FINDING OUR BALANCE: THE EFFECTS OF MULTIPLE RECESS ON ELEMENTARY CHILDREN MOTOR COMPETENCE AND EXECUTIVE FUNCTIONING ABILITIES

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A Dissertation for the Degree

Doctor of Philosophy

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Chapter 1: Introduction

Current State of Unintentional Falls in the United States

Falls are the second leading cause of unintentional deaths worldwide. Each year, approximately 684,000 individuals die from falls globally (World Health Organization, 2021). If not fatal, approximately 37.3 million of the falls that occur each year require medical attention resulting in disability-adjusted life years (DALY). DALY is one year of life expectancy lost (YLL) and the years lived with the disability (YLD) caused by prevalent cases of a disease or health conditions (Ding et al., 2022). Nearly 40% of the total DALY lost due to falls worldwide occurs in children (WHO, 2021). According to the Center for Disease Control and Prevention (CDC), an estimated 9.2 million children in the U.S. visited the emergency room for an unintentional injury with approximately 2.8 million of those children (33%) experiencing injuries from fall accidents. For the past ten years, falls have been the leading cause of non-fatal injuries for children under 15 years old (CDC, 2019). These unintentional falls cause complex injuries such as traumatic brain injuries (TBI), spinal cord injuries (SCI), and fractures/ligament tears in the lower extremities that can hinder a child's ability to perform voluntary movements. Furthermore, these types of injuries require the highest level of trauma care conducted by medical experts from various specialties to aid these children (Blosser & DE Pompei, 2019).

Not only do TBI, SCI, and lower extremity injuries create a physical burden on a child's life, families are impacted financially as well. Approximately $50 billion is spent on medical costs related to non-fatal injuries because of the high level of care required to rehabilitate children back to a healthy and functional state (Drake et al., 2021). Practitioners have suggested if an effective intervention is established with a subsequent 20% reduction in fall incidents among children under the age of 10, this could create a net savings of $120 million per year in fall injury-related costs (WHO, 2021). Injuries from unintentional falls have one common deficit

– motor competence. Motor competence (MC) is the degree of proficient performance in various gross motor skills as well as the mechanisms underlying this performance such as motor coordination which is the movement of multiple body parts as required to accomplish an intended action and postural balance which is the ability to maintain equilibrium by positioning the center of gravity over a base of support.(Coppens et al., 2021; King-Dowling et al., 2020). Historically, children with inadequate MC abilities have been shown to have poor control of joint movement, instability in keeping postural balance, greater hyperactivity, inattention, emotional problems, peer relationship difficulties, and fewer prosocial skills (King-Dowling et al., 2020; De Meester et al., 2020). More importantly, sedentary behaviors, insufficient physical activity, and lack of postural control have significantly contributed to children's poor MC (Bull et al., 2020; Dong et al., 2021; Thomas et al., 2021). Schools are considered the ideal setting for the promotion of physical activity.

Sedentary Behaviors and Physical Inactivity

School officials, over the past several years, have increased classroom instruction time to improve academic success, i.e., standardized tests (Jarrett & Coba-Rodriguez, 2019). In addition, technology has been incorporated into classroom instruction, such as the use of smart boards and school issued tablets, to complete classroom assignments and engage in eBook reading during quiet time (Ahmadi & Reza, 2018). All of these components have been implemented to enhance the children's classroom experience and quality of learning. However, according to Burns et al. (2019), 70% of a child's school day in the U.S. consists of engaging in some form of sedentary behavior to meet academic benchmarks. When children spend this much time sedentarily in the classroom, other very important aspects of a child are sacrificed, including physical and mental skills. This leaves little time for opportunities to engage in physical activity which is fundamental to the development of MC (Lopes et al., 2021). Two important places in a school setting children can gain physical activity (PA) and development of MC is in physical education (PE), also known as structured motor skill development. The second place is recess, which is a break within the school day that allows children to engage in unstructured, outdoor play (Rhea, 2016). This decision to cut physical activity opportunities in schools is counterintuitive for quality learning to take place (Graham et al., 2022). Research has shown providing recess, defined as unstructured, outdoor play throughout the school day improves whole child development (Farbo et al., 2020; Morris et al., 2020; Ramsetter & Murray, 2017; Rhea, 2022). If adults want to improve the ability for children to think and retain information, they must examine whole child development through effective theoretical constructs that connect cognitive development and play opportunities (Darling-Hammond & Cook-Harvey, 2018).

Piaget's Play and Cognitive Development Theory

Piaget's play and cognitive development theory suggests children move through four developmentally appropriate stages of learning using play and movement as the vehicle (Piaget, 1957). The sensorimotor stage (0-2 years old) is focused primarily on reflexes, senses, and motor responses. Children are focused on gaining mastery of their own bodies and external objects. This is considered "practice play" consisting of repeated patterns of movement or sound, such as sucking, shaking, banging, babbling, and eventually, "peekaboo" games in which objects are made to repeatedly disappear and reappear. As children learn more about the properties of objects and learn how to manipulate them, they begin to monitor the effects of play on their environment, and their relationship with that environment becomes increasingly systematic. In this stage, children have difficulty integrating cognitive, behavioral, and emotional skills. The preoperational stage (2-7 years old) is focused primarily on the emergence of language through play and movement. Children use those language skills to master symbolic functions including the association of objects with words. They begin to engage in make-believe games marked by the use of objects for purposes other than their intended function. The concrete operational stage (ages 7-11) still shows children are very concrete and literal in their thinking, but they become much more proficient using logic. The focus on ego and “me” from the previous stage begins to disappear as children become better at thinking about how others may view a situation. This shifts them to be more social and accepting of groups. The last stage, formal operational (11-adulthood), involves logic, the ability to use deductive reasoning, and an understanding of abstract concepts. The way this age range plays changes. Competitive games and games with codes of rules begin to predominate. At this point, adolescents and young adults become capable of seeing multiple potential solutions to problems and think more scientifically about the world around them.

Through these stages, Piaget believed that children take an active role in the learning process, make observations, and learn about the world (Babakr et al., 2019; Bhagat et al., 2018). As children interact with the world around them, they continually add new knowledge, build upon existing knowledge, and adapt previously held ideas to accommodate new information. In Piaget's view, early cognitive development involves processes based upon play, movement, and later progresses to changes in mental operations (Singer, 2022). Piaget believed children begin to acquire mental processes that engage the prefrontal cortex as a result of play as early as the concrete operational stage (Bolton & Hattie, 2017). Unstructured play prompts changes in the prefrontal cortex, the critical region of the brain's executive control center responsible for regulating the skills needed to make decisions and solve problems (Medina, 2014). Unstructured play creates opportunities for a child's brain to reboot, resulting in renewed cognition and learning once the child returns to the classroom. In addition, motor and cognitive development are located parallel in the brain and connected in the prefrontal cortex (Diamond, 2000). The prefrontal cortex is not only responsible for motor competence but also for executive function abilities.

Executive Function Development

Executive function (EF) is a set of mental skills referred to as a "family of top-down mental processes" needed when problem solving, concentrating, or paying attention (Malambo et al., 2022; Nemeth & Chustz, 2020; Sarvari et al., 2022). (PA) that is generated through play acts as a cognitive stimulant, especially in children to promote EF. There is ample evidence that recess increases blood flow, growth factors (e.g., brain-derived neurotrophic factors), brain activation, and induces neurogenesis, resulting in larger brain volumes or better connections between brain regions **(**Grey et al., 2018, p. 268). Children acquire mental processes, i.e., inhibition, working memory, and cognitive flexibility through the healthy blood flow promoted by play and physical movement (Sanchez-Lopez et al., 2019). Inhibition is the ability to prioritize tasks and avoid impulsive actions or reactions (Nweze et al., 2020). Working memory is the ability to retain and use separate pieces of information over a short period of time (Diamond et al., 2013). Cognitive flexibility is the ability to maintain or change attention in response to various demands or to apply different rules in various situations (Oberer et al., 2018). Children use these different skills every day in school and at home. When there are any impairments to the EF abilities due to lack of play and PA, it can be very harmful to children in a learning environment (Erickson et al., 2019). Cognitive impairments can make it difficult to remain focused, follow classroom instructions and handle all the emotional pressures that are exposed to children on a day-to-day basis.

Piaget and others would argue by increasing time to play outdoors daily and often provides physical activity (PA), language development, and emotion regulation which promotes MC and EF (Singh et al., 2019; Nesayan et al., 2019). The best place to promote play to develop

MC and EF is in a school setting where the majority of a child's day is spent (Bardark & Obradovic, 2019; McClelland & Cameron, 2019). If elementary schools would allow outdoor play opportunities to be infused in how children learn, they would be exposed to a variety of new interactions that would influence their MC and EF abilities. Piaget's four stages of cognitive development laid the foundation for other theoretical frameworks to clarify how these new interactions improve the development of MC and EF in children. One of the theoretical constructs that supports unstructured play and Piaget's work with movement is Dynamic Systems Theory.

Dynamic System's Theory's and Motor Competence Impact

Dynamic systems theory (DST) suggests that movement patterns 'emerge' naturally because of the complex interactions between three connected constraints (individual, environment, and tasks) (Colombo-Dougovito, 2016; Thelen, 1989). The individual constraint refers to the child's structural makeup like height and weight and functional characteristics like motivation, curiosity, and attention. Everything that makes the individual unique and one of a kind. The environment constraint refers to everything outside of the individual like indoor, outdoor, temperature, time, and space. The last constraint is a task that relates to everything involved with the action itself, like adjusting speed, fast or slow, to control oneself and keep personal space (Seifert et al., 2018).

These three constraints work together to create spontaneous behaviors, known as movement. DST allows children to mentally process their environment during play opportunities to develop movement patterns that enhance their motor competence abilities. This is viewed as multilevel, interactive, and bidirectional when children move through different movement planes to naturally develop their movement patterns. DST promotes attractor states, the natural adaptation of a preferred movement pattern through repetitive tasks over time (Yamamoto et al., 2020). When children are given the ability to engage in repetitive movements over time, the more comfortable and natural it becomes for them to perform a preferred movement. This adaptation occurs through actively exploring the environment and dynamic interactions between a child's characteristics and contextual influences (McClelland et al., 2015).

Recess, when unstructured and outdoors, naturally uses a DST approach to spark spontaneous movement patterns in children to achieve MC. Recess is the driving force behind the interaction between the three dynamic constraints when children engage in repetitive motor movements on the playground (Hillman et al., 2020a; Hultenn et al., 2020; Malambo et al., 2022). Therefore, providing children with a school-based recess intervention that has shown success improving children's physical, social, emotional, and behavioral development could be the spark needed to enhance their MC abilities and EF development.

Let's Inspire Innovation N' Kids (LiiNK) Project

The LiiNK Project (Let's Inspire Innovation N' Kids) is a whole child recess intervention addressing the gap between academics and physical, social, emotional, and cognitive health. Grades K-5 receive four 15-minute unstructured play breaks daily and 15-minute character development lessons throughout the school year. LiiNK has successfully exposed school-aged children to more outdoor play opportunities throughout their school day, which has had multiple benefits on their physical, social, emotional, and cognitive development. Physically, LiiNK has improved children's body fat by 7% (Farbo & Rhea, 2019), increased children's moderate-vigorous physical activity by 1,200 total steps per day (Farbo & Rhea, 2022), improved cardiovascular endurance (Farbo et al., 2020), and strength (Williams, 2021). Behaviorally, LiiNK has successfully decreased off-task classroom behaviors by 40% in the first year of the program (Rhea & Rivchun, 2018). Socially and emotionally, children's attentional focus has been improved throughout their school day (Lund et al., 2017), they are happier and more resilient (Maler & Rhea, 2017), and less chronically stressed (Kirby & Rhea, 2022).

The LiiNK intervention, unknowingly, has supported the DST model by providing children with an appropriate outdoor setting to engage in unstructured play opportunities to enhance children's MC and EF abilities for years. When children are given the opportunity to engage in outdoor play, they have the opportunity to learn how to fall, correctly, to prevent injuries (Garcia-Soidan et al., 2020). The key to decreasing the rate of unintentional falls is motor competence development in hopes to minimize injuries. MC and EF abilities have not been studied with this population. The challenge is assessing motor coordination and postural balance abilities, which are the key motor competence components. If an assessment tool were identified that allows researchers to study motor competence in children with multiple recesses daily, it could shed some light on the rise of falls and injuries in children today.

Motor Competence Assessments

Several motor coordination assessments that are age-appropriate for school-aged children have been used in the U.S., including the Movement Assessment Battery for Children (M-ABC), Bruninks-Oseretsky Test of Motor Proficiency (BOTMP), and the Peabody Development Motor Scales – 2nd edition (PDMS-2) (Adhvaryu et al., 2022; Griffiths et al., 2018; Lin et al., 2017). Nevertheless, no motor coordination assessment used in the U.S. is considered the gold standard in measuring motor competence abilities related to postural balance in school-aged children. According to Giuriato et al. (2021), the rule of thumb for researchers to select a motor competence assessment that fits the profile of the exact physical elements they would like to assess to determine which assessment is more feasible for them to use. Most MC assessments used in the U.S. are valid and reliable tools but focus on overall motor skills, which include fine and gross motor skills in school-aged children (Barnett et al., 2016; Cattuzzo et al., 2016). To determine motor competence principles related to postural balance abilities, fine motor skills do not match the physical principles needed to sustain postural balance. Gross motor skills are the physical components needed to assess a child's MC abilities related to postural balance (Bojanek et al.,2020).

When narrowing down the appropriate MC assessments to evaluate motor coordination and postural balance with U.S. children, three factors were considered: (1) it must focus on gross motor skills only because these specific motor skills are the physical components needed to determine a child's motor competence skills related to postural balance; (2) it must be able to evaluate atypical (children that present with motor deficits) and typical (normally developing) children to meet the demands of the wide development ranges across grade levels in the U.S.; and (3) it must fit into the context of a physical education setting in the U.S. This is vital because physical education (P.E.) settings have been known as the gold standard for administering physical testing assessments, annually, throughout the school day (Mckenzie et al., 2015) After an extensive search of a MC assessment that presents with these three key factors, there was only one.

The *Körperkoordinationstest fur Kinder* (KTK, Bardid et al., 2015) is a German-developed motor competence assessment focused exclusively on gross motor only skills directly related to sustaining a base of support. The KTK was designed to evaluate multiple physical fitness components, i.e., agility, speed, balance, strength, and coordination, that align specifically with postural balance skills (Nascimento et al.,2018). These skills are assessed through the administration of four battery subtests (1) Walking backwards (WB), Single leg hopping (SH), Lateral Jumping (LJ) and Sideways Stepping (SS) (Kiphard & Schilling, 1974, 2007). The KTK has been deemed a valid and reliable tool and to be highly effective in elementary school-aged children (Cancer et al., 2020; Iivonen et al., 2015; Niemisto et al., 2020) As a result, researchers from many other countries like Finland, Brazil, and England have adopted the KTK to assess children's motor competence abilities through sustained postural balance and motor coordination in P.E. classes (Iivonen et al., 2015; Laukkanen et al., 2015; Moreira et al., 2019).

Researchers in other countries have examined sex and age differences in elementary school-aged children to determine their motor competence abilities through the KTK. They found that males typically perform better than same-age females on three of the four KTK subtests (SH, LJ, and SS) and females perform better than males on the walking backward (WB) subtest (Giuriato et al., 2021; Moreira et al., 2019; Vandorpe et al., 2011). Additionally, children have shown motor competence ability improvements as they age (Bardid et al., 2015; Dirik & Sogut, 2021; Freitas et al., 2015).

Researchers have linked the KTK assessment to identifying cognition impairments in school-aged children (Vandorpe et al., 2011). The KTK has a 91% validity rate in identifying children with underlying cognitive impairments in conjunction with motor competence skills (Asunta et al., 2019). If children cannot complete the four KTK subtests, their ability to mentally process could reveal a hidden connection between their motor competence and cognitive functioning abilities that would warrant the child to undergo further cognitive evaluation with the appropriate licensed practitioner. Using an assessment tool of this magnitude will give researchers and physical educators in the U.S. the ability to test motor competence which can determine the risk for falls and injuries (Giuriato et al., 2021).

Since the KTK has only been used in other countries with validity and reliability, the assessment needs to be studied in the U.S. to determine its feasibility, validity, and reliability to deliver in a physical education setting with typically and atypically developing children. Feasibility includes translating the protocols and procedures and score sheets into English with fidelity and finding a way to develop the equipment with fidelity. If successful, it would allow

LiiNK and other researchers the ability to assess the role recess has on children's MC abilities. This knowledge will help us gain a better understanding if the KTK is the appropriate assessment tool for U.S. researchers and physical educators to evaluate MC abilities related to postural balance. It will also help researchers and physical educators develop the appropriate strategies to improve children's MC abilities or address MC deficiencies. This will determine if LiiNK and other recess interventions can be impactful in naturally improving the physical competencies needed to decrease the number of unintentional falls resulting in injuries.

Figure 1

Walking Backwards Subtest (WB)

Figure 2

Single-Leg Hopping Subtest (SH)

Figure 3

Lateral Jumping Subtest (LJ)

Figure 4

Sideways Stepping Subtest (SS)

Research Questions and Hypotheses

The primary purpose of the first manuscript was to determine if the KTK assessment was feasible to administer in U.S. physical education settings to assess gross motor competence specific to postural balance and motor coordination in American children. The feasibility was determined by addressing the three glaring U.S. challenges that may not be relevant in other countries: (1) Implementing the KTK assessment in a physical education setting by addressing the number of teachers needed to monitor each skill, identifying the best way to set up and rotate through the skill tests, and the number of students who can engage in the subtests simultaneously; (2) Time to assess each subtest in an American physical education class; and (3) Equipment availability and cost to run the tests. The secondary purpose of this study was to determine the adaptability of the scoring protocol from use in other countries to the U.S. The adaptability in this study was determined by converting the raw scores produced by purpose one into KTK motor quotients to determine children's motor competence levels ranging from severe to great. A Flemish suitability study was used to analyze the trends found from the scoring protocol between their children and U.S. children's MC abilities.

The primary purpose of the second manuscript focused on determining the fidelity of the KTK with U.S. physical educators' ability to set up, administer, and score each subtest in a. physical education setting. This was determined by creating a fidelity checklist highlighting a physical educator's ability to set up each subtest associated with the KTK assessment correctly, administer each subtest correctly to their students, including student organization, and score each KTK subtest accurately to produce measurable KTK motor quotient (MQ) values. These MQ values would determine children’s MC abilities. The secondary purpose of this study was to gather preliminary MC data comparing two very different elementary schools, determined by demographic variables (e.g., race, number of PE teachers, how often PE and recess were offered weekly, and sizes of classes) using the MC ability scores.

The first research question (RQ1) of the third manuscript was “Are there MC differences on the KTK subtests between the intervention children (60 minutes of recess) and control school children (30 minutes or less of recess) daily?”. The first hypothesis related to RQ1 was intervention children receiving 60 minutes of recess daily would improve significantly more on the four KTK subtests compared to children receiving 30 minutes or less daily over a calendar school year. An additional exploratory hypothesis for RQ1 was intervention and control children would demonstrate different MC ability profiles. The second research question (RQ2) of this study was “Is there a relationship between MC change scores and EF processes?”. The hypothesis related to RQ2 was a relationship would be found between MC abilities and EF.

Chapter 2: The Feasibility of Using the *Körperkoordinationstest fur Kinder* (KTK) in an Elementary Physical Education Setting to Assess Gross Motor Skills Specific to Postural Balance

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Abstract

Introduction: For the past ten years, falls have been the leading cause of nonfatal injuries for all age groups less than 15 years old. A significant rise in childhood sedentary behavior in schools and limited opportunities to be outside has led to motor coordination deficits which have contributed to fall injuries. **Method:** A German assessment tool, the *Körperkoordinationstest fur Kinder* (KTK), used for decades in Western European countries, allows researchers and physical education teachers to evaluate typical and atypical children's motor competencies related to dynamic postural balance successfully. No research has been published on the use of this assessment tool in the United States. If its use were found to be feasible in this country for identifying motor coordination deficits in typical and atypical children, it would close the gap in determining motor coordination. Therefore, this study sought in Phase 1 to determine the feasibility of using the *KTK* assessment in U.S. children and Phase 2 sought to determine the adaptability of the scoring protocol from use in other countries to the United States. **Results:** Phase 1 results revealed the KTK assessment was feasible to administer in U.S. physical education class by addressing three challenges for U.S. schools: (1) KTK implementation, (2) time to assess each skill, and (3) the equipment availability and cost to implement the test in a physical education setting. In Phase 2, raw scores and MQ scores showed similar scoring trends between U.S. and Flemish children from a previous study. **Conclusion:** This assessment tool was deemed feasible and adaptable which is the first step to use the KTK in the U.S.

