15 (2.65)	4.75 (0.43)	.04

Note: HR = heartrate, RPE = ratings of perceived physical exertion, RPME = ratings of perceived mental exertion, FS = feeling state.

Table 3. *Primary and Secondary Analyses: Repeated measures ANOVA effect of time by group*

Variable	*F*	*P*	Partial eta square
Interference RT	0.25	.78	0.01
Interference Inverse Efficiency	1.26	.30	0.06
Intrinsic Motivation Inventory	0.36	.70	0.02
Average Ratings of Perceived Mental Exertion during Flanker	0.11	.90	0.01
Task self-efficacy for completing second Flanker*	0.28	.76	0.01

Note: *One-way ANOVA, RT = response time.

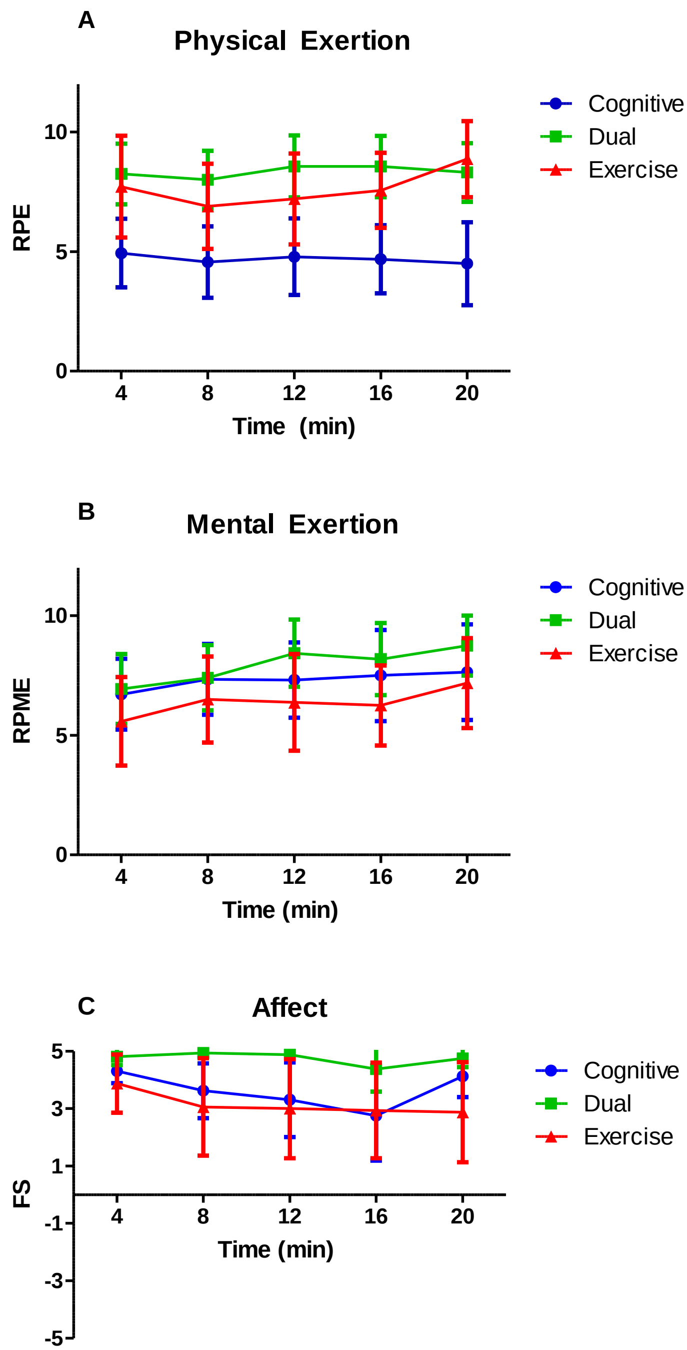
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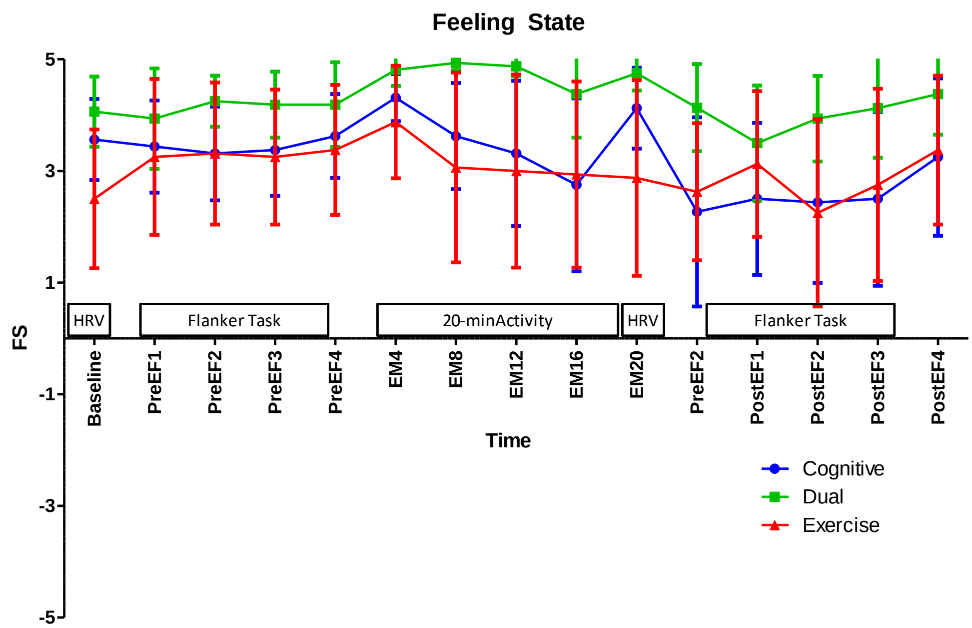
Figure 1a-c.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1
-1
-3
-5
FS
HRV
Flanker Task
20-minActivity
HRV
Flanker Task
Baseline
PreEF1
PreEF2
PreEF3
PreEF4
EM4
EM8
EM12
EM16
EM20
PreEF2
PostEF1
PostEF2
PostEF3
PostEF4
Time
Cognitive
Dual
Exercise