Introduction

According to the Centers for Disease Control and Prevention (CDC), an estimated 9.2 million children annually have had an initial emergency room visit for an unintentional injury (CDC, 2019). Approximately 2.8 million of those children had the initial emergency visit due to fall injuries. For the past ten years, falls have been the leading cause of nonfatal injuries for all age groups less than 15 years old (CDC, 2019). A significant rise in childhood sedentary activity and limited opportunities to be outside have led to motor coordination deficits which has contributed to fall injuries (Xiang et al., 2020; Delcastillo-Andres et al., 2018). Children spend at least 7-8 hours daily in a school setting which should lead to plenty of active time throughout the day. Sadly, adults have put a higher priority on the academic skills of children, placing physical education and recess as minimal offerings in schools (Brusseau & Hannon, 2015). For children who receive recess during their seven-to-eight-hour school day, the majority see no more than 20 minutes daily (Ramstetter & Murray, 2017).

Thirty years ago, recess was treated differently. It was recognized as an essential time for children to develop all dimensions of self (physical, mental, emotional, and social). Recess was always described as unstructured and outdoors where children had free choice of what they did at play, without teacher influence (Bauml et al., 2020). It was the only way children engaged in play (Lee et al., 2020; Rhea, 2021). Teachers supervised safety on the playground but did not interfere in the children's engagement in play. The value of play was recognized and given as a child's right (Bento & Dias, 2017, Article 31). Over the last few years, standardized tests have become the only marker of a child's success, leaving the best parts of a child behind in schools (Benner et al., 2016).

Much of the research has been focused on the detrimental effects of less play and recess on whole child development (Dickey et al., 2016). Offering recess in schools allows children to reboot their brains for learning (Heidorn & Heidorn, 2018), decrease distress and anxiety (Kirby, 2022; Ordonez, 2020), and improve attentional focus (Rhea & Rivchun, 2018). Unstructured, outdoor recess allows children to meet the CDC's (2020) recommended 60 minutes of physical activity daily which promotes healthy bodies and brain development (Farbo & Rhea, 2022; Farbo et al., 2021). Recess also boosts gross motor skill development through the engagement of running, jumping, swinging, and climbing, to name a few. These skills are highly beneficial for proper falling mechanics, motor skill proficiencies, and injury prevention (Dankiw et al.,2020; Lee et al., 2020).

Due to the decline of recess and unstructured, outdoor play opportunities in schools, physical activity researchers and physical educators have contributed this decline to motor skill deficiencies observed in physical education settings today (Ericsson & Karlsson, 2012). Researchers are realizing a strong parallel between children who have had outdoor play opportunities and their ability to be more proficient on motor skills in the physical education setting (Dankiw et al., 2020). Physical education (PE) teachers have recognized the decline in a child's ability to navigate different surfaces, coordinate motor skill movements, and fall in ways that prevent injuries (Hills et al., 2015). As the child ages, the alarming gap in skill proficiencies and number of injuries grows, especially as sport becomes the primary focus by middle school (Saunders et al., 2016). At the root of these issues is whether a child can demonstrate the ability to coordinate muscle sequencing that preserves stability and postural balance also known as motor coordination which is key to motor skill proficiencies and everyday movements (Freitas et al., 2015; Pellegrini & Bohn-Gettler, 2013).

Balance, categorized as static or dynamic, is the act of maintaining, achieving, or restoring a base of support during any posture or activity (Ludwig et al., 2020). Both types are essential for a child to have the ability to maintain body control during motor skill tasks

(Lengkana et al., 2020). Static balance is the ability to create a base of support during stationary tasks, whereas dynamic balance is the ability to create a base of support during tasks while moving (Conner et al.,2019). Developing dynamic balance proficiencies through recess and physical education are very important to master since they are predictors of a successful postural balance transition from childhood to adulthood (O'Brien et al., 2019). Dynamic balance unlocks a child's ability to perform functional activities of daily living that require maintaining a stable position, like grooming, dressing, walking down a hall in school, navigating uneven surfaces on the playground, and sitting at a desk to engage in classroom activities (Yu et al., 2017). Assessing dynamic balance through gross motor coordination skills is needed to ensure *c*hildren can engage in their environment across tasks effectively while limiting their risk of falling and preventing injuries inside and outside the school setting (Steinberg et al., 2018).

The physical education environment is the gold standard setting to evaluate school age children's gross motor coordination skills using appropriate assessment tools available to them (Loprinzi et al., 2015). Three issues need to be addressed when choosing an assessment tool for a physical education setting: 1) identifying the most appropriate assessment tool to use for the type of skill proficiency needed; 2) the person assessing the skills should be able to administer it accurately; and 3) knowing how to incorporate it with any physical education class size quickly and efficiently (Pangrazi, 2019). A motor coordination assessment must incorporate multiple fitness concepts that align with dynamic postural balance movements like strength, speed, endurance, and flexibility (Lengkana et al., 2020). Most motor coordination assessments are used in a clinical setting to diagnose individual motor deficiencies. If physical educators are going to use a motor coordination assessment, it must evaluate dynamic components of postural balance with the goal of preventing fall related injuries and be feasible in a variety of physical education settings (Cadore et al., 2013).

Several motor coordination assessments are used in the United States to assess a single fitness component related to balance and coordinative capacities rather than multiple fitness components related to dynamic balance (Vandorpe et al., 2011). Researchers have found it difficult to label one assessment as the best motor coordination tool (Bardid et al., 2016). The Movement Assessment Battery for Children (M-ABC) is a motor coordination assessment designed to detect and evaluate children's functional movement skill (FMS) development deficiencies (Johnston, 2016). The M-ABC evaluates fine and gross motor skills within the scope of the assessment's evaluation tasks (Wuang et al., 2009). Fine motor skills are essential to determining a child's manual dexterity but do not specifically address the motor skills needed to establish postural balance capabilities. Not only does it lack needed criteria, but it also takes longer per child to administer, i.e., 20-40 minutes, then is suitable for different physical education class sizes. Therefore, the M-ABC would not be the most appropriate assessment for physical educators to evaluate motor skills needed to assess only dynamic balance in children. The Bruninks-Oseretsky Test of Motor Proficiency (BOTMP) is another common motor coordination assessment designed to evaluate motor skill deficiencies in school-age children due to comorbidity from a specific diagnosis like cerebral palsy, developmental coordination disorder, and autism (Dourou et al., 2017). This motor coordination tool would not be the most inclusive assessment for physical education classes because it was designed to target atypical children defined as children with motor deficiencies. Physical education classes in the U.S. include very diverse developmental levels of children ranging from typically developing to atypically developing. In addition, the BOTMP generally takes about 60 minutes to administer to one child (Bruininks, 1978). That is not appropriate with the profile of physical education classes usually ranging from 50-60 children and have limited time of 35-45 minutes per class period on average. Therefore, the BOTMP would also not be an appropriate assessment for this study.

Unfortunately, limited motor coordination assessments exist in the U.S. designed to evaluate gross motor skills that are directly related to dynamic postural balance, focus on inclusivity, and meet the physical education class time constraints. This led to examining an assessment tool commonly used outside of the U.S. that meets these challenges.

The *Körperkoordinationstest fur Kinder* (KTK) (Bardid et al., 2015) is a German developed assessment tool focused exclusively on gross motor skills that take approximately 15 to 20 minutes per child. The KTK was designed to evaluate multiple fitness components, i.e., agility, speed, balance, strength, and coordination, that align specifically with postural balance skills (Nascimento et al.,2018). No U.S. studies have been documented that use the KTK, but studies from other countries like Germany, Finland, Brazil, and England have shown the KTK to be highly effective in elementary school aged children (Iivonen et al., 2015). As a result, researchers from many other countries have adopted the KTK to assess children's gross motor skills and postural balance abilities in PE classes (Iivonen et al., 2015). The KTK allowed these researchers to evaluate typical and atypical children straightforwardly and objectively with limited interference of other physical fitness components outside of the key four elements of strength, speed, endurance, and flexibility. In addition, the KTK has a 90% validity rate in identifying children with underlying cognitive impairments in conjunction with gross motor skills (Asunta et al., 2019). This illustrates the KTK assessment as one of a kind in its ability to connect gross motor skills directly to postural balance and cognitive abilities in children (Vandorpe et al., 2011).

Moreira and colleagues (2019) deemed the KTK assessment viable for research, professional practice, and educational settings. Many researchers have found the KTK to be a valid and adequate tool to assess motor coordination in children between the ages of 5-14 in comparison to the M-ABC and BOTMP motor coordination assessments that are widely used in western European countries (Fransen et al., 2014; Zoia et al., 2018). The KTK assessment has also been used with a variety of children's populations who have motor performance deficits. The flexibility of this assessment is designed to allow researchers and physical educators to evaluate multiple children within a physical education class who are presented as typically or atypically developing to establish a motor competence baseline. All indicators show U.S. physical educators should be able to adopt the KTK to assess and evaluate the multiple fitness components (i.e., agility, speed, balance, strength, and coordination) related to motor competence skills and postural balance in children through 14 years of age. The KTK would give physical educators an alternative way to identify development needs for children to reach age-appropriate motor abilities inside and outside the classroom and prevent injuries due to falls.

Although the KTK can be an ideal assessment tool to evaluate postural balance in schools, the assessment still presents some challenges that PE teachers must overcome for the assessment to be deemed feasible to use in a U.S. physical education setting. The three glaring challenges in the U.S. that may not be relevant in other countries are (1) Implementation of the KTK assessment (2) time to assess each skill; and (3) equipment availability and cost to run the tests.

Therefore, Phase 1 of this study was to determine the feasibility of using the *Körperkoordinationstest fur Kinder* (KTK) assessment to evaluate gross motor coordination skills specific to postural balance in American children. The feasibility was determined by addressing each of the challenges spelled out above. Phase II was to determine the adaptability of the scoring protocol from use in other countries to the United States. First, raw scores and motor quotient scores would be established through the subtest assessments and then will be compared between 8-10-year-old U.S. children who were assessed in physical education classes from this study with 8–10-year-old Flemish children from the 2008 suitability study (Vandorpe et al., 2011).

Phase 1 Assessment Preparation, Subtest Descriptions, & Feasibility Challenges

The KTK assessment preparation processes were developed to assure all researchers and school personnel involved in the KTK assessment knew the implementation processes, how to set up the subtests, and the assessment procedures before administering the KTK assessment. The KTK feasibility was addressed through identifying three implementation challenges associated with the KTK assessment novel to a U.S. population. The first challenge addressed implementation processes: 1) number of teachers needed to monitor each subtest, 2) identifying the set up and rotation subtest procedures, and 3) determining the number of children who can engage in each subtest at one time. The second challenge addressed the time it would take to assess each skill. The third challenge addressed the equipment availability and cost to implement the tests in a gym setting.

Pre-KTK Assessment Preparation Processes

The KTK is comprised of four subtests: Walking Backwards (WB), Lateral Jumping (LJ), Sideways Stepping (SS) and Single Leg Hop (SH). To assess whether KTK implementation is feasible in a U.S. physical education setting, the PI and research team needed to provide additional information to the physical educators to ensure a fluid and consistent evaluation of the assessment. Therefore, an initial meeting was scheduled with the physical education teachers at the school gymnasium where the subtests would be set up. The meeting, about an hour in length, consisted of explaining the benefits of the KTK, providing the procedures for each subtest, and demonstrating how to implement each subtest correctly in the gym setting. Physical educators were able to practice each subtest and ask any questions related to KTK equipment set up and implementation.

A second meeting, also about an hour, was scheduled two weeks later to demonstrate each KTK subtest again as well as introduce the subtest score sheets to assure that each PE teacher was competent in assessing and scoring their children correctly. Instructions and tips about how to rotate, monitor, and score each subtest were explained. The physical education teachers gave the PI and two other researchers a tour of the gym to develop an equipment setup strategy to ensure a child's safety at each of the subtest stations. After the teachers felt comfortable with the implementation and scoring processes at this meeting, the data collection days were scheduled for the following week.

The next step that had to be set up prior to the day of arrival was children's information organization and post testing feedback. The researcher requested and organized the children's rosters for each grade level into four equal groups depending on the number of children assigned to each class. The teachers were each given a master score sheet for each grade level on the first implementation day that had the children assigned to their station listed first followed by the children who would rotate to them sequentially throughout the two-day process listed next in order. Once each child completed a subtest the teacher would direct the child to the next subtest in a continuous manner until time expired for that class. If a child's name did not appear on the score sheet, then the teacher could simply write in their name to complete the evaluation process.

After each class period was complete, the PI met with the evaluation team to discuss the evaluation process and areas of improvement. The PI would document the percentage of completed subtests, the time taken to complete the subtest, the resources needed to complete each subtest, and the equipment to set up the subtest.

KTK Subtest Descriptions, Equipment needs, and Scoring.

In order to assure similar KTK assessment implementation, the KTK manual was acquired to substantiate the KTK subtest descriptions, equipment specifications, and scoring information.

Subtest 1: Balance Beam (WB)

Description and Equipment Information

This subtest measured balance, rhythm, and strength. All three of these physical skill components determine the child's ability to maintain postural stability while walking backwards on three different widths of balance beams. Balance beam one is 6.0 cm in width, followed by balance beam two which is 4.5 cm in width, and finally balance beam three which is 3.0 cm in width. All three balance beams are seven feet in length.

***Scoring Instructions*.** Children remove their socks and shoes before participating in the WB subtest. Children were instructed to walk backward on the three width-size balance beams (6.0 cm, 4.5 cm & 3.0 cm). The children were then asked to take a maximum of eight steps per trial, for a maximum of 24 steps per balance beam, with a total of 72 steps for the three different balance beams. Each child has three attempts per balance beam to reach the maximum of eight steps per beam. The child starts the evaluation process by walking up the balance beam until they reach the wooden platform. Once the child reaches the wooden platform, the backward walking assessment begins. The first step from the wooden platform onto the balance beam backwards is called the plantar step. This step does not count towards the eight steps possible per trial. One successful step backward equals one point for the possible eight points per trial. If a child falls off of the balance beam or any body part touches the ground while on the balance beam, the child must restart on the wooden platform for their next trial attempt. Once a child completes their three attempts, they transition to the next balance beam size to demonstrate the same procedures**.**

Subtest 2: Lateral Jumping (LJ)

Description and Equipment Information

This subtest measured speed, rhythm, and agility. All three of these physical components will determine the child's ability to move laterally and maintain postural stability while jumping back and forth repeatedly for 15 seconds. The lateral jump is assessed using a wooden obstacle measuring 5 ft 10 inches long by 24 inches wide with a flat wooden surface vertically positioned that is 25 cm long, 25 cm wide, and 5.7 cm high.

Scoring Instructions. Children were instructed to stand on the right side of the wooden divider with both feet flat on the ground before the lateral jump activity occurs. The child is tasked with jumping laterally over the wooden divider as many times as possible for 15 seconds. Children must successfully not touch the wooden divider and have both feet touch the ground simultaneously during their lateral jump attempt for the point to count towards their final score. Each successful jump counts for one point toward their final score. Due to this subtest being a timed test, there is no total maximum number. The child must try their best to reach their maximum number of successful jumps in the 15-second window. Each child had two attempts to complete the LJ subtest to populate a total sum score from the two attempts.

Subtest 3: Sideways Stepping (SS)

Description and Equipment Information

This subtest assesses how well children move sideways on a wooden platform using a repetitive crossover motion. The SS subtest measured speed, rhythm, strength, and balance. All three of these physical components will determine the child's ability to move laterally and maintain postural stability while stepping sideways repeatedly for 20 seconds. The sideways step subtest requires two wooden platforms with dimensions of 25 cm x 25 cm x 5.7 cm (L x W x H).

Scoring Instructions. Children were instructed to stand on one wooden platform before starting the SS subtests. The child would pick up the second wooden platform to the left or right of them and perform a crossover maneuver to the other side of their body. The child would then step sideways onto the platform and perform the crossover maneuver repeatedly for 20 seconds to determine how many times the child could step onto a new platform and do the crossover maneuver. The children were given two attempts on this subtest. A 10-second break must be given between each attempt to allow the child to regain composure before the next attempt. One point was awarded to the child for performing the crossover maneuver (1 pt. = Crossover), and one point was awarded for stepping onto the wooden plank after the cross maneuver was performed (1= stepping onto the new platform). This is a timed subtest, so there is no preset maximum number of steps, so each child is encouraged to do their best. After both attempts were completed, the sum of both attempts was documented.

Subtest 4: Single leg hop (SH)

Description and Equipment Information

This subtest assesses each leg individually to hop over a foam obstacle with an increasing height of 5 cm per successful hop. This subtest measured strength, rhythm, and balance. All three of these components work together in a synergy pattern to identify the explosiveness of a single leg to clear a successful landing over increased height of the foam pad. As children clear the height of each foam pad, the evaluator will add 5cm foam pad increments until they can no longer clear the height after three attempts. The Trifold mat is a requirement for children to complete this jumping subtest. The evaluator is responsible for ensuring the child has a clear pathway of at least six feet of space to ensure child safety. Twelve foam pads with a depth of

5cm each are needed to implement this subtest. The dimensions of the foam pad are 60cm x 20cm x 5cm (L x W x H). The goal is to clear all 12 foam pads stacked on top of each other (60 cm in height total) with each leg.

Scoring Instructions. Children removed their socks and shoes before participating in the jumping for height activity. The child stands off the trifold gym mat before starting the assessment. The child must be instructed on which leg is being evaluated then the child balances on that specific leg (right or left) before trying their first attempt over the foam obstacle. The child must hop over the foam obstacle from the evaluated leg, land on the same leg, and complete two hops after landing to receive a point-worthy score. Suppose the child had any other body part hit the ground, especially the non-evaluated leg or could not complete two additional hops. In that case, the point score does not count. Children will be given three attempts per leg (right & left) to hop over the foam obstacle. Points for this subtest are determined by what attempt the child can successfully hop over the foam obstacle. Three points are awarded to the child if they can complete the hop on the first attempt (1st =3 points), two points are awarded if the child completes a successful jump on the second attempt (2nd= 2 points), and one point is awarded if the child can complete a successful jump on the third and final attempt (3rd= 1 point). After one leg is complete then the evaluator will complete the same scoring procedure for the opposite leg. After each leg has been evaluated, the evaluator will increase the height of the foam obstacle in increments of 5 cm up to 60 cm total (5 cm, 10 cm, 15 cm, 20 cm, 25 cm, etc.) For example, suppose the child is not able to successfully jump over the foam obstacle in three attempts. In that case, they will receive a score of zero and indicate to the evaluator that they have reached their JH ceiling. The child will not be able to move forward in height with that specific leg. Once both legs have been eliminated by not reaching the three-attempt threshold, the evaluation for the child must be stopped and the total score must be summed together. The child can reach a maximum of 72 points for this subtest if the child is able to successfully hop over each foam obstacle on their first attempt to receive a score of three for each of the twelve obstacles.

Feasibility Challenges

Next, was to address challenges we felt would prevent the KTK from being feasible in physical education classes from the U.S.

KTK implementation

The first challenge, implementation, included three parts: 1) the number of evaluators needed to monitor each subtest; *2*) identifying the set up and rotation subtest procedures, and 3) determining the number of children who can engage in each subtest at one time.

Evaluator Needs. The PI scheduled one researcher or teacher to administer and assess each of the four subtests. The evaluation team consisted of the PI and one additional member of the research team along with two physical education teachers.

Subtest Procedures. The PI and teachers arrived 30 minutes before the first physical education class was to arrive to set up the equipment, provide the score sheets with the children's rosters included, clipboards and pencils, and review subtest responsibilities for each evaluator. One gym (approximately 120 feet long by 75 feet wide) was used to complete the subtests. Most elementary school gyms in the U.S. are not this big, but even for the smallest of gyms, there is still plenty of space to have all four subtests set up simultaneously. At this school, though, it was easy to set up the stations far enough apart to address any safety concerns and not overwhelm an area with too many children. Each subtest needed to have about 8 feet of space to execute all protocols for each subtest completely. The PI administered the equipment set-up and execution of the subtests along with the physical educators. After completing the KTK evaluation the PI had a brief meeting with each evaluator to ask if there were any questions regarding the evaluation process before children arrived for class.

Number of manageable students. Since only one set of equipment was used at each station, the children were divided equally into four groups and assigned to one of the four subtests. Each of the grade levels had 20-35 children, therefore a station could have anywhere from 5-9 children depending on the grade level class size. For example, if a class had 20 total children, the class would be evenly distributed with five children going to each of the four stations. The plan was for each child to rotate chronologically to the next subtest as they completed a subtest. The plan was that two subtests would be completed by all children on the first day and the other two subtests would be completed on the 2nd day. Each physical education grade level had a varied time schedule. The 3rd graders had 40 minutes, the 4th graders had 35 minutes, and the 5th graders had 45-minutes. Although each grade level had varied minutes and number of children, the PI felt the two day schedule could still work because the smallest number of children (20) was linked to the grade with the lowest number of class time minutes (35) The largest class sizes had the most minutes of class time, so we felt the class sizes with the number of minutes would work out the same for all three grade levels. A third day would be used to perform any make-up subtests for children who were absent during one or both days of evaluation.

After completing all subtests for the three grade levels, the evaluators reflected on how well the KTK implementation worked overall. First, the equipment set up took approximately 30 minutes prior to a class arriving. So, equipment set up should take place at least 45-60 minutes prior to the first-class arrival so there is sufficient preparation time prior to child entry. Second, the setting up of two subtests on the right side and two subtests on the left side of the gym was feasible with four evaluators. The physical educators felt the subtest implementation and scoring could be accomplished with two to three evaluators per class, depending on the class size, the class minutes, and the amount of equipment available for the teacher to use in each class. This study showed that for a class up to 35 children, divided into no more than nine children per subtest group, it was feasible to execute the evaluation process, manage children, and be able to successfully move children to their next subtest without any downtime.

Time to assess each subtest

The second challenge examined the amount of time it took to assess each subtest. This was evaluated by taking the number of minutes each physical education class period had with how many children were in each class, and then determining how long it took to evaluate the four subtests for each grade level. For example, the largest number of children (N=37) was the 5th grade class which had 45-minute classes daily. After monitoring the assessment to completion, it took180 minutes or four 45-minute physical education class periods to complete the subtests for 5th grade, but it took the same number of days for each of the other grade levels as well due to the lower number of class minutes daily. The time per child averaged about four and half minutes to complete all four subtests. This time element was based on only using one set of equipment over the four days and one evaluator per subtest per day. After discussing this time element with the teachers, the consensus was introducing more sets of equipment for each subtest would aid in quicker subtest completion. We also realized that the balance beam and single leg hop subtests took longer to evaluate each child because the requirements for those two tests were more cumbersome than the other two tests. For example, the balance beam (WB) subtest had three trials for each level of completion and for the single leg hop (SH), it required three trials for each leg per level of completion. The other two subtests were for speed and agility, so they were set with a stopwatch and only needed two trials per subtest. If additional equipment is provided expressly for the WB and SH subtest, more children can be evaluated simultaneously for less overall completion time.

Equipment availability and cost

The third challenge examined how to acquire the equipment and how much it would cost to purchase the equipment. No commercial manufacturer builds the three balance beams of differing sizes, sidestep boards, the lateral step single board, or the single leg hop pads that are required to assess the KTK subtests. The research team took the dimensions for each piece of equipment given in the equipment section above and hired a carpenter to make the equipment based on the specifications. Once built, each piece had to be sanded and painted to create smooth wood surfaces for safety and for the balance beams, they were painted different colors to represent the width differences. Pictures and videos were available to make sure the equipment we produced met the KTK equipment requirements and matched the other countries.

The wood for the WB, SS, and LJ subtest was purchased from a local hardware store for $150. The foam pads for the single leg hop subtest were created out of a pillow top cushion that cost $50. The labor charged for the whole set would probably vary by carpenter to build the different equipment pieces. Therefore, the equipment materials for this study cost $200 and the labor for our carpenter was $100 for a total of $300 to have one set of equipment made.

Phase 1 Discussion

In order to determine feasibility of the *Körperkoordinationstest fur Kinder (KTK),* preparing for the assessment and substantiating the KTK subtest descriptions, equipment specifications, and scoring information had to be accomplished. These steps were effectively completed. Teachers were engaged in the process of where to set up the subtests in the gym, how many children would be assessed, and how to score each of the subtests. This created a smooth transition to the feasibility phase which showed the *KTK* was feasible to administer in an

American physical education class. The three identified challenges the U.S. schools would face are 1) KTK implementation, 2) time to assess each subtest, and 3) the equipment availability and cost to implement the test in a physical education setting. The interpretation of how to set up the equipment, implement the subtests, score each subtest, and manufacture the equipment needed for each subtest went smoothly in this setting. This is very promising for implementation of this battery of tests in 5-14 age children.

Although one full set of the KTK subtest equipment was feasible to evaluate each grade level with smaller class sizes, i.e., 20-35, this study has shown at least two to three sets of some of the equipment may be necessary to accommodate larger numbers of children and complete the tasks in two to three days. Other researchers have communicated that it takes approximately 20-30 minutes per child to complete all four subtests (Nascimento et al., 2019). We found that it takes approximately five minutes per child to complete all four subtests if you have one piece of equipment. We feel the assessments can transition much quicker if more equipment is set up. We determined that that single leg hop subtest takes the most time because a child must do the right leg hop from five cm up to 60 cm, followed by the left leg hop from 5 cm to 60 cm prior to completing the subtest.

Anecdotally, we found that the children enjoyed participating in the four subtests. Multiple child comments were heard, and non-verbal cues were seen while the children participated in the KTK subtests. They were excited, had smiles on their faces, challenged themselves to improve, and encouraged each other through the process. This could be a result of the KTK assessment being novel and fun. We observed that children did not feel that other children were watching them make a mistake when participating in the four subtests. Children did not know why the assessment was conducted and the instructions provided did not specify that the KTK was an assessment. The children were informed we were assessing balance, agility, and coordination. So, children treated the assessment as any other physical activity incorporated into their physical education class and did not seem to feel the pressure of failing when participating in the KTK assessment.

Lastly, teachers stated that they felt they could implement the subtests with success. They also loved that there was a meaningful outcome given for each subtest. The feedback derived from these scores would be very helpful for teachers to adjust the physical education curriculum to assist in postural balance development. Future studies will help determine if these challenges can be addressed more succinctly, but overall, the KTK is feasible to use in a United States physical education class.

Phase 2 Determining Adaptability of the KTK Assessment

Participants

The participants for this study were children attending a North Texas school identified for the feasibility study. The children were between the ages of 8-10 and identified as either a boy or a girl to match the standardization profile of the norm scores. The children had the opportunity to engage in three 15-minute outdoor, unstructured play breaks resulting in 45 minutes of recess along with a daily 35-45-minute physical education class depending on the grade level. The children were identified as typically developing children and presented at different development levels during their physical education classes. All the children were able to follow instructions and had no glaring injuries that would prevent them from participating in the evaluation of the KTK assessment.

Table 1 provides the number and percentage of children involved in the KTK analyses by age and sex. A convenience sample of 82 boys and girls, ages 8-10 (grades 3-5), completed the KTK assessment. Inclusion criteria were parent consent, assent of each child, daily involvement in physical education and recess, and full use of their whole body to complete each physical component of the KTK subtest. The exclusion criteria were injuries preventing a child from executing a required body movement or a child's verbal refusal to participate at any time during the data collection process. Each child who met the inclusion criteria above was evaluated on all four KTK subtests. An additional 12 children did not complete all four subtests because of injury or refusal to participate and therefore were removed from the sample for the final total of 82.

Table 1

Participants by Age and Sex

Age	Males 40 (%)	Females 42 (%)
8-years	12 (15.0)	13 (16.0)
9- years	10 (12.5)	10 (12.5)
10-years	18 (21.5)	19 (22.5)
Grand Total	32 (48.7)	42 (51.0)

Procedures

The University Institutional Review Board approved the cross-sectional feasibility study design. One school in the North Texas region was identified to participate in this study who had at least 45 minutes of recess daily. The school administration team and physical education teachers at this school were asked to participate and approved prior to submitting letters to parents. Children were included who had parent consent but could decline participation at any time if they felt uncomfortable being evaluated. All these procedures were completed prior to the data collection phase.

Subtest Procedures. All subtest instructions were explained to all children at the beginning of the class period. After the instructions and demonstration were given, children were divided into even groups depending on their class sizes and each assigned subtest evaluator took their group of children to the subtest station. Each evaluator collected all scores on their subtest score sheet for each child. Once a subtest was completed for a whole group, the evaluator would direct the children to the next subtest for evaluation. At the end of each P.E. class, the PI collected all score sheets and secured them until the next evaluation day. Once each child finished all subtests, the PI collected all score sheets and completed a focus group session with the teachers.

KTK Motor Coordination Ability Scoring

The KTK was used to measure gross motor coordination abilities related to dynamic postural balance. The KTK manual provides the process to determine each child's motor coordination ability. Raw scores must be determined, followed by converting them to individual child motor quotients (MQ). The raw scores were created by adding the number of attempts together from each KTK subtest. The total MQ value was computed by adding the individual converted MQ values from the four subtests and then standardizing them by age and sex using Table 2 numbers provided below (Kiphard & Schilling, 1974; 2007). All four-subtests had to be completed for the raw scores to be converted to Motor Quotient scores. These MQ scores are required to determine motor coordination ability levels.

Table 2

Motor Quotient Conversion Values

Sum MQ1-MQ4	M-Q	Sum MQ1-MQ4	M-Q	Sum MQ1-MQ4	M-Q
215-217	40	341-343	81	468-470	122
218-220	41	344-346	82	471-473	123
221-223	42	347-349	83	474-476	124
224-226	43	350-352	84	477-479	125
227-229	44	353-355	85	480-482	126
230-232	45	356-358	86	483-485	127
233-235	46	359-361	87	486-488	128
236-238	47	362-364	88	489-491	129
239-241	48	365-367	89	492-495	130
242-244	49	368-371	90	496-498	131
245-248	50	372-374	91	499-501	132
249-251	51	375-377	92	502-504	133
252-253	52	378-380	93	505-507	134
254-256	53	381-383	94	508-510	135
257-259	54	384-386	95	511-513	136
260-262	55	387-389	96	514-516	137
263-265	56	390-392	97	517-519	138
266-268	57	393-395	98	520-522	139
269-271	58	396-398	99	523-526	140
272-274	59	399-402	100	527-529	141
275-278	60	403-405	101	530-532	142
279-281	61	406-408	102	534-536	143
282-284	62	409-410	103	537-539	144
285-287	63	411-413	104	541-543	145
288-290	64	414-417	105	544-546	146
291-293	65	418-420	106	547-549	147
294-296	66	421-423	107	500-552	148
279-299	67	424-426	108	553-555	149
300-302	68	427-429	109	556-559	150
303-305	69	430-433	110		
306-309	70	434-436	111		
310-312	71	437-439	112		
313-315	72	440-442	113		
316-318	73	443-445	114		
319-321	74	446-448	115		
322-324	75	449-451	116		
325-327	76	452-554	117		

328-330	77	455-457	118		
331-333	78	458-460	119		
334-336	79	461-464	120		
337-340	80	465-467	121		

Note: Motor Quotients (MQ) scores. MQ1=MQ for LJ; MQ2=MQ=MQ for SS; MQ3 for WB; MQ4=MQ for SH

The total MQ identifies a child's motor coordination performance into five categories based on norms determined by age and sex. According to Kiphard & Schilling (2007), children who have MQ values less than 70 are categorized as having severe gross motor coordination abilities. Children scoring between 71 and 85 have moderate gross motor coordination abilities, and children scoring between 86 and 115 have normal gross motor coordination abilities. Children scoring between 116 and 130 have good gross motor coordination abilities, and children scoring above or equivalent to 131 have great gross motor coordination abilities. Biino and colleagues (2022) reported that the KTK has an acceptable construct validity and a test-retest reliability score of 0.97. Each subtest item had a reliability coefficient ranging from 0.80 to 0.96.

Results

Raw Scores and Motor Quotient Scores

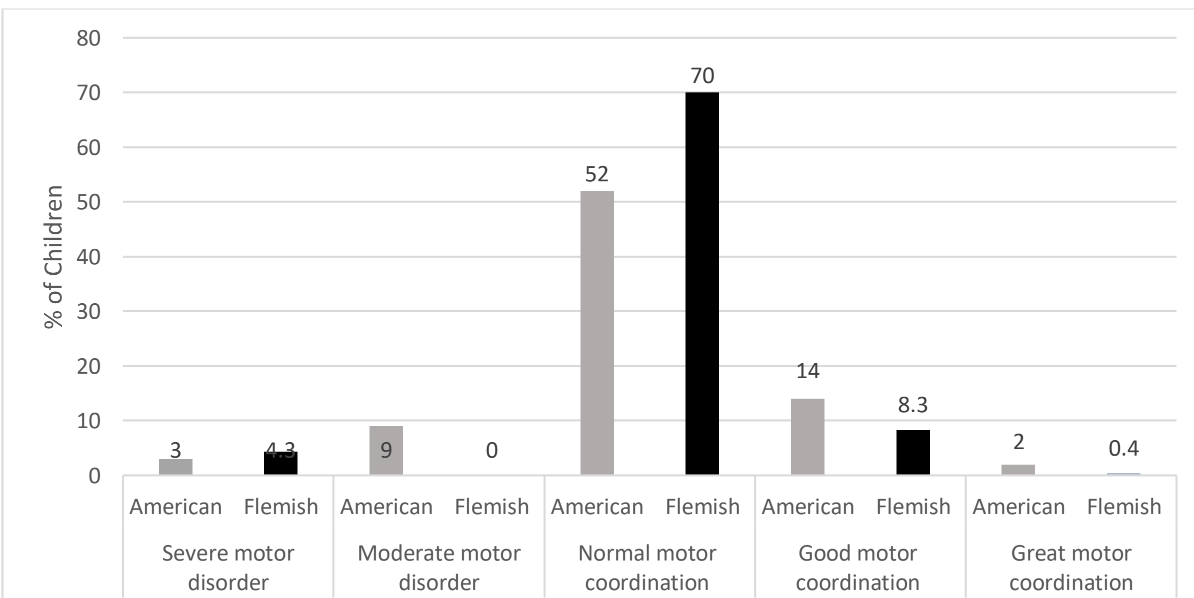
The children in this study were scored on the four KTK subtests using the scoring protocol established in Phase 1 of this study. These scores were needed to determine the adaptability of the scoring protocol from use in other countries to the U.S. The U.S. research team revealed they were able to produce measurable raw scores from each KTK subtest. The raw scores were then converted to KTK motor quotient scores to determine each child's motor coordination ability (see in Table 3). Descriptive statistics were used to determine the means and standard deviations for the total sample by age and sex which can be seen in Table 4.

Motor Coordination Performance Levels

The Motor Quotients for the entire sample in Table 3 revealed 15% of the American 8, 9 and 10-year-old children presented with motor problems (severe and moderate) according to the MQ values, 65% of the total sample presented with normal gross motor coordination ability, and 20% of total sample presented with good to great gross motor coordination according to the manual. The Flemish 8, 9 and 10-year-old children reported similar trends with 21% of their total sample identifying as having severe or moderate motor problems, 70.2% of their total sample presented as having normal motor coordination ability, and 8.7% of their total sample presented with good to great motor coordination.

Figure 1

American and Flemish Motor Coordination Levels Determined by the KTK



American/Flemish MQ Similar Trends

Means and standard deviations of American and Flemish children's total MQ values for each of the four KTK subtests are reported in Tables 4 and 5 below by age and sex. Similar trends can be seen across each of the subtests. The scoring was similar by sex and age for the majority of subtests. For example, the nine-year-old and ten-year-old American and Flemish groups had similar trends of females performing better than the males on the WB subtest and males performing better than females on the LJ subtest. The two subtests that had a little more fluctuation between the two groups were SH and SS and mainly with the eight-year-olds. There was not enough fluctuation for any of the subtest scores to warrant any scoring concerns with the U.S. population.

Table 3

American MQ Values by Age and Sex

American Participants Motor Quotient Values												
	8-year-olds M (SD)				9-year-olds M (SD)				10-year-olds M (SD)			
	N	Male	N	Female	N	Male	N	Female	N	Male	N	Female
WB	13	100.5 ± 13.42	12	99.92 ± 16.23	10	86.8 ± 14.29	10	89.6 ± 15.25	19	91.2 ± 19.35	18	94.83 ± 12.55
SH	13	104.1 ± 15.04	12	114.7 ± 17.08	10	99.8 ± 18.56	10	100 ± 12.77	19	105.15 ± 15.56	18	105.5 ± 10.14
SS	13	88.5 ±14.11	12	95.23 ±12.94	10	87.3 ± 13.58	10	95.2 ± 18.82	19	97.26 ± 20.78	18	77.83 ± 9.79
LJ	13	115.4 ± 17.43	12	118.69 ± 17.71	10	117.7 ± 17.7	10	101.5 ± 24.79	19	125 ± 17.1	18	95.7 ± 12.9
Total by Gender	13	102.1 ± 15.0	12	107.13 ± 15.99	10	97.90 ± 16.03	10	96.57 ± 17.91	19	104.65 ± 18.19	18	93.46 ± 11.34
Total Combined	25	104.62 ± 15.49			20	97.23 ± 16.97			35	99.05 ± 14.76		

Table 4

Flemish MQ Values by Age and Sex

Flemish Participants Motor Quotient Values												
	8-year-olds				9-year-olds				10-year-olds			
	N	Male	N	Female	N	Male	N	Female	N	Male	N	Female
	238	87.95 ± 15.17	248	91.49 ± 13.71	279	88.7 ± 13.73	266	91.6 ± 14.65	147	89.67 ± 13.40	212	91.93 ± 13.14
	238	105.1 ± 12.78	248	105.82 ± 14.14	279	105.24 ± 11.57	266	97.99 ± 13.28	147	104.49 ± 11.91	212	94.37 ± 13.77
	238	93.01 ±14.35	248	93.95 ±13.28	279	92.3 ±14.19	266	92.29 ± 13.21	147	88.48 ±11.99	212	88.52 ±13.34
	238	105.6 ± 14.39	248	105.61 ± 12.81	279	108.62 ±12.11	266	94.72 ± 15.79	147	103.48 ±13.06	212	93.12 ±13.95
	238	97.19 ± 14.83	248	98.56 ± 13.87	279	98.22 ± 13.08	266	92.34.3 ± 14.91	147	95.36 ± 12.55	212	89.50 ± 13.60
	486	97.87 ± 14.37			545	95.21 ± 14.34			359	92.96 ± 13.29		

Phase 2 Discussion

Phase 2 purpose was to determine the adaptability of the scoring protocol from use in other countries to the U.S. This study's research team demonstrated they could score each KTK subtest. These individual scores were then able to produce measurable raw scores that could be converted to KTK motor quotient scores to determine their children's motor coordination abilities. This research team followed the scoring protocol established in Phase 1 to produce these results, indicating that the scoring protocol is adaptable to use in a U.S. physical education setting.