Figure 2.

Figure Captions

Figure 1a-c. Ratings of physical exertion (A), mental exertion (B), and affect (C) during the experimental manipulation by condition. RPE = ratings of perceived physical exertion RPME = ratings of perceived mental exertion. FS = feeling state.

Figure 2. Repeated assessment of feeling state across the study protocol. EF = executive function, EM = experimental manipulation, HRV = heart rate variability assessment.

CHAPTER 6: DISCUSSION

In pursuit of optimizing child health and development, the study of movement skills and its influence on various other aspects of development is critical. Although optimal development does not occur naturally on its own, it can be greatly facilitated when children have opportunities to participate in early childhood education or programs that directly attend to these multiple aspects of development (1,2).

Extant research has primarily focused on secondary and tertiary prevention for children with developmental delay or older, school-aged children (3). Estimates of any delay in young children ranges from 16-20% leaving 80-84% of children developing typically (4,5). Furthermore, population estimates indicate that 93% of children are not sufficiently active (6), 21% are overweight or obese (7) and 28% are not ready to enter grade one (8). Clearly, given the high prevalence of inactivity, overweight/obesity, and lack of school readiness, we cannot conclude that only children with atypical development are the sole contributors to these risk groups – even though they are certainly over-represented. Primary prevention strategies are urgently needed to curb these increasing health and developmental concerns. However, these interventions must be tested and refined and should be designed using best practices from early education, movement, and exercise sciences. Generation of evidence in support of specific interventions or intervention approaches should be systematic and iterative and this evidence may come from multiple sources. However, prior empirical work has tended to focus on special populations as secondary or tertiary prevention, have neglected to implement best-practice strategies, and have failed to comprehensively evaluate the full impact of interventions as experienced by its participants.

Therefore, this thesis was centered around two overarching goals:

1) Explore the influence of movement-based interventions on physical development, cognition, and self-perceptions during early childhood.
2) Explore various methodological approaches that can be employed to study these relationships in childhood.

In addressing these two research goals, three studies were designed and executed. The first study was a quasi-experimental wait-list controlled trial. This study compared changes in motor and pre-literacy skills, initially between children participating in the Move 2 Learn (M2L) program and those on a wait-list not participating in the program, and then followed changes in the wait-list control group once they completed M2L. This first study served as the foundation for the second study, which used mixed methods to re-evaluate M2L and its effect on motor and pre-literacy skills, self-perceptions of physical competence, and parental engagement. Finally, the third study explored the use of an acute randomized three-arm trial to test the cognitive effects of different physical activities in children.

Study 1 Findings (Chapters 2 and 3)

When comparing the experimental and the control groups, we found a significant intervention effect of M2L on gross motor raw scores overall ($F(1, 16)=4.67$, $p<.05$; $\omega_p^2 = .16$) and print-concept knowledge ($F(1, 16)=11.9$, $p<.05$; $\omega_p^2 =.38$) (Chapter 2). However, there was the possibility that the positive findings may be attributed to either selection bias or to the experimental group regressing towards the mean, given that children in the control group demonstrated higher motor skills at baseline. Therefore, we conducted within-group analyses of the wait-list control group to track possible intervention effects following their participation in the intervention (Chapter 3). There was a statistically significant effect of time on the change in gross motor skills (Wilks' lambda=.090, p=.002), print-concept skills (Wilks' lambda=.09, p=.001), and alphabet knowledge (Wilks' Lambda=0.29, p=.046). Post-hoc analyses reveal non-significant changes during their control period for motor and print-concept skills and significant changes in all three outcomes between time 2 and time 3, during which time they participated in M2L. This study filled several research gaps and illustrated both the utility and limitations of the quasi-experimental study design. In terms of intervention content and delivery, the M2L program was novel in its approach to use a modular program structure that incorporated both movement and pre-literacy skill building activities. Typically, these skills domains are targeted independently in separate programs; however, the decision to integrate their delivery within a single program was driven both by empirical evidence supporting possible synergistic learning improvements resulting from a combined movement and reading program (9), as well as by practical considerations, specifically in addressing school curricular concerns in academic content and attending to children's intrinsic interest in shared book reading activities with their caregivers. At the time of developing M2L there were few programs that intentionally targeted multiple domains of development in a single program, with a notable exception of the work by Piek and colleagues (10,11). Another novel aspect of M2L was the integration of parent engagement throughout the intervention sessions. Despite consistent recommendations from systematic reviews of effective movement interventions, very few existing programs include active involvement of parents (12,13). This is likely because most programs are developed and subsequently tested in school settings, and thus parents are minimally involved (13). Another consequence of the extant research primarily evaluating school-based interventions is that few include children under the age of 5 years, which leaves an important gap in the literature on the effectiveness of these types of interventions in children yet to enter school (13). Early intervention prior to school entry is critical for several reasons. Firstly, rapid neurodevelopmental changes that occur in children under the age of four years represent a high degree of neuroplasticity; therefore, experiences in quality education and targeted developmental programming have a large potential to enhance growth (14–16). Secondly, young children's perceptions of self are often overestimated relative to their actual skills level and this perception-skill gap tends to narrow when children enter school; therefore, preschool represents a critical window of time where children may be more likely to engage and persist with skill-building activities before they develop more accurate self-judgements (17). Thirdly, there are often formal or informal expectations that children possess certain skills prior to school entry, including FMS and pre-literacy skills (18); therefore, it is critical that the foundation of these domains are learned in early childhood before beginning school to facilitate their success in the development of new and more complex skills (2).