The KTK also connects the child's cognitive abilities to their motor abilities. The motor coordination abilities of the U.S. children revealed that even when the schools provided 45 minutes of recess daily and daily physical education classes, 15% of these children presented with severe and moderate motor coordination abilities. On average, the additional opportunities for physical activity throughout their school day are more than most children receive in most school districts in the U.S. Because recess has diminished from U.S. schools for the past ten years, some of the subtest scoring differences may be because of the lack of movement and increased sedentary behaviors. The KTK was shown to be highly effective in identifying children's motor ability differences. These results allow researchers and physical educators to examine a child's motor strengths and weaknesses as the child focuses on tasks, they find fun and engaging instead of arduous.

The final step for these results was to examine similar trends between the U.S. children and the Flemish children by following the protocol provided in the implementation section in Phase 1, utilizing the scoring instructions for each subtest, and using the replicated subtest equipment with our American children in a physical education setting. The trends were very similar for the most part. Further investigation would be interesting to determine why differences might occur between children from different countries. The differences could be caused by the amount of movement each group receives daily or how much class time is spent on performing these movements. However, similar trend analyses did reveal that the scoring protocol was adaptable to use in a U.S. physical education setting because we could generate raw scores by following the implementation criteria. Once the raw scores were generated, the MQ values were able to be determined and ability levels were identified based on the KTK standardized norms. Establishing an assessment tool of this caliber in the U.S. will not only identify dynamic postural balance weaknesses and strengths through motor competence deficiencies, but it could also aid physical education teachers in the process of reducing the child injury rates due to falling. This type of motor identification could benefit physical educators in their curriculum development process to target specific skills needed for each grade level depending on their class performance and aid in motor coordination support for atypically developing children.

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Limitations

One limitation is the manual needed to be translated from Dutch to English so some of the elements might have been misinterpreted for the standardized procedures necessary to administer the assessment. We have not developed a standardized procedure for the KTK assessment. Therefore, the structure of how the assessment can be administered could change in future studies to fit the demands of a physical education classroom.

Chapter 3: Assessing the Fidelity of Physical Educator's Ability to Administer the *Körperkoordinationstest fur Kinder* (KTK) in a U.S. Physical Education Setting: A Pilot Study

Daryl M. Campbell-Pierre, Deborah J Rhea

Abstract

The *Körperkoordinationstest fur Kinder* (KTK, Kiphard & Schilling, 1974; 2007) is a standardized, norm-referenced measure used in school settings of many other countries, but not the U.S. to evaluate motor coordination (MC) of 5-to-14-year-old children. Recess (unstructured, outdoor play) may be an essential element to produce MC in children. The first aim was to validate the KTK through use of a Fidelity Checklist in two very different elementary school settings. The fidelity checklist assessed subtest equipment set-up, subtest administration, and scoring each subtest. The second aim was to gather preliminary data to assess MC ability of 10-year-old children (N= 60 School 1 N= 32; School 2 N=28) from the two schools. The preliminary findings using the fidelity checklist showed the KTK was a valid and reliable assessment to use in physical education settings. Additionally, preliminary results determined school differences played a role in 10-year-old children's MC abilities from the KTK motor quotient scores. School 1 had fewer MC deficits than school 2. School 1 scored 22% in the great MC category, whereas School 2 children scored none. In conclusion, this pilot study shows promise for the KTK assessment to be used in a more extensive U.S. study to determine motor coordination in elementary aged children.

Keywords: Physical education, Postural balance, Children, KTK, Sedentary, Assessment, Coordination

Introduction

For the past ten years, falls have been the leading cause of non-fatal injuries for those under 15 years old (CDC, 2019). It has been reported that approximately 2.2 million children a year under 15 are admitted and treated at the hospital emergency rooms due to injuries from an unintentional fall (WHO, 2022). Furthermore, these unintentional falls can cause complex injuries such as traumatic brain injuries, spinal cord injuries, and fractures in the lower extremities, which can exacerbate future fall injuries (Blosser & DePompei, 2019). Although each unintentional fall is complex and has its own etiology of how the fall occurred, the main reason why most children fall is due to deficiencies in their static and dynamic balance capabilities (Barnett et al., 2016). Having adequate static and dynamic ability allows children the motor competence to achieve basic postural balance (Campbell et al., 2022). Overall, postural balance is the most critical factor in mastering movement skill stability to overcome fall related injuries (Shim et al., 2019).

The rise in sedentary behaviors and limited physical activity (PA) opportunities are the main factors contributing to minimal movement experiences and increased non-fatal fall injuries in children today (Gilbert et al., 2021). Sedentary behaviors are at an all-time high in schools typically ranging from 5 to 7 hours daily because of testing pressures to spend at least five hours daily on classroom content required minutes (Bai et al., 2016; Rhea, 2022). This means most U.S. children are developmentally deprived of daily physical activity and recess (unstructured, outdoor play) in schools, which is vital for a strong brain-body connection. Children learn to move kinesthetically which means they can perceive the movement of a limb and its direction while engaging in single or combined motor tasks like walking, running, jumping, dodging, and climbing (Dankiw et al., 2020). Kinesthesis is developed best and most consistently through unstructured, outdoor play which is so vital to motor activities that test their physical limits

(Tsuda et al., 2020). These skills are foundational for proper fall development and injury prevention (Dankiw et al.,2020; Lee et al., 2020).

Offering school recess has historically improved children's health through increased physical activity levels (Parrish et al.,2020). However, the decline of school recess over the past few years has prevented children from reaching the recommended 60 minutes of physical activity needed daily (CDC, 2022). According to the national summary of physical activity over the previous decade, only 24% of children between the ages of 6-11 participate in 60 minutes of physical activity daily (CDC, 2022). Interventions have focused on creative ways to introduce physical activity back into school days, i.e., before or after school programs and lunch recess (Lee et al., 2020). These interventions are usually more centered on physical activity, though, instead of all facets of the child.

A well-established school-based intervention called LiiNK (Let's inspire innovation 'N Kids), implements multiple 15-minute unstructured, outdoor recess breaks and a 15-minute character lesson daily to develop the whole child, ultimately improving academic outcomes. This intervention is different than most because it is daily, starts with kindergarten and first grade children and follows them through at least 5th grade. The LiiNK project has shown longitudinal social/emotional developmental improvements with empathy (Rhea & Rivchun, 2018), happiness (Maler & Rhea, 2017), and stress and anxiety (Kirby, 2022; Ordonez, 2020). Cognitive benefits have been shown with improved on-task behaviors (Rhea et al., 2018) and attentional focus (Lund et al., 2017). Lastly, LiiNK has shown multiple physical health benefits in children such as decreased body fat levels (Farbo et al., 2020; Farbo & Rhea, 2021) and improved physical activity and fitness levels (Blackburn & Rhea, 2022; Farbo & Rhea, 2022; Williams et al., 2021) by providing recess breaks throughout the day. Introducing this school-based intervention has given children opportunities to explore more advanced motor movements as other studies have demonstrated (Dankiw et al., 2020), but until now have not been assessed for motor coordination abilities. One step LiiNK researchers have already taken is to identify a gross motor assessment tool that determines motor coordination abilities related to postural balance in elementary school children (Campbell-Pierre & Rhea, 2023). Limited assessment tools exist that measure these abilities in typically and atypically developing children.

The *Körperkoordinationstest fur Kinder* (KTK; Kiphard & Schilling, 1974; 2007) from Germany, is one of the few valid assessment tools available for identifying gross motor coordination deficiencies related to postural balance in children between the ages of 5-14 years (Giuriato et al., 2021). The KTK has been used extensively in other countries other than the U.S. like England, Germany, Brazil, and Finland (Giuriato et al., 2021). Researchers from these countries have repeatedly found the tool to have construct validity, internal consistency, and intra-rater reliability when integrated into different physical education settings to determine a child's kinesthesis, postural balance, and motor coordination related to gross motor aspects (Bardid et al., 2015; Ceyhan & Sogut, 2021; Vandorpe et al., 2011). The KTK involves four different subtests including walking backwards on a balance beam (WB), single leg hop (SH), sideways step (SS), and lateral jump (LJ). Quite a few studies have examined many differences in elementary aged children using these KTK subtests including sex and age (Bertapelli et al., 2020; Laukkanen et al., 2020; Pienaar et al., 2022).

These studies have found 5–14-year-old males typically perform better than same age females on the single leg hop (SH), lateral jump (LJ) and sideways step (SS) subtests (Giuriato et al., 2021), whereas females typically perform better than males on the walking backwards (WB) subtest (Moreira et al., 2019; Vandorpe et al., 2011). Additionally, when examining motor quotient scores to assess children's motor coordination abilities, children improve as they age (Bardid et al., 2015; Dirik & Sogut, 2021; Freitas et al., 2015). Again, since the KTK has not been used in the U.S., but the results demonstrate this is a quality assessment tool for postural balance and gross motor coordination, a study was completed recently in the U.S. and deemed to be feasible to use in physical education settings with 8-10-year-old children (Campbell-Pierre & Rhea, 2023). This was accomplished through 1) interpreting the German scoring protocol and procedures into the English language; 2) determining the time to assess each skill in a U.S. physical education setting and 3) determining equipment availability and cost to run the four KTK subtests. Due to this battery of tests only being used to test feasibility in the U.S., psychometrics and fidelity needed to be established next (Iivonen et al., 2015).

Therefore, the aims of this pilot study were: 1) To determine the fidelity of the KTK through subtest set-up, subtest administration, and scoring each subtest and 2) To gather preliminary motor competence data comparing two different schools administering the KTK assessment.

Aim 1 Methods

Physical Educator Profile

For this pilot study, four physical educators from two elementary schools were trained to set up the equipment, identify the skills needed to do the tasks and score the children with fidelity when implementing the tasks. Both schools were in the North Texas area. School 1 was a private school with three 15-minute unstructured, outdoor recess breaks daily, physical education 45-minutes daily, and no free and reduced lunch. School 2 was a public school with two 15-minute unstructured outdoor recess breaks daily, physical education 50 minutes twice a week. Each school had one male and one female physical educator per class. All four teachers had at least five years of experience teaching physical education in an elementary setting and had previously administered other assessments yearly in their physical education classes.

Children Demographics Performing the KTK Assessments

A convenience sample of 60 10-year-old boys and girls, (5^{th} grade), had parent consent and assented to complete the KTK assessments during a scheduled physical education class. The inclusion criteria was full use of their whole body to complete each KTK subtest. The exclusion criteria were injuries preventing a child from executing a required body movement or a child's verbal refusal to participate at any time during the data collection process. Each child who met the inclusion criteria above was evaluated on all four KTK subtests. Fourteen children did not complete one or more subtests because of injury or refusal to participate, therefore were removed from the sample for the final total of 60. Table 1 provides the number and percentage of children involved in the KTK analyses by age and sex.

Table 1

Participants by Group and Sex

	School 1	**School 2**
Male	19 (59.5%)	18 (64.5%)
Female	13 (40.5%)	10 (35.5%)

Measures

Körperkoordinationstest fur Kinder (KTK; Kiphard & Schilling, 1974; 2007)

This assessment tool has shown acceptable construct validity using intercorrelations between the four subtests which varied from 0.60 (WB/LJ) to 0.81 (SH/SS) and a test-retest reliability score of 0.97 on the KTK in countries outside of the U.S. (Moreira et al., 2019; Vandorpe et al., 2011). Each subtest item reflected intra-rater reliability as well (WB: 0.80; SH: 0.96; SS: 0.84 and LJ: 0.95) (Giuriato et al., 2021). The four KTK subtest descriptions are listed below.

Subtest 1: Walking Backwards on Balance Beam (WB)

The WB subtest measures balance, rhythm, and strength. All three of these physical skill components determine the child's ability to move vertically and maintain postural stability while walking backwards on three different widths of balance beams (6.0 cm, 4.5 cm & 3.0 cm widths, 5cm height). A child is given three attempts to reach a maximum of 24 steps per balance beam (8 per attempt), which equates to 72 maximum steps (24 x 3 balance beam steps) for this subtest.

Subtest 2: Lateral Jump (LJ)

The LJ subtest measures speed, laterality, rhythm, and agility. All four of these physical components determine the child's ability to move laterally and maintain postural stability. A child jumps laterally as many times as possible over a wooden obstacle (25 x 25 x 5.7 cm) for 15 seconds. Two attempts are required. The number of jumps over two attempts is summed for the total score.

Subtest 3: Sideways Step (SS)

The SS subtest measures speed, laterality, rhythm, and balance. All four of these components will determine the child's ability to move laterally and maintain postural stability. This subtest assesses how well children move sideways on a wooden platform (25 x 25 x 5.7 cm) using a repetitive crossover motion for 20 seconds The child transfers one of the plates to the other side of the plate they are standing on, steps onto the next plate, and repeats this process to accumulate as many transfers as possible in the 20 second time limit. A plate transfer counts for 1 pt and stepping onto the next plate counts for 1 pt. The total points are counted from each plate transfer and step onto the next plate, then summed from two attempts for the total score.

Subtest 4: Single Leg Hop (SH)

The SH subtest measures balance, strength, and rhythm. All three of these physical skill components determine the child's ability to move vertically and maintain postural stability while performing a single leg hop over a foam obstacle (60cm x 20cm x 5cm) with an increasing height of 5 cm per successful hop through 60 cm. Each leg is assessed separately with the same procedures. The children are given three attempts to perform a successful hop over each foam obstacle. A score will be given to reflect the number of attempts it took the child to complete a successful jump per leg (1st attempt = 3 pts, 2nd attempt= 2 pts, and 3rd attempt = 1 pt.). A maximum of 36 points per leg can be achieved if they are successful at hopping over each obstacle height in the first attempt. The total points from each leg are added together for a range of 36-72 points depending on how many attempts it takes to complete the task.

KTK Scoresheet

The KTK scoresheet was transcribed into English from the original KTK standardized handbook (Kiphard & Schilling, 1974; 2007). The score sheet is replicable and easy to document. A sample can be seen below in Figure 1.

Figure 1

Scoresheet Sample

KTK Score Sheet

Name: ______________________ Gender: ___________________

Grade: ______________________ School: ____________________

DOB: _______________________

Balance Beams (WB)

- Calculate the backward step the participant takes.
- The first step from the platform does not count towards the total number of reps. This is known as the plantar step so participant can find balance before walking backwards on the balance beam.
- The number of steps is counted until the bar has been walked end to end or 8 steps have been reached. If the bar is cleared in less than 8 steps, the score is 8.
- Add up all the scores from all three attempts.

Total

Fidelity Checklist

The Fidelity Checklist was created for this study to validate and monitor the evaluation process of all four KTK subtests consistently across teachers and schools. The fidelity checklist consists of 72 total items divided into three key categories: Subtest Set-Up (8 items), Subtest Administration (22 items), and Subtest Scoring (43 items). The setup category listed all equipment materials needed and how they should be set up to ensure safety and accuracy during the evaluation process. Table 2 shows the WB subtest setup requirements as an example of how all four subtests were set up.

Table 2

WB Set Up Section

	Yes	No
1. Does the WB subtest have all the equipment needed to administer the assessment? • Yellow Balance Beam • Red Balance Beam • Green Balance Beam • Balance Beam Platforms (1 per balance beam) • Clip Board • Pen or Pencil		
2. Is the subtest set up correctly for evaluation? • Balance Beam must be set up from largest width to smallest width. • Set up each balance beam at least 3 feet away from the next balance beam. Ex. Yellow balance Beam (6.0 cm) 3 ft away from Red Balance Beam (4.5 cm) then another 3 ft away from Green Balance Beam (3.0)		

The subtest administration section focuses on how well the teacher administers each subtest following the scoring guidelines. Table 3 shows the WB subtest administration section requirements as an example of the administration process used for each subtest.

Table 3

WB Subtest Administration Section

	Yes	No
(1) Did the evaluator provide a clear space of at least 3ft for the child to move appropriately before beginning the evaluation of this subtest?		
(2) Were the non-active students standing in a single file line at least 4 ft away from the evaluation area so the active participant is not distracted during the evaluation of this subtest?		
(3) Did each student get a chance to participate in the balance beam subtest in the same order each time?		
(4) Did each student start at the opposite end of where the wooden plank was located so they could have a chance to walk up the balance beam forward before participating in the backwards steps?		
(5) Did each student hand off their score sheet to the evaluator when it was their turn to do the subtest?		
(6) Were the students told the instructions prior to beginning the subtest?		

The subtest scoring section focuses on how well the teacher executes the scoring of the subtests to produce a valid raw score for overall performance. Table 4 shows the WB subtest section requirements as an example of the four subtests.

Table 4

WB Scoring Section

	Yes	No
(1) Did each child begin with the yellow balance beam (The widest at 6.0 cm)?		
(2) Did the child reset at the wooden plank if they fell off the balance beam to begin the next attempt?		
(3) Did the Evaluator wait until the 2nd backward step to begin counting the 8 steps possible? i.e., "The first Step, "**plantar step**", is not supposed to count toward the child's total maximum backward steps		
(4) Did the evaluator count the number of steps completed walking backwards (from 0 to a maximum 8) and record on the score sheet?		
(5) Did the child have 3 attempts on the yellow balance beam?		

(6) Did the child move to the red balance beam (4.5 cm) after completing the three trials at the yellow beam? And then move to the green balance beam (3.0 cm) after completing the three trials at the red balance beam. *Steps 1-5 presented above should be repeated for each balance beam (yellow, red, and green) during the administration of this subtest.		

Procedures

The University Institutional Review Board (IRB) approval was granted, each physical educator and parent consented to this study, and each child assented to the tasks during the physical education class. Once approvals and parent consent were in place, a KTK adherence training was scheduled at both schools to address the KTK implementation in each physical education class. The training addressed each required objective from each of the subtest sections. This training took approximately 90 minutes at each school. During the training, physical educators were required to move through all fidelity checklist steps with the researcher. This included setting up the equipment, administering the subtests, and scoring the subtests. Once the physical educators demonstrated they could perform each part successfully, dates were scheduled for each school to implement the subtests in their 5th grade classes. The fidelity checklist was left with each educator for review prior to assessing the children.

On the assessment day, the primary researcher arrived 30 minutes ahead of the class start time to do the fidelity check on the equipment set up in the gym. Next, the fidelity checklist was used to determine if subtest directions were done correctly, and the scoring rubric was followed correctly. If at any point, the teacher omitted a directive or step in the process, the researcher would stop the teacher, have them correct the issue, and re-evaluate the child.

The two physical educators at each school began their class with instructions for KTK participation, followed by a brief demonstration of each subtest. Then the class was split in half, approximately 14-16 children in each group, and dispersed to their assigned subtest station. The teacher then gave each child a pencil and a score sheet attached to a clipboard to complete the demographic section. Once completed, the physical educator had the children line up in a single file line and maintain possession of their clipboard/scoresheet until called to participate. Once each child completed a task, the next child would be called up, hand their scoresheet to the evaluator, and perform the task. The evaluator administered the subtest, recorded their scores, handed the score sheet back to the child to return to the end of the line. Once the two groups completed the subtest, the groups swapped and worked to complete the other subtest. At the end of each class, the evaluators would mark where they were with the subtest if not completed, instruct the children to return their score sheets to the evaluator, and prepare to leave for their next class. It took three 45-minute class periods at both schools to complete all four subtests.

Results

Subtest Set-Up Section

The results revealed the physical education teachers at both schools scored 100% on the fidelity checklist for setting up each of the four KTK subtests. Each subtest included two setup items for a total of eight items in that section. Equipment for each subtest was accounted for during the evaluation process and set up correctly in the gym with the proper amount of space between each subset station.

Subtest Administration Section

The results from the administration of each subtest revealed that both schools scored 95% accuracy on the fidelity checklist. The WB Subtest has six items, LJ has five items, SS has five items, and SH has six items resulting in 22 total items. All physical educators scored 21/22 items correctly in the subtest administration section. The item missed by all was #4 in the SH subtest section. This item requires the child to start behind the mat, hop onto the mat and then over the foam pad with the same foot all the way through. The physical educators were allowing the children to approach in different ways. The researcher corrected each evaluator and had them start again so the scoring was not impacted.