The quasi-experimental study was able to demonstrate the potential of a movement- and pre-literacy program implemented in the community with active involvement of parents to improve movement and pre-literacy skills. However, there were many limitations to this study which prompted the development of new and subsequent research questions. Non-random assignment to the experimental and control group increased the risk of selection bias and, in fact, the experimental group demonstrated statistically lower movement skills compared to the control group at baseline. Therefore, despite statistical control of baseline differences using analyses of covariance, residual confounding may have influenced the results. Measurements of the outcomes were also conducted by the same researchers who delivered the intervention, which may have increased the risk of performance and detection bias. Finally, this study was limited to the measurement of only two primary outcomes, both assessed quantitatively; therefore, it did not provide insight into the subjective experience of the participants and it was still unclear whether the intervention had an effect on other aspects of health and development.

Study 2 Findings (Chapter 4)

Based on the findings from Study 1, a mixed methods study was planned to further evaluate M2L. The results of the RCT did not show statistically significant intervention effects, nor did results show any adverse effects from participating in M2L. However, the embedded qualitative study provided an additional lens to view the effectiveness of M2L by capturing parents’ perceptions of improvements in different dimensions of the outcomes of interest, as well as revealing additional effects of the program on parents. The decision to conduct a mixed methods study and the design considerations of the RCT were specifically intended to address the limitations of the previous study. First, assignment to either the experimental or wait-list control group was random to minimize the risk of selection bias. Second, quantitative measurements were obtained by trained assessors who were blind to the child's group status and were not involved in the delivery of the intervention, thereby reducing the risk of detection bias. Third, the intervention was delivered by trained students independent from the research team, therefore minimizing the potential for performance bias during the program sessions. Fourth, the integration of a qualitative study yielded two important advantages: it enabled analyses of alternate dimensions of movement and pre-literacy skills, perceptions of physical competence, and parental engagement levels; and it provided an opportunity explore unexpected outcomes, such as M2L serving as a learning experience for parents and strengthening the parent-child relationship. While this study had multiple methodological strengths, there were several limitations that restrict overall conclusions of the effectiveness of M2L. These limitations, however, encourage further study of the intervention and suggest that possible modifications to the intervention could enhance the short-term intervention effect.

Study 3 Findings (Chapter 5)

The third study emerged from a more generalized research inquiry of the acute effect of manipulating a short bout of a movement-based activity to intentionally target executive function among children. Ultimately, this research is meant to inform the design of longer-term interventions by exploring the acute effects of small changes to movement-based interventions, which may in turn affect or lead to long-term outcomes. The most methodologically appropriate design to evaluate this research question was an acute RCT comparing activities with varying levels of physical and cognitive demands. A repeated measures ANOVA found no significant difference between groups with respect to executive function. However, possible explanations for these findings include overexertion during the acute bout of PA and depletion of positive affect prior to performing the post-intervention EF tasks. This study addressed several limitations in the extant literature. Specifically, there are few studies that manipulated the cognitive demands of PA and directly compared cognitively engaging PA and non-cognitively engaging PA (19). Additionally, due to the difficulty of assessing executive function in children, few studies sample children and fewer still include children under the age of 10 years (20); therefore, our study offers new insights into the potential acute effects of cognitively engaging PA in young children. Methodologically, this study was advantageous in the application of random assignment to each trial arm, use of standardized and valid assessments of executive function, and the measurement of personal-motivation factors typically excluded from previous empirical work. The limitations present in this study highlight unique methodological considerations of assessing executive function and its associated constructs and implementing acute research design paradigms in young children (21). Most relevant constructs lack a valid and reliable method of measurement in young children (specifically: internal motivation, self-efficacy, feeling state, and perceived physical and mental exertion) and the controlled nature of acute experimental design may obstruct the ecological validity of the intervention under study.