Subtest Scoring Section

The number of subtest fidelity items varied: the WB subtest had 15 items, LJ had six items, SS had eight items, and SH had 14 items resulting in 43 total items. School 1 physical educators scored 42/43 items (97%) accurately across the four subtests. School 2 physical educators scored 41/43 items (95%) accurately for the four subtests. Item #3 from the WB subtest section was missed by all four PE teachers. This item required the first backward step called the plantar step to be a practice step which they tried to count. School 2 physical educators also missed item #5 on the SS subtest section. This item required physical educators to give a 10 second break between the two SS attempts. For both errors, the researcher corrected each evaluator and had them start again so the scoring was not impacted.

Reliability

Reliability was calculated to assure the scoring of the subtests was reliable. The findings showed similar sufficiently reliable coefficients as the other countries (WB:0.80; MS: 0.84; HH:0.96; JS:0.95) (Giuriato et al., 2021). The reliability coefficients of the four subtests for this study were WB: 0.88; SH: 0.93; SS: 0.96; and LJ: 0.94.

Discussion Aim 1- Fidelity

In order to determine if the physical educators could administer the KTK in a U.S. physical education setting, the fidelity checklist was used to assess the physical educator's ability to set up the subtest, administer the subtest, and score the KTK subtests accurately to produce measurable KTK outcomes. Overall, the fidelity checklist showed the KTK can be used in the U.S. with accuracy.

The physical educators at both schools consistently set up the equipment at each subtest correctly prior to administration. The physical educators were also able to follow the protocol and procedures to administer the KTK subtests during their scheduled P.E. classes, with both schools scoring 95% accuracy on the fidelity checklist. Lastly, the physical educators demonstrated they could score each subtest correctly, with each school scoring 95-97% accuracy on the fidelity checklist.

However, the three errors made with either administration or scoring steps need to be addressed for KTK use in the future since they will impact the execution and scoring if not performed accurately. One recommendation, across all subtests, but especially for the SH subtest, is to practice the fidelity steps 2-3 times during the training session before evaluating the subtest with the children. Each teacher only practiced one time and it was assumed they would be ready. Adding subtest demonstration videos could give a much stronger visual for each evaluator and help with the three details missed as well. Finally, adding some prompting cues to the fidelity checklist to assist evaluators during the evaluation period would promote accuracy. For example, adding a note at the bottom of the score sheet of each fidelity checklist subtest giving scoring tips to reference quickly on the day of evaluation may help (Figure 1). Since this was a pilot study, assessing U.S. physical educators again with the fidelity checklist after including the improved training steps should create a highly accurate assessment tool.

The physical educators were able to show reliability comparable to KTK study results from outside the U.S. on the SH and LJ subtests (Giuriato et al., 2021). This study's results showed higher reliability on the WB and SS subtests. Those findings are a credit to the recently published protocol and procedures (Campbell-Pierre & Rhea, 2023), the newly developed fidelity checklist, training prior to the KTK, and maybe even the physical educator prior experiences assessing children in their physical education settings.

A recommendation for future researchers, based on previous researchers' time constraints using the KTK, is to use at least two sets of KTK equipment, especially for the SH and WB subtests. The evaluators in this study used two sets for each of these subtests with no incidence. They not only found the time per student was cut in half, but the children had much less downtime between attempts. Finally, the ease and adaptability of the KTK to U.S. physical education settings is very important. The physical educators stated on numerous occasions that the setup, administration, and scoring were very manageable and easy to assess. This goes a long way for teacher use over time.

Aim 2 – Preliminary Motor Competence Data

Procedures

The second aim of this study was to gather preliminary motor competence data of two different schools administering the KTK assessment. The KTK subtest raw scores were converted into four individual motor quotient (MQ) values by using a German derived conversion table used in the U.S. feasibility study and with the original KTK assessment (Campbell-Pierre & Rhea, 2023; Kiphard & Schilling, 1974; 2007). The four MQ values were summed to produce a total MQ score according to the child's age and sex. Once a total MQ score was established, a child's motor coordination abilities ranging from severe to great were determined. In order for the motor coordination ability scores to be accurate, physical educators had to perform the fidelity checklist protocol and procedures accurately which was shown in aim 1 of this study.

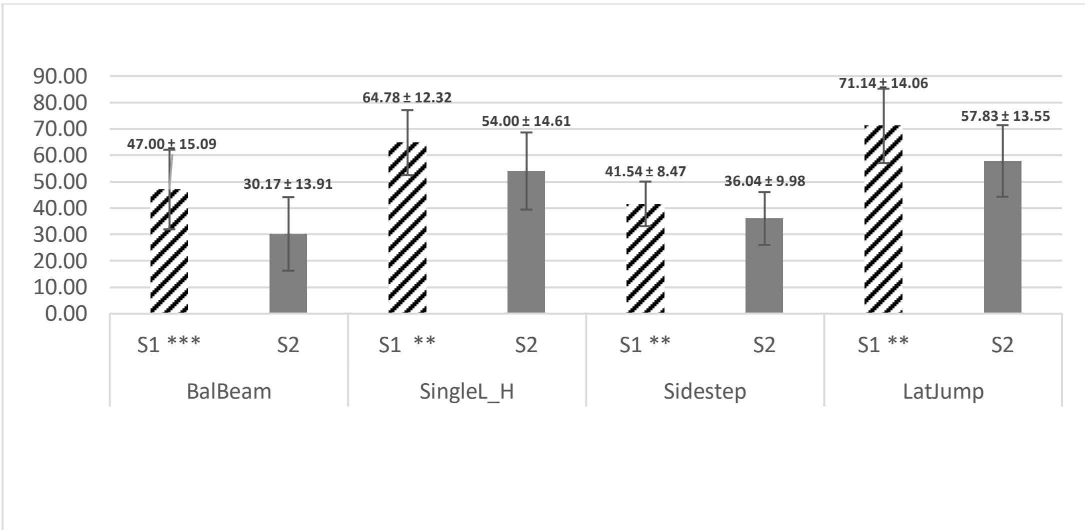
Results

School Descriptives

The means and standard deviations for the four KTK subtests are shown by School 1 and School 2 below in Figure 2. According to Figure 2, there are a few differences between the two schools' KTK performance.

Figure 2

KTK Subtests Means and Standard Deviations by School



***= p<.001, **=p<.01; Cohen's D: WB (.969) SH (.386) SS (.967) and LJ (1.38)
Note. S1=School 1; S2=School 2.

Multivariate Analysis of Variance (MANOVA)

A MANOVA was performed to determine motor quotient score differences on the four KTK subtests between the two schools while controlling for sex. All MANOVA assumptions were met including normality, homogeneity, linearity, and no outliers. The MANOVA revealed school differences on the KTK subtest scores, Wilks Lambda= F (4,53) =6.303, p<.0001. There were no interaction effects in this model, indicating there were no sex differences by group. Follow up pairwise comparisons were then calculated to determine main effect differences.

School

The schools were statistically significant on all four KTK subtests: Balance Beam (WB), F (1,5) =18.02, p<.0001, η^2 =.243, Single Leg Hop (SH) F (1,56) = 10.42, p=.002, η^2 =.157, Lateral Jump (LJ), F (1, 56) = 16.95, p<.0001, η^2 =.232 and Sideways Step (SS) F (1,56)=7.42, p=.009, η^2 =.117. School 1 children scored significantly higher than School 2 children on all four subtests. On average, School 1 children scored 17 more steps backwards on the WB subtest, 10 more points on right and left legs with the SH subtest, 14 more jumps laterally than School 2 children on the LJ subtest, and five more sideways steps than School 2 children on the SS subtest. Figure 2 shows the significant differences of the four KTK subtests by school.

Sex Differences

The means and standard deviations for the 10-year-old children by sex can be seen in Table 5 below. The pairwise comparisons revealed the males, in general, performed significantly better than the females on Lateral Jumping (LJ) $F(1, 56) = 16.95$, $p<.0001$ and Sideways Stepping (SS) subtests $F(1, 56) = 7.416$, $p=.009$. On average, males were faster, scoring 12 more lateral jumps on the LJ subtest and eight more sideways steps on the SS subtest than the females. No other significant differences were found by sex.

Table 5

Subtest Means and Standard Deviations by Sex

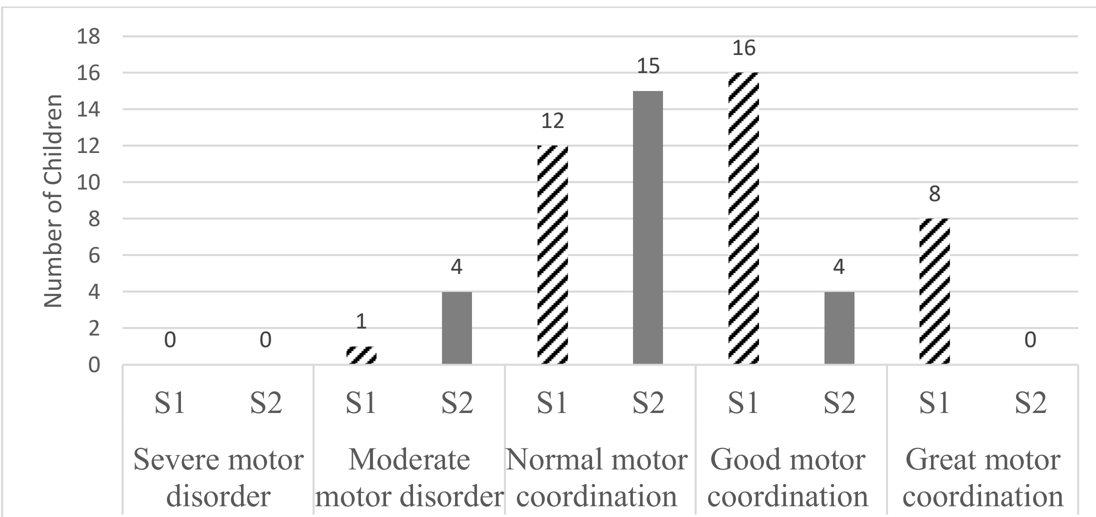
KTK Subtests	N	Male (*M* ±*SD*)	N	Female (*M* ±*SD*)
WB	32	37.48 ± 15.23	28	39.79 ± 13.94
SH	32	60.50 ± 15.41	28	57.78 ± 10.46
SS	32	42.66 ± 9.68	28	34.26 ± 6.36
LJ	32	69.94 ± 12.59	28	58.30 ± 12.45
Total by Sex	32	52.64 ± 13.22	28	47.53 ± 10.80
Total Combined	60	50.61 ± 13.25		

KTK Motor Coordination Ability levels

Based on the motor quotient scores, the KTK motor coordination ability levels for School 1 children in Figure 3 revealed 2% of the children, presented with moderate motor problems, 32% of the children presented with normal motor coordination ability, 43% of the children presented with good motor coordination ability, and 22% of the children presented with great motor coordination ability level. For School 2 children, 17% of the children were presented with moderate motor problems, 65% of the children presented with normal motor coordination ability, and 22% of the children presented with good motor coordination ability. School 2 did not have any children score in the great motor coordination ability level.

Figure 3

Motor Coordination Performance Levels between Schools



Discussion Aim 2 – Motor Coordination Abilities

This pilot study showed the MQ scores could determine each child's motor coordination ability levels similar to other country's results. As a first step, this helps physical educators identify children's motor coordination deficits and provide specific physical skill development to enhance postural balance and prevent awkward falls and injuries. Second, school differences had an impact on children's gross motor skills, postural balance, and fall skills. Preliminary results revealed School 1, a private school that participated in 45 minutes of physical education daily, and received at least 45 minutes of recess daily, seemed to allow children to build more confidence and control of their bodies vertically and laterally than School 2, a public school that participated in two 50-minute physical education classes weekly, and received 30 minutes of recess daily.

The impact these school differences had on the motor coordination results achieved was very interesting. The combination of the different school variables (School Type, P.E and recess opportunities daily) showed some telling ability differences. First, for School 1 to have 22% of the 10-year-olds score in the great motor ability level and School 2 10-year-olds have none at that level is astonishing. Second, for School 2 10-year-olds to have 15% more children reporting moderate motor disorders than School 1 is also astonishing. Other studies have reported a higher percentage of children in motor deficit categories (14%- 29%) and lower percentages scoring in the great ability level (3-14%) (Giuriato et al., 2021; Kiphard & Schilling, 1974; Moreira et al., 2019; Vandorpe et al, 2011). These studies did not account for the different school variables playing a role like race, physical education, and recess opportunities, which the children in School 1 naturally received to promote motor coordination and postural balance (Vandorpe et al., 2011).

Not surprising, both schools offered their children at least 30 minutes of unstructured play breaks daily and the majority (78%) scored between normal and good ability levels. Also, males scored better than females on three of the four subtests which is similar to many other studies (Giuriato et al., 2021; Moreira et al., 2019; Vandorpe et al., 2011. Surprisingly, U.S. females performed better than females from other countries revealing a possibility that more recess daily has a positive effect on lower extremity strength and balance (Giuriato et al., 2021). Based on previous studies, when children have age-appropriate motor coordination abilities, they can perform spontaneous movements during functional activities to prevent themselves from falling (Sullivan, 2020). School 1 provided their children with additional PA opportunities through their school day showing the overall range of healthy motor abilities was boosted by another 10%. These extra PA opportunities exposed to School 1 children allowed them to have an extra 75 minutes of recess and an extra 75 minutes of physical education classes weekly which equates to an extra 5400 minutes of PA over a school year. PA has been known to provide many gross motor skill repetitions in a natural setting, which may contribute to why School 1 scored so much better than School 2.

Although School 1's children outperformed School 2 children on the KTK subtests, neither recess group had any children with severe motor coordination ability scores, which is the lowest level of motor abilities determined by the KTK. Other studies have shown at least 21% present in this category when assessing typical and atypical children (Vandorpe et al. 2011). When a child presents with severe motor abilities, research has shown a strong correlation with cognitive or intellectual disabilities preventing the child from performing motor movements (Hasegawa et al., 2020). Since none of the children in either school presented with severe motor deficits, one would assume none were severely cognitively or intellectually disabled. This would warrant additional information from a licensed professional to determine the severity of the motor or cognitive delays which could be considered in future studies.

Further, both schools did provide PA opportunities that included physical education classes and at least 30 minutes of unstructured play breaks which is more than most children receive in many school districts in the U.S. presently. Hodges et al., 2022 stated that when children lack physical activity opportunities, it can hinder their movement and impact their cognitive abilities. Further investigation is needed to see exactly which school variable may play the larger role in children's MC abilities.

Limitations and Future Directions

This was a pilot study with a small sample size. Future studies need to further evaluate the fidelity of the KTK and different amounts of recess in U.S. physical education settings with a larger sample size. Also, this study only included 10-yr-old children. Broadening the age group to include elementary aged children (5-12) is recommended for future studies. Finally, we did not have anyone reporting in the severe motor coordination deficit category. We do not know if this is because there were no children who had cognitive or intellectual disabilities or if the PA opportunities enhanced skills for children with disabilities as well. Future studies should include those known to have cognitive or intellectual disabilities as well. The children in this study were instructed to take off their shoes but could keep their socks on or be barefoot to participate in the KTK evaluation depending on the surfaces. This was due to slippery floors at some locations, but since the only requirement was that children did the subtests without shoes, this did create inconsistencies with surface texture. This could have had an impact on the results, so a more consistent instruction around socks on or off should be identified in the future.

Conclusions

In conclusion, this pilot study shows promise for the KTK assessment to be used in a larger U.S. study to determine motor coordination and postural balance abilities. The translated scoresheet, fidelity checklist, protocol, and procedures as developed and documented in this study reflect similar results to previous studies, as well as demonstrating similar reliability and validity (Giuriato et al., 2021). These preliminary findings suggest different school variables play a role in children's motor coordination abilities in U.S. 10-year-old children. Testing which variable has the biggest impact is the key to finding the missing piece for children who need to enhance their motor skills, postural balance, and falls in order to prevent future injuries.

Chapter 4: The Effects of a Year Long Recess Intervention on Elementary School Children's Motor Competence and Executive Function Abilities

Introduction

Motor competence (MC) is the degree of proficient performance in various motor skills and the underlying mechanisms such as motor coordination and postural balance (Coppens et al., 2021; Utesch & Bardid, 2019). It is well documented in the literature that MC has beneficial effects on children's general health (Cattuzzo et al., 2016; Robinson et al., 2015). MC is known to be positively associated with many health-related outcomes including physical activity (Britton et al., 2020), physical fitness (Utesch et al., 2019) and cognitive health (Hudson et al., 2021; Robinson et al., 2012; Willoughby et al., 2021). MC involves fundamental motor skill mastery, which is the foundation for more advanced motor skill development and executive function improvement (Cicero et al., 2021; Logan et al., 2018; Malambo et al., 2022).

Executive function (EF) is a set of mental skills referred to as a "family of top-down mental processes" needed when concentrating or paying attention (Malambo et al., 2022). These processes include inhibition, working memory, and cognitive flexibility (Diamond et al., 2013). Inhibition includes self-control (behavioral inhibition) and interference control (selective attention and cognitive inhibition); it refers to stopping an impulse and deliberately choosing a different response (Diamond et al., 2013; Nweze et al., 2020). Working memory refers to the process of mentally focusing on and manipulating information. It allows children to retain and process information over short periods (Diamond et al., 2013). Working memory is used to perform tasks such as calculating mental math problems, creating a step-by-step plan of action, and reading a story (Diamond, 2013). Inhibition coupled with working memory provide the foundation for the third subcategory: cognitive flexibility. Cognitive flexibility is the ability to maintain or change attention in response to a variety of demands or to apply different rules in a variety of situations (Oberer et al., 2018). The main applications of this category, which develop later than inhibition and working memory, are adjusting plans and changing perspectives (Diamond et al., 2013). These subcategories have key differences, but they are dependent on each other and weave together to construct behaviors that are particularly important in classroom learning (Nelson et al., 2017).

Piaget's Cognitive Development Theory and Executive Function Relationship.

Piaget's documented developmental stages show EF develops significantly during childhood. Before age three, research indicates that children have difficulty integrating cognitive, behavioral, and emotional skills; from age three to age seven, children switch from reactive behaviors to the higher processes of cognitive-behavioral self-regulation (Ahmed et al., 2019). This is not an automatic switch; children need adult models, opportunities, and support to grow and develop EFs as their brains mature. While genetics and socioeconomic status play a role in the development of EF, they can be "trained" or practiced in order to improve (Center on the Developing Child, 2017).

Physical activity (PA) acts as a cognitive stimulant, especially in children. There is "ample evidence that it increases blood flow, growth factors (e.g., brain-derived neurotrophic factors), brain activation, and induces neurogenesis, resulting in larger brain volumes or better connections between brain regions" **(**Grey et al., 2018, p. 268). PA is the driving force between MC and EF abilities as a result of children engaging in repetitive motor movements on the playground which provide the increased blood flow to the brain (Hillman et al., 2020a; Hultenn et al., 2020; Malambo et al., 2022). As a result, children's EF skills such as decision-making, memory, and attentional focus are enhanced (Fernandes et al., 2016). Therefore, repetitive movement is the key to achieving developmentally appropriate physical and cognitive skills, but sadly, sedentary behaviors have become a way of life for children and adults (Hesketh et al., 2017).

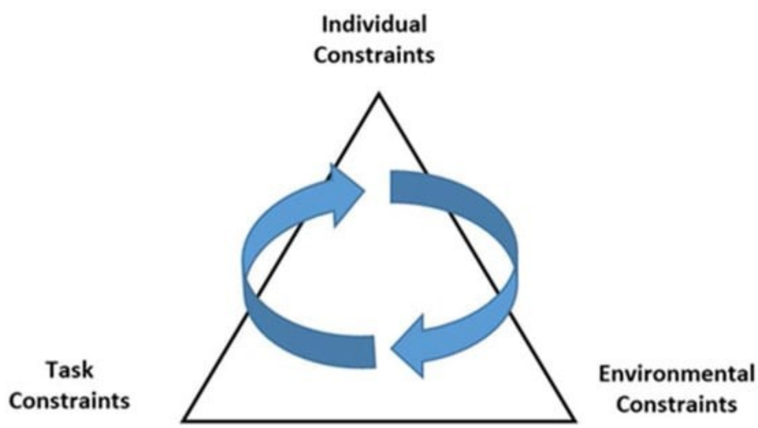
Sedentary behaviors in children, especially in school settings, have grown exponentially over the past decade (Rhea, 2022). The decline and sometimes removal of recess and physical education in elementary schools has been a major fault in reducing all aspects of a child’s health, especially the ability to practice motor skills in many situations (Farbo et al., 2020; Koorts et al., 2022; Yuksel et al., 2020). When children experience prolonged periods of idle time in the classroom, it begins to sacrifice opportunities for them to connect with different play environments and engage in interactive tasks to enhance MC abilities. Different theories have been developed and tested to explain how movement patterns emerge. Dynamic Systems Theory (DST) has been used quite often to compare those who have been more sedentary with those who move more (Panahi & Tremblay, 2018)

Dynamics Systems Theory

DST suggests that movement patterns ‘emerge’ naturally as a result of the complex interactions between three connected constraints (individual, environment, and tasks), as seen in Figure 1 (Colombo-Dougovito, 2016; Ismail, 2021; Ku, 2020; Sigmunsson et al., 2017). DST views children’s development as multilevel, interactive, and bidirectional which allows children to self-organize through different dynamic interactions to influence movement. DST promotes attractor states, which is the natural adaptation of a preferred movement pattern through repetitive tasks over time (Yamamoto et al., 2020). This adaptation occurs through actively exploring the environment and dynamic interactions between a child’s characteristics and context influences (McClelland et al., 2015). An example of this on a playground or at school recess is that the environment offers many movement opportunities children can engage in repetitively during a 15-minute period, providing ever-changing (dynamic) interactions such as a tag game on uneven play surfaces. As a result of the development of complex movement skills, EF is promoted through PA (Hillman et al.,2020b; Seifert et al., 2018). If children are given more opportunities to engage in PA, they will develop the MC needed to sustain postural balance to decrease the risk of injuries due to unintentional falls (Hill et al., 2019). Providing children with a school-based intervention that allows them to engage in more PA throughout the context of their school day could be beneficial to developing the child's MC and EF abilities.

Figure 1

A Diagram of the Interaction of the Three DST Constraints (Sigmunsson et al., 2017)



The LiiNK Intervention

The LiiNK (Let's inspire innovation in Kids) Project, a school-based recess and character development intervention, focuses on bridging the gap between the whole child and learning. Recess, defined as unstructured, outdoor play, is provided four times daily for 15-minutes each and a character curriculum called Positive Action is delivered as daily 15-minute lessons to emphasize healthy character behaviors, i.e., empathy, trust, respect, honesty, self-confidence, and self-esteem to connect the child positively with the playground environment and the classroom. Results over the past eight years have shown grades K-5 whole child improvements including on-task classroom behaviors (Rhea et al., 2018), moderate-vigorous physical activity (MVPA) (Farbo et al., 2020), cardiovascular endurance (Farbo et al., 2020), strength (Williams, 2021), healthy body fat percentage (Farbo et al., 2021), positive emotions (Clark & Rhea, 2017), happiness (Kirby, 2022), and attentional focus (Lund et al., 2017).

DST is a unique model that provides clarity of MC and EF development in a child when given PA and unstructured play opportunities. The LiiNK intervention, unknowingly, provides the dynamic interaction between the three DST constraints. The LiiNK intervention has provided children (individual) with an appropriate outdoor setting (environment) to engage in unstructured play opportunities (task) to enhance children's MC and EF abilities for years. However, the appropriate assessment tool has not been presented to evaluate the intervention impact. Therefore, the LiiNK researchers have recently focused their attention on finding an assessment tool that would assess gross motor coordination and postural balance (MC) in LiiNK children, since they have shown to be so much more active during recess than children with 30 minutes or less of recess (Farbo et al., 2020; Farbo & Rhea, 2022). The KTK, a German derived assessment, was identified as a strong tool to explore in the U.S. due to its ability to identify children with severe motor competence to those with great motor competence in physical education settings reliably and with validity (Guiatrio et al., 2021; Vandrope et al., 2011). Recently, the KTK was introduced in U.S. physical education classes and shown to be feasible, reliable, and valid which means it could be used to compare MC scores and ability levels of children with varying amounts of recess (Campbell-Pierre & Rhea, 2023a, 2023b). An extension of this outcome would be to evaluate if there is a relationship between MC and EF in these children.

Research Question 1: Are there MC differences on the KTK subtests between the intervention children (60 minutes of recess) and control school children (30 minutes or less of recess) daily?

H1: The intervention children will improve significantly more than the control children on KTK subtest MC scores over a school year.

H2 (Exploratory): The intervention children will demonstrate different profiles of MC abilities than the control school children. Operation definition of profile of MC abilities is the category of MC abilities ranging from severe to great determined by the KTK.

Research Question 2: Is there a relationship between MC change scores and EF processes?

H3: A negative relationship will be found between MC change scores and EF processes. A negative relationship is defined as EF reaction scores decreasing as MC scores improve to show EF reaction scores are reacting faster.

Methods

Study Design

A non-equivalent pretest-posttest design was used to determine the MC differences according to the KTK subtest between the three groups using the KTK subtest scores. Pretest data was collected in the early fall to establish a baseline between the three recess groups. Post-test data was collected in mid-spring of the same year with the same three groups of children. A Pearson product correlation was used to answer the second research question. An executive function assessment, referred to as listening effort, was assessed on one day (two time points) in the spring to determine the EF processes of inhibition and working memory in children. The KTK and listening effort results were used to determine the relationship between attentional resources (EF) using reaction time scores and MC change scores.

Participants

A convenience sample of 352 3rd, 4th and 5th grade boys and girls from six elementary schools located in North and South-Central Texas were selected to participate in this study. The two intervention schools had 60 minutes of recess daily, while two of the control schools had 30 minutes of recess daily and the other two controls schools had 20 minutes or less daily. Each child had their parent's consent and assented to complete the KTK assessments during a scheduled physical education class (Table 1). For the EF assessment, all children who had parent consent and assent for the KTK may not have given approval for this assessment. As a result, the number of children included for EF (Table 2), was significantly less than the number collected for the KTK (Table 1). Inclusion criteria were: (1) children had to receive either 60, 30 or 20 minutes of daily recess for a full school calendar year; (2) they had full use of their whole body and cognitive/language skills to complete each KTK subtest and EF assessment; and (3) they needed to complete the KTK subtests and the EF assessment in the fall and spring semesters. The exclusion criteria were injuries or cognitive issues preventing execution of KTK required body movements or brain processing, missing data from either time point when the KTK and EF assessments were administered, or a child's verbal refusal to participate at any time during the data collection process. Each child who met the inclusion criteria and did not meet any exclusion criteria were evaluated on all four KTK subtests and EF assessments. Eight children did not complete one or more subtests due to injury or refusal to participate and therefore were removed from the sample for the final total of 352. For the EF assessment, 15 children did not complete both same day EF sessions, one in the fall and one in the spring, so were removed from the sample for a final total of 132. Table 1 provides the number and percentage of children involved in the KTK analyses by group and grade. Table 2 provides the number and percentage of children involved in the EF assessment by group and grade.

Table 1

KTK Participants by Group and Grade (N=352)

	Intervention n=130	**Control 1 n=138**	**Control 2 n=84**
3rd	44 (12.5%)	49 (14.0%)	44 (12.5%)
4th	44 (12.5%)	46 (13.0 %)	40 (11.0 %)
5th	42 (12.2 %)	43 (12.3 %)	0 (0 %)

Note. Intervention = 60 recess minutes; Control 1 = 30 recess minutes; Control 2 = 20 recess minutes

Table 2

EF Participants by Group and Grade (N=131)

	Intervention n=18	**Control 1** n=56	**Control 2** n=57
3rd	5 (3.7%)	15 (11.3%)	30 (22.7%)
4th	3 (2.3%)	20 (15.2 %)	27 (20.4 %)
5th	10 (7.5 %)	21 (16.0 %)	0 (0 %)

Note. Intervention = 60 recess minutes; Control 1 = 30 recess minutes; Control 2 = 20 recess minutes

Measures

Gross Motor Competence Assessment: Körperkoordinationstest fur Kinder (KTK)

Gross motor competence was evaluated using the Körperkoordinationstest fur Kinder (KTK; Kiphard & Schilling, 1974; 2007) which consists of four subtests:

1. ***Balance Beam (WB):*** walking backwards on three different decreasing widths of balance beams (6.0 cm, 4.5 cm & 3.0 cm widths, 5cm height).
2. ***Lateral Jumping (LJ):*** jumping laterally over a wooden obstacle (25 x 25 x 5.7 cm) as fast as possible for 15 seconds.
3. ***Sideways Stepping (SS):*** laterally transferring wooden plates from one side of the body to the other while using motor coordination to move their body from one plate to the next as they lay each plate down. This process is repeated continually to accumulate as many transfers as possible for 20 seconds.
4. ***Single leg hop (SH):*** generating a single leg hop over a foam pad with an increasing height of 5 cm per successful hop to 12 pads stacked or 60 cm which is equivalent to 24 inches.

Executive Function Assessment: Listening Effort

EF was evaluated using the Memory for Digits subtest of the Comprehensive Test of Phonological Processing- Second Edition (Wagner et al.,2013). Dual-task paradigms have been used successfully by many researchers to measure listening effort, or the attention resources required to process and understand the speech signal (e.g., Downs, 1982; Hicks & Tharpe, 2002; Howard et al., 2010; Rakerd et al., 1996; Sarampolis et al., 2009). This task requires a listener to simultaneously complete two tasks: a primary task and a secondary task (Feerstein, 1992). The primary task, a listening and speech-processing task, demands the majority of a participant's attention resources. It measures a child's ability to repeat increasingly long strings of numbers accurately and has been validated for use with elementary aged children. The children are told accurately repeating numbers is the main task they should focus on, and the examiner will show the children their scores at the end of the task.

The secondary task, in this case, a reaction-time task, measures any remaining attention resources available to the participant. Thus, changes in secondary task performance are indicative of changes in attention resources (i.e., changes in listening effort). The children are asked to push an arrow key corresponding to a right or left facing arrow that appears on a laptop computer screen. Stimuli for the secondary task are designed and controlled by the E-Prime 2.0 software program (Psychology Software Tools, 2012). Arrows appear in a randomized order at pre-set, variable time intervals. The children are instructed to push the correct corresponding arrow as fast as possible when it appears on the screen. This EF assessment has been deemed valid and reliable to use with elementary school aged children (Rashotte, & Pearson, 2013).

Procedures

The University Institutional Review Board (IRB) approval was granted (#1801-065-1801), school personnel approved, and parents consented to their child's participation. Once approvals and parent consent were collected, a KTK adherence training was conducted among the LiiNK Project research team members who would be assisting with data collection. The lead researcher addressed the different KTK equipment pieces related to each subtest and how to set up the equipment, administer and score the subtests using the fidelity checklist (Campbell-Pierre & Rhea, 2023b). This training took approximately 50 minutes. After familiarizing the team with the fidelity checklist procedures, the lead researcher had the team practice each fidelity section (setup, administering the subtests, scoring the subtests) while the lead researcher evaluated their accuracy. Once the team demonstrated they could perform each of the subtest procedures successfully, dates were scheduled at each school to implement the KTK assessment with each school's 3rd, 4th, and 5th grade classes.

KTK Setup Procedures

Administering the KTK at six schools took three weeks in the fall semester and three weeks in the spring semester. All children in this study were evaluated during their physical education classes which took place in the morning before children had lunch for all schedules. The schedule did not change from Fall semester to Spring semester. The two intervention schools (60 minutes of recess) and two of the control schools (30-minute recesses) had 50-minute physical education classes so it only took two days to administer the KTK assessment, while the two 30-minute physical education classes (20-minute recesses) required three days to collect. The LiiNK project team (four evaluators) would arrive 30 minutes ahead of the physical education class start time to set up the KTK subtest equipment in the gym for data collection. The research team began on Day One at four of the six schools with the SH and LJ subtests and began on Day Two at each of those same four schools with the WB and SS subtests. If a third day was required, the subtest not completed on the previous day was administered to ensure all children completed all four subtests. Four of the two control schools that took three days to complete, they began with (which tests). On the second day they would complete the tests from the previous day and begin the next two subtests. On the third day they would complete the tests from the previous day and complete any make-up. All schools in this study were evaluated in the morning before children had lunch for the day.

KTK Administration Procedures

Once the subtests were setup for each day, the four LiiNK team members would separate into two teams of two to administer their designated KTK subtest for the day. When children arrived in class, instructions for KTK participation were given by the primary researcher, followed by a brief demonstration of each subtest. Then, the class was split in half, with approximately 12-14 children in each group and dispersed to their assigned subtest station.

Each team member, evaluator, had a score sheet for each child in their group and scored each child as they participated. The demographic information was provided at least two days in advance and transferred to the child's score sheet prior to the KTK implementation day. Once the children arrived at the subtest station, the evaluator lined them up single file and with possession of their clipboard/scoresheet until called to participate. After a child completed the task, the next child was called to participate at which time they would hand their scoresheet to the evaluator, get set for the task, and perform the task. The evaluator would administer the subtest, record scores, and hand the score sheet back to the child to return to the end of the line. Once the two groups completed their subtests, the groups switched and worked to complete the other subtest. At the end of each class, the evaluators would note where they were with the subtest if not completed, instruct the children to return their score sheets to the evaluator, and prepare to leave for their next class.

KTK Scoring Procedures

The scoring procedures on how to score the WB, LJ, SS and SH subtests correctly to be able to produce measurable raw scores that can be converted to KTK motor quotients is provided in an original feasibility study produced by the LiiNK research team (Campbell-Pierre & Rhea, 2023a). An English translated score sheet was used to collect children's KTK scores in this study (Campbell-Pierre & Rhea, 2023a)

Listening Effort Setup and Administration Procedures

Once all children completed all four KTK subtests in their physical education classes, those with parent consent for the listening effort dual paradigm task were asked to participate on two days: one in the fall; one in the spring. Each of those data collection days required the children to participate in the listening effort assessment once in the morning and once in the afternoon, all assented children completed the task at the beginning of the school day prior to any recess participation and in the afternoon after several recesses for intervention children or after at least one recess for the control group children.

The task was set up in a separate room with little to no noise distraction. Once the computer stations were set up, one of the evaluators would go to each classroom to gather four to eight students at a time to complete the task at four different stations. At the designated assessment classroom, the lead evaluator would use a script to introduce the children to both tasks and give them a chance to practice the primary and secondary tasks for 10 reaction time trials and five number lists (simultaneously). Children who understood the task were invited to continue the experimental task by signing the assent form. The children were told accurately repeating numbers was the main task they should focus on and that the examiner would show the children their scores on the number task when they finished. For the cognitive task, children completed 60 reaction-time trials for the secondary task and as many trials for the primary task as possible in the time taken to complete the secondary task. The evaluators recorded the child's primary-task responses online. Secondary task reaction-time responses were recorded by E-Prime 2.0 software, measured as the time between the appearance of the arrow stimulus and hitting the correct corresponding button.

KTK Conversion Procedure

The KTK subtest raw scores were converted into four individual motor quotient (MQ) values by using German derived conversion tables translated and tested in the U.S. feasibility study (Campbell-Pierre & Rhea, 2023b; Kiphard & Schilling, 1974; 2007). The four MQ values were summed to produce a total MQ score according to the norms of a child's age and sex. Once a total MQ score was established, a child's motor competence abilities ranging from severe to great were determined.

Statistical Analysis

A data screening was performed to analyze the descriptive statistics for each research question below then the inferential statistics was performed to reflect the reporting of the results below.

Research Question 1: A change score analysis, derived from one Fall and one Spring time point, was performed in place of a repeated measures design. A MANOVA analysis was then performed using the four KTK subtest change scores (WB, SH, LJ, and SS) as the dependent variable (DV) and recess groups (60, 30 and 20 minutes), age and sex as the independent variables (IVs) to determine any subtest differences.

For an exploratory MC profile analysis with RQ1, the KTK subtest raw scores were converted into four individual motor quotient (MQ) values by using a German derived conversion table used in the feasibility study Campbell-Pierre & Rhea, 2023) and with the original KTK assessment (Kiphard & Schilling, 1974; 2007). The four MQ values were summed to produce a total MQ score according to the child's grade and sex. Once a total MQ score was established, a child's motor coordination abilities ranging from severe to great were determined for group differences by ability categories. The percentage difference between the two groups was assessed.

Research Question 2: A Pearson-product correlation was performed to evaluate the relationship between the spring MC subtest scores and listening effort (EF) processes scores in the spring semester. The EF scores are the reaction time scores collected from two time points (one time point in the morning and another time point in the afternoon in the Spring semester).

Results

Recess Groups

A preliminary KTK subtest analysis was performed for the fall data between the 20 and 30-minute recess groups since they were so close in daily recess time to make sure they should represent separate comparison groups. The preliminary findings revealed no significant difference between the two groups ($p<.05$); therefore, the research team combined those two groups to show clarity between the two remaining groups of 30 vs 60 minutes of daily recess**.** The statistical analysis detailed above to answer RQ1 was performed using the remaining two recess groups on all analyses and for further reference.

Descriptives Statistics of KTK subsets

Descriptive statistics for the four KTK subtests by recess group and grade can be seen in Table 3. The larger number of control group children was due to combining the 20-minute and 30-minute recess groups for comparison with the 60-minute recess group since they were not different and the 20-minute group did not have 5th grade in their schools.

Table 3

KTK Subtest Means and Standard Deviations by Recess Group and Grade

Subtest	Grade	N	Intervention *M* ± *SD*	N	Control *M* ± *SD*
WB Total		130	6.63 ± 11.30	222	4.83 ± 12.39
	3	44	7.13 ± 09.82	93	-5.56 ± 12.65
	4	44	7.86 ± 11.80	86	-5.86 ± 12.50
	5	42	4.80 ± 12.23	43	-1.20 ± 11.15
SH Total		130	6.98 ± 09.81	222	0.58 ± 08.95
	3	44	6.47 ± 08.09	93	-0.12 ± 08.41
	4	44	9.81 ± 10.82	86	-1.16 ± 09.07
	5	42	4.54 ± 09.82	43	0.91 ± 09.92
LJ Total		130	8.46 ± 11.39	222	2.34 ± 11.77
	3	44	12.27 ± 10.84	93	2.74 ± 13.98
	4	44	8.27 ± 13.15	86	1.72 ± 09.30
	5	42	4.40 ± 08.42	43	2.74 ± 11.16
SS Total		130	2.98 ± 15.94	222	1.38 ± 11.10
	3	44	6.65 ± 12.72	93	1.93 ± 11.51
	4	44	4.18 ± 14.13	86	0.38 ± 10.46
	5	42	-2.11 ± 19.44	43	2.20 ± 11.55

Note. WB=Balance Beam; SH=Single leg hop; LJ=Lateral Jumping; SS=Sideways Stepping

Research Question 1

A MANOVA was performed to determine KTK subtest change score differences between recess groups (60 vs 30 minutes or less of recess) while controlling for grade and sex. All MANOVA assumptions were met including normality, homogeneity, linearity, and no outliers. The MANOVA revealed recess group differences on the KTK subtest scores, Wilks Lambda = F (1,340) =24.72, p=.0001. but not by grade Wilks Lambda = F (1,340) =1.76, p=.083 or sex Wilks Lambda = F (1,340) =1.86, p =.116. Hypothesis 1 was accepted. There were no interaction effects in this model. Follow up pairwise comparisons were then calculated to determine main effect differences.

Recess Group

The 60-minute intervention group was significantly different from the control group on three out of four KTK subtests seen in Table 4. Balance Beam (WB), F (1,340) = 66.5, p=.0001, Single Leg Hop (SH), F (1,340) =35.68, p=.0001 and Lateral Jumping (LJ), F (1,340) = 21.52, p=.0001. On average, intervention school children scored 10 points higher on their WB subtest, six points higher on their SH subtest, and six points higher on their LJ subtest than the control school children. The Sideways Stepping (SS) scores were not significantly different, F (1,340) = 1.106, p= .294.