Methodological Implications

This thesis has methodological implications that will help advance the fields of child development, early childhood education, and movement and exercise science. For example, the findings from this thesis demonstrate that multiple methods are required to efficiently and comprehensively answer a series of research questions regarding health and development in children. The results from any single study, whether an RCT, an acute experimental study, or a qualitative study will answer only a part of the research question; each can and should be employed and integrated to comprehensively investigate health and development in children. The siloed nature of research both within and between qualitative and quantitative methodologies contributes to a general resistance towards using more than one approach when designing studies. The fundamental dissonance and perceived incompatibility between philosophical stances of qualitative and quantitative research often makes it difficult for researchers trained and situated within one philosophical stance to apply their methodologies and methods in a mixed method study. Critiques of mixed-methods research, particularly embedded studies, are regarding the compromises to one methodology for the sake of maintaining integrity of the other (22). From either perspective, there will always be design limitations with respect to embedding qualitative within quantitative (or vice versa); however, this is true of any study. Research design always requires carefully balancing practicality with rigor to best address the research question. Methodological compromises do not necessarily lessen the importance or value of any one study. Therefore, future research should refrain from generating conclusions on the basis of single studies and instead to be open to the insights and perspectives offered through the implementation of varied research paradigms. Furthermore, future research should the continue to explore other ways of integrating these study designs, such as using an acute trial to test the immediate effect of a single session from a long-term intervention (e.g., the effect of session 5 from a 10-week intervention) or the implementing an RCT nested within a longitudinal observational study across childhood. The complexity of child development demands creativity and adaptability in research design.

Research Implications

Studies 1 and 2 also implicate the direction of future research towards a modular approach to the design of movement-based programs to impact development more broadly and the active inclusion of parents. Despite the relatively low-dose of the M2L program, results from study 1 show the potential that both motor and pre-literacy skills may be improved through a single program targeting both skills delivered once a week. However, it should be acknowledged that, overall, the evidence on the effectiveness of M2L is mixed as study 2 was unable to detect significant quantitative intervention effects yet the qualitive findings revealing positive developmental and learning outcomes reported by parents. While this does not diminish the utility of a module-based intervention, it indicates that more research is needed to identify modifications to each component of the program that can enhance the intervention effect on each outcome. Moreover, the modular framework to movement-based interventions begets unlimited potential for creating interventions targeting multiple different domains of development, such as cognition, nutrition, or socio-emotional learning. For example, James and colleagues (23) used the modular framework of M2L to design the Move 2 Smile program which exchanges the pre-literacy modules for activities targeting social emotional development. Preliminary testing of Move 2 Smile similarly demonstrates the potential of a modular approach to movement-based interventions to impact multiple domains of development (23). Future research should continue to explore the benefits of modular movement-based interventions in young children. Also, the intentional integration of parents throughout the program session created a learning environment for parents and subsequently enabled their child's skill development to continue outside the setting of the program. Evidence from the qualitative study indicated that the inclusion of parents in the program reframed their perspective on the importance of and approach to teaching movement and pre-literacy skills to children prior to their entry into school. Therefore, future research should continue to emphasize the unique and crucial role of parents and caregivers in the design of movement-based interventions.

The results from study 3 highlight that movement-based activities designed to target cognition of young children must be designed carefully to ensure that task parameters facilitate enjoyment and sufficient physical and cognitive exertion to initiate potential synergistic mechanisms to enhance cognitive performance, as well as consider the impact of the experimental protocol and personal-motivational factors. Given the novelty of this type of investigation with young children, future research should be directed towards evaluating varied durations and intensities of bouts of activities, explore effects across multiple facets of executive function following varying lengths of delay, and continued to analyze the role of motivation, self-efficacy, and affect in this relationship.