Table 4

Recess Group Differences by KTK Subtests

Subtest	N	Intervention *M* ± *SD*	N	Control *M* ± *SD*
WB Total***	130	06.63 ± 11.30	222	-04.83 ± 12.39
SH Total***	130	06.98 ± 09.81	222	00.58 ± 08.95
LJ Total***	130	08.46 ± 11.39	222	02.34 ± 11.77
SS Total	130	02.98 ± 15.94	222	01.38 ± 11.10

Note. ***p<.0001
Note. WB=Balance Beam; SH=Single leg hop; LJ=Lateral Jumping; SS=Sideways Stepping

Exploratory KTK MC Ability Level Differences

Figure 2 shows the intervention schools total group KTK MC Fall and Spring motor abilities. In the Fall, 95% of the intervention children scored in the normal to great MC ability level and only 5% scored in the moderate motor disorder ability level. By the end of the Spring semester, there was a 4% improvement to 99% of the children scoring in the normal or above ability levels, which means the number of children in the moderate motor disorder ability level decreased by 4%.

Figure 3 shows the control schools total group KTK MC Fall and Spring abilities. In the Fall, 90% of the control children scored in the normal to great MC ability levels and 10% scored below normal. By the end of the Spring semester, 5% of the children in the normal ability level had dropped to the moderate disorder category, which means the moderate disorder category increased from Fall to Spring to 10%.

There were no intervention or control children who scored in the severe motor disorder category Fall or Spring. The most interesting finding is the intervention children who scored in the great motor coordination ability went from six (5%) children in the Fall to 22 (17%) children in the Spring. This is a fairly large jump over a year. Whereas the control children only had 2 children (<1%) who scored in the great motor coordination ability in the Fall with a slight increase of 4 (<1%) in the Spring semester.

Figure 2

Intervention Children Motor Competence Performance Levels for Fall and Spring Semesters

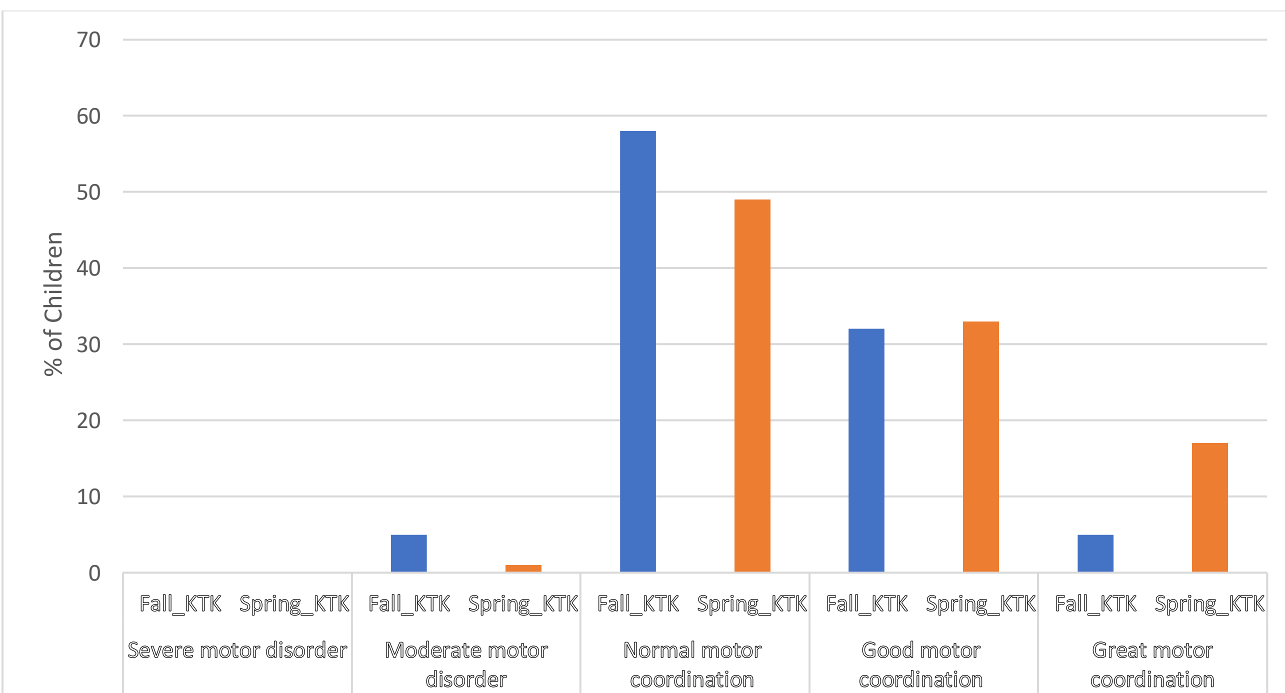
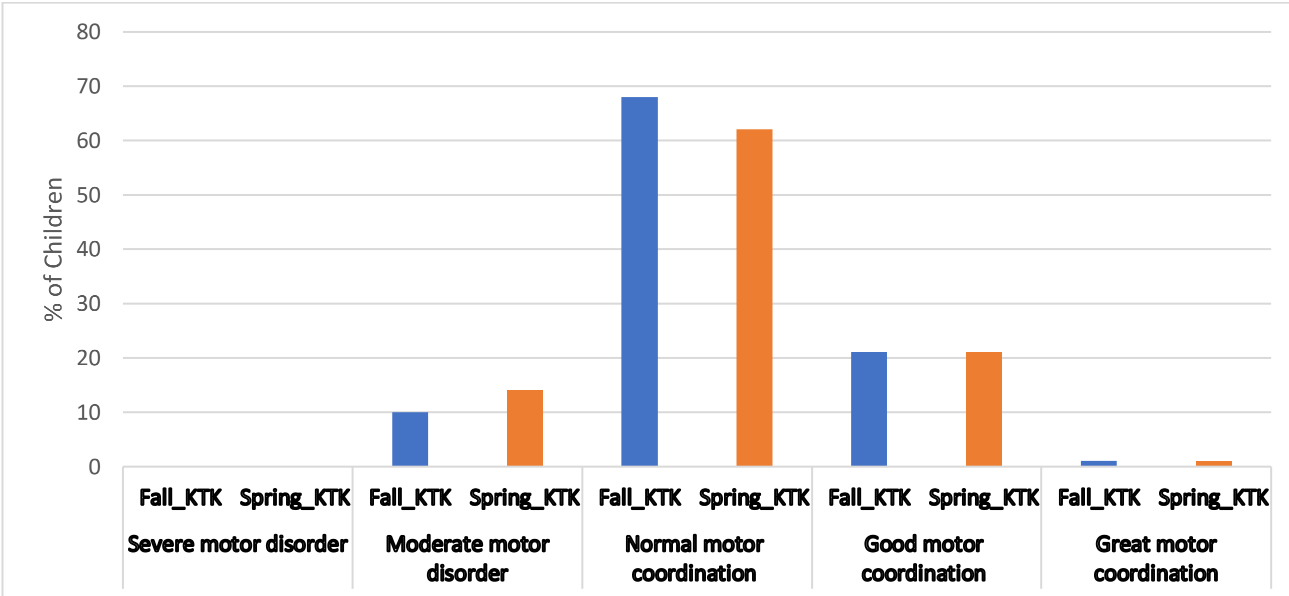


Figure 3

Control Children Motor Competence Performance Levels for Fall and Spring Semesters



Research Question 2

EF Descriptive Statistics

Descriptive statistics for the Spring 2023 EF scores by recess group and grade can be seen below in Table 5. The EF numbers are noticeably different between the intervention and control schools. The intervention schools reflected only 27 children representing three grade levels, whereas the control schools reflected 111 children representing three grade levels. The number of children per grade level and overall was not large enough in the intervention group to examine any exploratory effects between the groups.

Table 5

EF Scores per Semester by Recess Group and Grade

EF	Grade	N	Intervention	N	Control
EF Spr 1		27	1592.74 ± 1743.20	111	1366.00 ± 1651.19
	3	8	1898.05 ± 1926.48	37	1362.02 ± 1470.94
	4	7	1430.57 ± 1164.60	52	1069.25 ± 1566.76
	5	12	1883.51 ± 2329.69	22	807.89 ± 670.93
EF Spr 2		27	937.17 ± 890.03	111	977.02 ± 1182.00
	3	8	705.89 ± 168.45	37	1028.79 ± 774.99
	4	7	635.62 ± 153.10	52	1069.25 ± 1566.76
	5	12	1267.26 ± 1275.10	22	671.99 ± 451.60

Research Question 2

A Pearson product correlation was performed to assess the relationship between Spring MC subtest scores and EF processing scores which can be seen in Table 6. The correlation analysis revealed a non-significant relationship between MC subtest scores and EF scores.

Table 6

Correlations among MC Subtest Scores and EF Scores

		EF SPR1	EF SPR2	SPR WB	SPR SH	SPR LJ	SPR SS
EF SPR1	Correlation	-	.834**	0.091	0.041	-0.096	0.047
	Sig.		0.01	0.330	0.659	0.303	0.617
	N		117	117	117	117	117
EF SPR2	Correlation		-	-0.068	-0.059	-0.087	-0.063
	Sig.			0.467	0.531	0.350	0.499
	N			117	117	117	117

**p=0.01

Discussion

This study showed that LiiNK (60 minutes of recess daily) promoted much better postural balance and motor coordination skills, i.e., WB, SH, and LJ, than children with no more than 30 minutes of recess daily. Both groups participated in unstructured, outdoor recess (play) daily, but the number of minutes is what seems to determine the difference between the groups for three out of the four subtests. These results support that LiiNK is providing the appropriate setting for dynamic interactions (DST) to emerge when children are given several unstructured, outdoor recess opportunities throughout their school day. Children can engage in natural large muscle movement patterns which are considered multilevel, interactive, and bidirectional, which triggers the child's attractor states (DST) to naturally shift to levels of proficiency over time (Colombo-Dougovito, 2016).

The second supporting evidence that 60 minutes of recess enhances MC in children over 30 minutes or less is this study's MC ability level findings. Children that received 60 minutes of recess daily were exposed to a minimum of 150 more minutes to engage in natural motor skill development per week which equates to 5,400 more minutes in a school year. When children only receive 30 minutes or less of PA daily, they not only acquire much less opportunity to move throughout the year, but they also do not meet the recommended moderate-vigorous physical activity (MVPA) a child needs daily, according to the CDC (CDC, 2019). This study supports Dankiw et al., 2020 that children who receive 60 minutes of recess daily become more comfortable controlling their bodies through their play experiences which supports motor movements needed to sustain postural balance. This finding is consistent with the preliminary data gathered in a previous study revealing that when schools provide more PA opportunities for children, like recess and physical education, it seems to play a role in their MC abilities (Campbell & Rhea, 2023b).

Although there was support for the 60 minutes of recess positively impacting postural balance and motor coordination, the data did reveal two areas that need to be addressed. The first area was no significant differences were found between the intervention and control groups on the SS subtest. Other studies have not addressed what type of play activities could enhance children's lateral movements evaluated in the SS subtest (Draghi et al., 2021; Estevan et al., 2021; Giuriato et al., 2021). According to attractor states influenced by the DST, children must engage in play activities that require them to move laterally and repetitively, for them to naturally adapt to the preferred movement (Ismail, 2021b). In this study, we were not able to determine what type of activities children were engaging in during their recess opportunities. It would be interesting to incorporate qualitative observation to observe if children participate in repetitive lateral movements during recess. This might be something physical educators need to pay more attention to if it's not applied naturally on the playground. Further investigation would be needed to assess if children are engaging in any play activities during recess to help enhance their lateral movement development.

The next area that needs to be addressed is that no children in this study presented severe MC abilities. Researchers have connected severe MC to underlying cognitive deficits that impact a child's movement abilities (Beeldman et al., 2016; Dhondt et al., 2020; Fluss et al., 2020). In a previous KTK feasibility study (Campbell-Pierre & Rhea, 2023a), a blend of typical and atypical children participated in the evaluation process. Atypical children were not excluded from the evaluation process when accompanied by their designated support because the KTK allows for an inclusive evaluation of various developmental levels in other countries. In this study, there was no blend of typical and atypical children usually accompanied by designated referral support in the gymnasium during the collection process. It would be interesting to evaluate a paired group of atypical and typical children to understand better the impact recess can have on a more inclusive group of children's MC abilities over time.

The study did not support our second research question hypothesis that a significant relationship would exist between Spring MC subtest scores and EF scores. The main reason a relationship was not detected between MC and EF was because the two assessment tools used to evaluate the scores measured two different time variables. For example, the EF assessment measured an acute period of time, meaning the children were evaluated across two different time points in one day, morning and afternoon. We now know this type of assessment cannot be compared to tests that collect single data points, like the KTK. Therefore, finding a different EF test is needed to assess whether there is a significant relationship between EF scores and KTK subtest scores, which assess MC.

Limitations and Future Directions

This exploratory study evaluated the impact recess has on MC abilities in one calendar school year. To better understand the natural benefits recess can have over time on children's MC abilities, offering various amounts of recess with matched controls using the KTK from year to year is recommended. Although we did assess the difference between three different recess groups, this study was administered in one area of the country and cannot be generalized to all populations. As a result, it is suggested for future studies to assess the KTK subtest scores from different states in the U.S. to examine if demographics from a larger sample size plays a larger role in children's MC abilities.

For EF, the sample size for the intervention group was much smaller than the control group total. A more matched number per group that meets the power analysis for the study is needed in future studies. An effective EF measure needs to be identified for future studies to examine a true relationship between MC using the KTK and EF processes.

Conclusions

In conclusion, the study showed that recess is having a positive impact on children's motor coordination and postural balance abilities. Previous researchers that have used the KTK have not used recess as an intervention to connect children's PA opportunities to MC abilities. Future researchers and physical educators should begin to consider the impact recess can have on children's MC abilities related to postural balance. Second, a relationship was not found between MC and EF, but we know through other research, that there is a relationship between the two (Mazzoccante et al., 2020). This was the first attempt to study the connection between MC change scores and EF processes in the U.S. Finding the right EF assessment tool must be considered in future studies to assure the connection is or isn't there.

Chapter 5: Discussion

Overview

Unintentional falls are the second leading cause of non-fatal injuries in school-aged children. One of the main contributors is the increasing rate of sedentary behaviors and lack of unstructured, outdoor play which seem to play a role in MC deficits (Carvalho et al., 2021). Coppen et al. (2021) defines MC as the degree of various motor skill proficiencies and the underlying mechanisms such as motor coordination and postural balance. The LiiNK intervention (Let's inspire innovation n' Kids) provides children with four, 15-minute outdoor unstructured recess (play) breaks that expose them to play opportunities. These play opportunities allow children to engage in repetitive movements to enhance their MC abilities. As a result, children learn how to fall correctly when given the time to navigate their surroundings regularly and develop MC (Garcia-Soidan et al., 2020).

The LiiNK project has a long history of providing children with recess to enhance their physical and psychosocial development by increasing their MVPA by 40% (Farbo et al., 2020). Based on the findings, we assumed having four recesses daily in school would improve children's MC abilities which should enhance their ability to fall correctly thus preventing major injuries, as well as improve their EF. Two different theoretical constructs support MC and EF. Piaget's play and cognitive development theory's four stages of learning through play and movement is well established (Piaget, 1957). Piaget believed children begin to acquire mental processes that engage the prefrontal cortex as a result of play as early as the concrete operational stage (ages 7-11). He laid the foundation for other theoretical constructs to be established that clarify the development of MC and EF abilities in children through unstructured, outdoor play. One of those newer theoretical constructs is Dynamic Systems Theory (DST). DST is the dynamic interaction between three constraints (individuals, environment and tasks) to promote spontaneous behavior also known as movement. When a child engages in repetitive movements through recess opportunities it helps them naturally adapt to the new movements over time. The repetitive engagement in movement has also been linked to promoting healthy blood flow to a child's brain, improving their EF abilities, simultaneously.

The LiiNK intervention provides children with the appropriate setting for the dynamic interactions between the three DST constraints to emerge. During recess, the child is the individual constraint, exposed to an outdoor school play setting (environment constraint) to engage in unstructured play opportunities (task constraint). These dynamic interactions provide support for the development of fundamental motor skill proficiencies naturally through the shifting of the attractor states (Colombo-Dougovito, 2016). Since this is fundamental for children and supports Piaget's play developmental stages as well, the next step was to evaluate children who receive multiple recesses daily with those who receive very few for its impact on MC abilities. There are no MC assessments used in the U.S. that evaluate postural balance effects for typical and atypical developing children with norm referenced competence levels. This led to whether an inclusive MC assessment tool, the KTK, identified as a valid and reliable tool in foreign countries could be translated into English and used in a U.S. physical education setting to determine MC with similar valid and reliable results. All three studies focused on using the KTK assessment. Study 1 tested the feasibility of the assessment through (1) KTK implementation, (2) time to assess each skill, and (3) the equipment availability and examining the adaptability of scoring protocol in other countries to the U.S. physical education setting. Study 2 assessed if physical educators could use the KTK with fidelity. Study 3 examined if the varying amounts of recess provided daily over a school year would determine MC level differences, as assessed with the KTK, and a relationship of MC abilities to EF.

Summary of Findings

Feasibility of the KTK

Study 1(Chapter 2) was a two-phase study that sought to determine the feasibility and adaptability of an inclusive gross MC tool called the *Körperkoordinationstest fur Kinder* (KTK) (Kiphard & Schilling, 1974; 2007), allowing researchers and physical educators to evaluate typical and atypical children. Unfortunately, no literature exists on use of the KTK in the U.S. to determine children's MC abilities. Study 1 was the first step to bridge the gap in knowing whether the KTK could be used in the U.S. Previous literature does support KTK usage cross-culturally outside of the U.S. in physical education settings (Livonen et al., 2016; Moreira et al., 2020). The main reason U.S. researchers and physical educators have not used the KTK in physical education settings is that the assessment tools are not published in English. However, Study 1 was focused on translating the scoring protocol/procedures, score sheet, equipment from German to English, introducing the KTK to U.S. physical education teachers for use in their setting, and assessing the feasibility of use in the future. The results revealed that the KTK was feasible to administer a U.S PE setting by showing three challenges could be solved: (1) KTK implementation, (2) time to assess each skill, and (3) the equipment availability and cost to implement the test in a physical education setting. In addition, phase two results revealed that the scoring protocols used in other countries were adaptable. These findings produced measurable raw scores that could be converted to KTK motor quotients that produced children's MC abilities levels as other studies have done (Vandrope et al., 2011).

Fidelity & Preliminary Findings

Since the KTK was found to be feasible to administer in a U.S. physical education setting, Study 2 (Chapter 3) focused on introducing the psychometrics and fidelity needed for physical educators to replicate the administration of the KTK in their physical education setting

(Iivonen et al., 2015). Study 2 was twofold. It assessed the validity (fidelity checklist) and reliability of the U.S. physical educators administering the KTK assessment. Second, it focused on gathering preliminary data to assess two very different schools' roles in MC abilities. The lead researcher held an adherence training with the physical educators to introduce the fidelity checklist, demonstrate all the KTK subtests, and practice equipment set-up, scoring procedures, and administration of the KTK with the different subtests. The fidelity checklist developed for this study to validate its use in U.S. schools consists of 72 total items divided into three key categories: Subtest Set-Up (8 items), Subtest Administration (22 items), and Subtest Scoring (42 items). The physical educators from both schools were evaluated by the fidelity checklist and demonstrated they could replicate the KTK with fidelity after completing the KTK training. All four physical educators scored 95% and above in all three categories of the fidelity checklist for the KTK assessment. In addition, the reliability of the KTK assessment administered by physical educators in both schools determined all four KTK subtests were reliable (WB: 0.88, SH: 0.93, SS:0.96 LJ: 0.94.). Studies from other countries have produced similar alpha coefficients (WB:0.80, SH: 0.84, SS:0.96, LJ:0.95) consistent with this study. This study reflected higher intra-rater reliability for the WB and SH subtests than studies from other countries but reflected very similar intra-rater reliability for the LJ and SS subtests. This is a significant finding that the KTK is reliable to administer in a U.S. physical education setting, even with new physical educators evaluating the tool. This finding provides support for the training and fidelity checklist developed for this assessment.

The combination of the different school variables showed some telling ability differences. The results revealed the variables in School 1 played a role in children having more confidence and control of their bodies vertically and laterally than those children at School 2. There were three significantly different variables between the two schools which could have played a role in improving School 1's MC abilities compared to School 2. The differences included private vs public, 45 minutes of physical education daily vs 50 minutes of physical education two times a week, and 45 minutes of daily recess vs 30 minutes of recess. Other studies have identified school types (private or public), PE opportunities, and unstructured play breaks as children's primary sources of PA throughout their school day, which has the ability to enhance their MC abilities (Lee et al., 2020). With additional PA opportunities through attending a private school, having daily PE and daily recess, the school performed better on all four KTK subtests. The results revealed that 22% of children at School 1 reached great MC ability, according to the KTK. While 15% of the children at School 2 scored moderate motor deficits, which is a lower MC level. Other studies have reported higher percentages of their children scoring moderate motor deficits (14%-29%) and scoring lower in the great MC levels (3-14%) (Giuriato et al., 2021; Kiphard & Schilling, 1974; Moreira et al., 2019; Vandorpe et al., 2011). Therefore, the schools in our study performed slightly higher than other children assessed in other countries. One other important find was neither school had children with severe MC deficits in their classes. If they had found this motor deficit with any children, the research has shown those children would have been labeled with cognitive deficits as a result of not being able to perform any of the motor movements (Hasegawa et al., 2020).

These findings led to the 3rd study to determine whether there is a relationship between MC abilities and cognition while providing children with different recess opportunities. In conclusion, these preliminary findings suggest that factors like race, physical education class opportunities weekly, and daily multiple recess opportunities could impact children's MC abilities in U.S. 10-year-old children. Determining which variables may enhance motor competence more is still in question. Understanding more about this area will determine the impact of postural balance and motor coordination on fall prevention and non-fatal injuries.

Recess, Motor Competence and Executive Function

The KTK is now a feasible, adaptable, reliable, and fidelity was determined to administer in a U.S. Physical Education. Study 3 (Chapter 4) was to determine the LiiNK intervention impact on children's MC abilities compared to children receiving 30 minutes or less in different school districts across north and south-central Texas. The results showed the 60-minute group did significantly improve a child’s MC abilities compared to the 30-minute or less group over a calendar school year. The LiiNK children performed significantly better on three (WB, SH & LJ) out of four KTK subtests compared to children receiving 30 minutes or less. Other researchers that have used the KTK in other countries have not evaluated the impact of an unstructured, outdoor play intervention on MC abilities using the KTK assessment. According to the DST, outdoor unstructured play set the stage for the dynamic interaction between three constraints (individual, environment and tasks) for children to engage in repetitive movements overtime (Columbia-Dougovito, 2016). The four 15-minute recesses daily through LiiNK provided children more play opportunities to promote consistent repetitive movements, than school districts that offered less recess (30 or 20 minutes). It seems these extra minutes daily supported a natural shifting to preferred movements through attractor state repetitions, supported by the dynamic systems theory (DST) (Massis & Jeffreys, 2021). It was also important to determine if a child’s EF was related to the child’s MC ability levels. Study 3 analyzed the relationship between MC change scores and EF processes (inhibition, working memory, and cognitive flexibility) over a calendar school year. The finding revealed no significant relationship between MC and EF processes in this study. There are two main reasons why a more appropriate EF assessment tool must be considered when examining the relationship between MC and EF abilities using the KTK. The first reason is that the two assessment tools were used in this study to measure two different variables of time which hindered the relationship between EF and MC. For example, when the EF assessment was conducted, we utilized an acute approach to gathering the data. Children were evaluated across one acute period of time in one day, morning and afternoon, for Fall and Spring. When the KTK assessment was conducted, we took a longitudinal approach to gathering the data. Participants were evaluated across two different independent time points, Fall semester and Spring semester, over the course of an entire school year. When evaluating the relationship between EF and MC in this study, we were analyzing two very different durations of time which was never going to result in a correlation when examining the two variables. The second reason is that the EF assessment that was used in the study measured three different EF processes (inhibition, working memory, and cognitive flexibility). According to other researchers that have identified a relationship between MC and EF using the KTK, MC abilities related to postural balance have a stronger relationship with working memory instead of all three (Mazzoccante et al., 2020). Therefore, it would be appropriate to reassess the relationship between MC and EF abilities using a non-norm referenced EF tool designed to evaluate working memory to better align with the type of MC abilities assessed when using the KTK.

Contribution to Knowledge Base

All three dissertation studies sought to address some of the gaps in the literature and provide researchers and physical educators with KTK implementation strategies that needed to be considered if more was to be known about how to prevent falls and the rise of injuries in children. The KTK was missing an English translation of a very successful measure used in other countries. All three studies provided insightful information researchers and physical educators can use if they understand the benefit of having the KTK assessment in their physical education settings. Study 1 provided a blueprint for researchers and physical educators to begin their journey using the KTK assessment in the U.S. The KTK was missing an implementation strategy for English speaking researchers and physical educators that was already established in other countries. Study 1 provided KTK protocols and procedures needed to administer the assessment. The time to administer the KTK was shortened from 25 minutes per child in other countries to 2.5 minutes per child in the U.S. The equipment instructions were provided so the physical educators could purchase the appropriate supplies to replicate the equipment needed for the four subtests. There was a concern about being able to score the KTK like other countries because of the lack of translated assessment properties. The translations were completed accurately for the scoring procedures and an English version of the score sheet was developed to replicate the original scoresheet from the German manual (Kiphard & Shilling, 1974, 2007). Study 1 also demonstrated that the scoring protocol used in other countries was adaptable in the U.S. by converting KTK raw scores into motor quotient scores to determine each child individual MC abilities. This finding was significant for U.S. researchers and physical educators because it serves as the first step to being able to identify children's motor competency strengths and weaknesses in typical and atypical children.

A significant gap in the literature was to validate whether the KTK could be used accurately with the protocol and procedures developed for the U.S. physical education setting. In Study 2, physical educators demonstrated that it was possible to replicate and administer the KTK assessment in two very different schools by following a fidelity checklist developed and tested in Study 2 and scoring procedures developed and tested in Study 1. The U.S. physical educators demonstrated they could set up, administer, and score each KTK subtest with minimal errors in a physical education setting. This finding revealed that physical educators could administer a reliable KTK evaluation with fidelity therefore validating the KTK as a valuable MC assessment tool to use in a U.S. physical education setting. This contribution of knowledge should serve as a vote of confidence for other U.S. physical educators and researchers that they can replicate the administration of the KTK with the appropriate assessment properties provided in Studies 1 (Chapter 2) and 2 (Chapter 3).

Researchers in other countries that have used The KTK to assess MC abilities related to postural balance have not usually used unstructured play breaks as an intervention to enhance children MC development. The LiiNK intervention revealed that unstructured play breaks could be a contributing factor to enhance impact children's MC abilities related to postural balance. Children who received 45-60 minutes of recess daily throughout the school year boosted their motor competence level by 11% in one school year. This is a significant finding researcher from other countries and the U.S. can further explore. Ultimately examining a recess intervention like LiiNK that requires 45-60 minutes of unstructured, outdoor recess daily is needed to determine which variables are most significant in shifting the MC ability scores found in this study.

Implications

The body of evidence has relevant implications for school officials, researchers, and physical educators about the discovery of being able to use the KTK assessment tool in the U.S. to evaluate typical and atypical children to determine MC abilities related to postural balance. More KTK studies need to be executed in the U.S. to determine the effectiveness of these subtests as a substitute for other assessments that may not assess exactly what they need to know. The KTK has now been established as a valid and reliable tool of children's MC abilities in the U.S. and other countries (Vandrope et al., 2011). As a result, physical educators demonstrated their ability to set up, administer and score the four KTK subtests once they received the appropriate resources (i.e., scoring protocol/procedures, score sheet, and KTK implementation training). They could produce measurable outcomes converted to KTK motor quotients to determine their children's MC abilities. Very strong internal consistency was found by administering the KTK assessment with the research translated protocols and procedures consistently. The alpha coefficients produced from the physical educator's evaluation were comparable to other studies that reported reliable coefficients (Guiatrio et al., 2021). This finding is a vote of confidence that more physical educators have the skills and ability to administer the KTK assessment in their physical education classes when provided with the proper training and understanding of the score conversion method to be able to determine their children's MC abilities.

Other researchers using the KTK in other countries have yet to use the assessment with unstructured play breaks as an intervention to promote children's MC abilities. Recess has a long history of promoting physical, psychological, and social development in children. The CDC recommends that children receive 60 minutes of moderate-vigorous activity daily (CDC, 2019). A practical method for children to achieve the recommended physical activity needed is by being offered recess opportunities in schools. There is no mandate that children need to be offered recess in most states in the U. S. However, when children are offered recess opportunities in most school districts, they only receive 20 minutes to participate in child-led activities. In the final study of the dissertation, 60 minutes of unstructured play daily was evaluated compared to other school districts that offered 30 minutes or less. Children that received 60 minutes of recess improved their MC abilities over the year significantly compared to children in school districts receiving 30 or 20 minutes of unstructured play breaks daily. If children are allowed to engage in 60 minutes, it can enhance their skills development through repetitive movements initiated by the children. Children are more likely to increase their engagement when they have the autonomy to choose what play activity they want to engage in, and unstructured play allows the child to lead their MC development as they see appropriate in a natural manner. These findings suggest that MC can be enhanced in children with 60 minutes of outdoor unstructured play breaks. However, more schools need to understand the benefits it can have on children's MC abilities to determine if recess is the key to slowing down the trend of injuries because of unintentional falls.

Future Research

The collective findings throughout this dissertation still present several gaps that must be addressed. When using the KTK in the U.S., it is still in the beginning stages to determine the impact the assessment can have, providing researchers and physical educators a better understanding of children's MC abilities over time. To better understand the impact the LiiNK intervention can have on children's MC abilities from year to year. A longitudinal study examining the effects the LiiNK intervention can have on children's MC abilities throughout their elementary school experience by evaluating kindergarteners through the 5th grade (K-5). This information would allow LiiNK to see how recess opportunities impact MC's abilities to build more awareness of the importance of providing unstructured play breaks to school children.

Study 3 assessed the relationship between MC change scores and EF processes. A significant relationship was not found between MC change scores and EF processes (inhibition, working memory, and cognitive flexibility). However, researchers have suggested that MC skills related to balance are more connected with EF processes related to working memory (Mazzoccante et al., 2020). To better understand whether a relationship between MC change scores and EF processes can be found. A study that used an EF assessment centered around working memory should be selected to see if it is a more appropriate tool to pair with the KTK assessment to analyze if a more substantial relationship can be identified.

All three studies of this dissertation focused on establishing the KTK assessment as a tool for U.S. personnel to evaluate physical components related to postural balance abilities in children. The KTK is a newer assessment for researchers and physical educators to start using in the U.S. as an alternative MC tool for physical educators to utilize to help with their skill development related to postural balance. Physical educators in Texas have annual assessment tools that they must complete with their children to report scores at the state level (Pilum & Gard, 2018). To continue to build awareness around the KTK as an asset to physical educators, it would be appropriate to launch an exploratory study to assess MC abilities determined by the KTK compared to a fitness assessment called Fitness Gram (Godoi-Filho et al., 2021). A future study should be considered that assesses the relationship between MC abilities provided by the KTK and health-related physical fitness abilities provided by the Fitness Gram. The study would further our understanding of KTK capabilities in relation to a well-respected U.S. assessment tool examining fitness components.

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EDUCATION

Ph.D. in Health Sciences — Texas Christian University
Anticipated-May 2023 — Kinesiology
Dissertation Title: Finding Our Balance: Evaluating various amounts of unstructured play breaks and their impact on motor control abilities in children ages 8-11.

M.S. — Bay Path University
May 2018 — Occupational Therapy

B.S. — North Carolina Central University
May 2016 — Psychology

Professional Experience

Research Graduate Assistant
August 2020-Present
The LiiNK Project (Let's Inspire Innovation 'N Kids)
Texas Christian University, Fort Worth, Texas.

Occupational Therapist
2018- 2020
Compleat Kidz Gastonia, North Carolina

Teaching Experience

Texas Christian University
Instructor of Record:

August 2021-December 2022
- KINE 30733- Exercise Psychology
- KINE 10101-Intro to Kinesiology

Texas Christian University
Teaching Assistant:
January 2021-May 2021
- KINE 30713 Sports Psychology

Research Experience

Graduate Research Assistant
August 2020- Present
Department of Kinesiology, Texas Christian University, Fort Worth, Texas. The LiiNK Project, Director: Dr. Debbie Rhea

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RESEARCH GRANTS AND FUNDING

External Grants Funded:

1. Shape America: Thomas L. McKenzie Research Grant
   Title: The Effects of Multiple Recesses Daily on Children's Motor Coordination
   Role: Principal Investigator
   Amount: $2,000
   Dec. 2021

2. Children & Nature 2022 Inside- Out International Conference Scholarship
   Atlanta, GA
   Amount: $500
   March 2022

Internal Grants Funded:

1. TCU Open Access Fund ($2,080)
   Texas Christian University, *April 2023*

2. HCNHS Student Travel Grant Award *($500)*
   Texas Christian University*, February 2023*

3. HCNHS Student Travel Grant Award *($500)*
   Texas Christian University*, February 2022*

4. TCU Graduate Studies Travel Grant Award *($400)*
   Texas Christian University, *January 2022*

5. HCNHS Student Travel Grant Award *($178)*
   Texas Christian University, *October 2021*

6. HCNHS Research Grant Award *($500.00)*
   Texas Christian University*, September 2021*

7. HCNHS Student Online Conference Grant Award *($200)*
   Texas Christian University*, February 2021*

8. HCNHS Research Grant Award *($498.55)*
   Texas Christian University*, September 2021*

RESEARCH PUBLICATIONS

1. **Campbell-Pierre, D.,** Rhea, D.J., Baker, K. (2022). What is the relationship between outdoor play breaks & no play breaks on postural balance?: A Systematic Review. *Journal of Health and Physical Literacy*, *1*(2), 122–134. https://johpl.org/index.php/johpl/article/view/10.
2. **Campbell-Pierre, D.** & Rhea, D.J. (2023) The Feasibility of Using the *Körperkoordinationstest fur Kinder* (KTK) in an Elementary Physical Education Setting to Assess Gross Motor Skills Specific to Postural Balance**.** *Frontiers in Sports and Active Living. doi: 10.3389/fspor.2023.1133379.*
3. **Campbell-Pierre, D.** & Rhea, D.J. (in review, 2023) The Feasibility of Using the *Körperkoordinationstest fur Kinder* (KTK) in an Physical Education Setting to Assess Gross Motor Skills Specifics to Postural Balance. *Journal of Teaching Physical Education (JTPE).*

RESEARCH PRESENTATIONS

1. Rhea, D., **Campbell-Pierre, D.** & Webb, K. (2021). Engaging physical educators in assessing fitness differently 2.0. TAHPERD Winter Conference. Corpus Christi, Texas
2. **Campbell-Pierre, D.** (2022) The Impact of Multiple Recess on human development in school aged children. Association for Applied Sports Psychology Conference. Fort Worth, Texas
3. **Campbell-Pierre, D.** & Rhea, D.J. (2022). The Impact of Multiple Recess on Gross Motor Competence in 10-year-old boys & girls. U.S. Play Coalition Conference. Clemson, South Carolina.
4. **Campbell-Pierre, D.** (2022). Falling can be fun: An Accessibility study through LiiNK. Texas Christian University, HCNHS 3-Minute Thesis Competition. Fort Worth, Texas.
5. Rhea, D., Farbo, D., & **Campbell-Pierre, D**. (2022). Outdoor playscapes make the difference for physical literacy. Health and Physical Literacy Summit. Birmingham, Alabama.
6. Rhea, D., Farbo, D., **Campbell-Pierre, D.** & Moore, E. (2021). Engaging physical educators in assessing fitness differently. TAHPERD Winter Conference. Arlington, Texas
7. **Campbell-Pierre, D.** & Rhea, D. THE Effectiveness of The Korperkoordinationstest fur Kinder (KTK) on Static and Dynamic Balance. TAPHERD Convention, 2021, Arlington, Texas
8. **Campbell-Pierre, D.,** & Farbo, D. The value of play is all in the design. U.S. Play Coalition Conference, 2021, Clemson, South Carolina.
9. **Campbell-Pierre, D.** Through my OT lenses: Assessing National Boards Rate in Minority OT students. National Black Occupational Therapy Caucus Conference, 2018, Pennsylvania, PA
10. **Campbell-Pierre, D.** Academic Satisfaction in Minority College Students: An Accessibility study through LiiNK. Bay Path University, BPU Thesis Competition, 2017, Longmeadow, Massachusetts.

HONORS AND AWARDS

1. **Scientist Mentoring & Diversity Program Scholar 2022 Scholar Recipient**
   International center for professional development, Murrieta, CA, June 2022
2. **Children & Nature Network 2022 Inside & Out Scholarship Recipient**
   Department of Kinesiology, Texas Christian University, *February 2022*
3. **2nd Place Student Poster Research Symposium Presentation**
   Title: THE Effectiveness of The Korperkoordinationstest fur Kinder (KTK) on Static and Dynamic Balance. TAPHERD Convention, 2021, Arlington, Texas.
4. **Frances Swift Scholarship Recipient**
   Organization: National Black Occupational Therapy Caucus, Bay Path University, *March 2017.*

PROFESSIONAL AFFILIATIONS

Scientist Mentoring Diversity Program (SMDP), 2022-Present

Association for Applied Sports Psychology, 2022-Present

Shape America Association Member, 2020-Present

US PLAY Coalition, *2020-Present*

Texas Association for Health, Physical Education Recreation and Dance Member (TAPHERD), 2021-Present

American Occupational Therapy Association Member *2017- Present*

National Black Occupational Therapy Caucus Member, *2018-Present*

Abstract

Finding our balance: The effects of multiple recess on elementary children motor competence and executive functioning abilities

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Harris College of Nursing and Health Sciences
Texas Christian University

Dissertation Advisor: Dr. Debbie Rhea, Professor of Kinesiology, Director and Creator of the LiiNK Project

Unintentional Falls is the second leading cause of nonfatal injuries in the United States (U.S.). Sedentary behaviors are at an all-time high in schools leading to children not engaging in enough physical activity throughout their school day. Physical education and recess opportunities have decreased in school for the past ten years, leading to children having motor competence deficits and becoming victims of fall injuries due to the lack of physical activity exposure. A foreign motor competence assessment was identified that allows researchers and physical educators to evaluate motor competence abilities directly related to postural balance abilities called the *Körperkoordinationstest fur Kinder* (KTK). The KTK has been deemed a valid and reliable assessment tool in other countries but has not been used in the U.S. This raised whether the KTK can be a valid and reliable tool for physical education to evaluate typical and atypical school-aged children.

Our first study examined if the KTK assessment tool is feasible and adaptable to administer in a U.S. physical education setting. We translated the scoring protocol, procedures, and scoresheet to be able to administer the KTK in a U.S. physical education setting. We found

that the KTK was feasible to administer in a U.S. physical education setting by establishing a KTK implementation strategy, assessment time, and equipment availability. The KTK scoring protocol and procedures were used in Studies 2 and 3 to determine the fidelity of KTK in a U.S. physical education class and whether recess can impact children's MC abilities. In Study 2, we found that the KTK was a reliable assessment physical educators could administer with fidelity (validity), determining that the KTK is a valuable assessment tool to administer in a U.S. physical education class. In study 3, we found that when children are provided 60 minutes of recess a day can enhance their motor competence abilities compared to children receiving 30 or 20 minutes of recess daily.

In conclusion, the KTK is a valid and reliable assessment tool in the U.S. The KTK can be used as an alternative tool to determine children's motor competence abilities related to postural balance abilities to identify children motor competence abilities. Additionally, recess can be used as an intervention to enhance children's motor competence abilities using the KTK assessment. For example, when children were given 60 minutes of recess daily, it allowed them to enhance their motor competence abilities compared to children receiving 30 or 20 minutes daily over an academic school year.