Practical Implications

Additionally, this thesis has practical implications which may be helpful by informing practitioners, policymakers, and parents on the most efficient allocation of resources to ensure young children are provided with sufficient support to lead an active, healthy, and happy life. Previous literature has demonstrated the importance of intervening early through movement and the results of study 1 and 2 provide preliminary evidence of the potential impact that movement-based programs may have on development and well-being in the short-term and theoretically in the long-term. In consideration of the results of both the quasi-experimental and mixed methods study, there is clearly potential for M2L to produce gains in movement and pre-literacy skills; however, in the short-term these gains may be small. The qualitative study suggests that the program may have impacted children in other ways such as improved diversity of movement vocabulary, increased interest in reading and exploring text, enhanced confidence overall and in their reading skills, a greater willingness to try new movement activities, and a general predilection to participate in PA and reading activities. Collectively with the evidence indicating that parents are practicing M2L activities at home, this suggests that the program may be able to confer important developmental and health gains in the long term. Nonetheless, it would be worthwhile to consider modifications to the program to improve short-term intervention effects. The results of study 3 are also relevant to practitioners, policymakers, and parents because they highlight the need to be aware of intensity, perceived exertion, enjoyment, and feeling state when planning and implementing PA opportunities for young children. While there are a multitude of possible explanations for the null findings comparing activities of varying physical and cognitive intensities, a likely rationale remains that when children participated in a cognitively demanding PA their cognitive capacities were overfatigued and thus their performance on the executive function task was negatively affected. The results also highlight the importance of considering enjoyment when designing activities to enhance cognition as well as maintaining a positive feeling state after the activity prior to engaging in tasks that require cognitive control.

Limitations

The results of this thesis cannot be interpreted without consideration of several limitations. Common to each of the three studies contained in this thesis are issues of statistical power. Recruitment and retention of participants is a familiar barrier to lab-based research that recruits convenience samples of children and youth from the community. Multiple methods of recruitment were employed in each study including dissemination of paper study flyers throughout the community, posting on social media, advertisements in newspapers, in-person attendance at local early year centres and community events, and direct contact through listservs of families indicating their interest in participating in research through the university. Despite these extensive recruitment efforts, rates of recruitment in each study were moderate-to-slow and eventually the resource and timing constraints of the projects led to termination of recruitment prior to achieving target sample size estimates. Additionally, studies 1 and 2 were further restricted by attrition rates of 10% and 19%, respectively. Further compounding the issue of power was heterogeneity between participants. The detection of intervention effects is particularly difficult in early childhood because rapid developmental changes take place in short time periods and growth rates are highly variable between children; this creates large variation between and within participants that diminishes the ability of quantitative measures to detect small intervention effects. Another limitation related to measurement concerns the use of scales measuring personal-motivational factors in Study 3, which had not been rigorously validated for application in young children; therefore, limited inferences can be made on these outcomes. Additionally, we were unable to validly measure relevant and important variables like PA and executive function in studies 1 and 2. Both assessments were attempted through the use of accelerometery and administration of response inhibition tasks, respectively; however, there was insufficient valid data available to conduct analyses.

Notably, all three studies conducted short-term outcome assessments immediately following the intervention (with the exception of the 5-week follow-up of the wait-list control group in Study 1, Chapter 3), which precludes our understanding of the long-term effects of these interventions. The findings of Study 2 suggest that important intervention effects may emerge over time as families incorporate movement and pre-literacy activities into their daily life. Therefore, future research should explore long-term effects of movement-based interventions as the effects may fluctuate overtime.

There are also limitations of the generalizability of the results of each of these studies. Each sample was of generally high SES and education and therefore not fully representative of all children and not representative of children most likely to need environmental enrichment, that is, children from socioeconomically deprived communities. Future research must address this gap by fostering relationships with these communities in need and focusing recruitment efforts towards families with children at risk of experiencing negative developmental trajectories.

Conclusions

Overall, this series of studies demonstrates the power of epidemiological study designs to investigate and optimize child health and development. This thesis has shown the promise of a movement-based intervention for children, elucidated important design considerations of cognitively-engaging physical activities, and stimulated several new avenues of research including, though not limited to, further testing of the Move 2 Learn program and evaluations of potential modifications to the program. Moreover, the thesis has demonstrated the utility of using multiple designs to investigate a research question and highlights the unique methodological considerations of conducting research with developing young children.

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