Core Muscle Endurance and Its Relationship to Functional Balance and Motor Play Skills in Kindergartners

Thesis

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By

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Abstract

Development of balance and functional motor skills in children is a complex phenomenon that requires the interaction of many systems. There is not currently one reliable, practical, play-based method to measure the musculoskeletal contribution of the trunk to balance and gross motor function in young children. **AIM:** To investigate relationships between anthropometrics, age, measures of trunk muscle strength, and functional measures of balance and gross motor skill in Kindergarten children enrolled in regular education. **METHODS:** Twenty participants, 7 male, 13 female (mean age: 5yr 8mo), assessed with 1) Prone Extension timed hold test 2) Supine Flexion timed hold test 3) Functional Reach Test (FRT), and 4) three subtests (Balance; Running Speed and Agility; Strength) of the Bruininks-Oseretsky Test of Motor Performance-2nd edition (BOT-2). Anthropometric data was collected for height and weight to be analyzed as possible confounding variables. **RESULTS:** The only variables that were significantly correlated were height and weight ($r= .834 p < .01$). There was a moderate correlation at a marginally significant level between 2 of the BOT-2 subtests: Running Speed/Agility and Strength ($r= .428 p < .06$). **INTERPRETATION:** The positional hold tests may not be valid measures of core muscle strength. There is neither a clear relationship between core muscle control and balance nor core muscle control and overall motor function. Overall body strength, such as measured by the BOT-2 subtest, may relate more to functional motor performance than isolated core muscle strength.
Dedication

This document is dedicated to my dear husband, Jay, and to our precious children, Elyse, Isaac, and Gavin, who have lovingly encouraged and supported me throughout the entire process of earning a master’s degree.
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CHAPTER 1: INTRODUCTION

Background of the Problem

Assessment in Pediatric Physical Therapy

When assessing the gross motor skills of a young child, pediatric physical therapists look at the abilities of the child, most often using a combination of two very different methods. First, they employ observational analysis relying heavily on knowledge of typical development as well as experience and clinical instinct. While there aren’t necessarily formal guidelines for this phase of the evaluation, it is accepted as part of the art of the field. This informal but valuable type of assessment is followed up with testing in a more structured manner in which the therapist utilizes clinical tools and assessment measures. These tools and measures must be evidence based and represent the science of the field of physical therapy. Ideally, the entire assessment is conducted in a play-like atmosphere. The combination of these three elements: art, science, and play are essential for a sound assessment and represent the challenge as well as the joy of pediatric physical therapy.
Assessment of Balance in Children

Many dynamic systems interact to produce balance control, and therefore, many causes must be considered if balance is identified as an area of difficulty, based on the initial assessment. Systems that must be assessed include the neurological system by way of muscle tone, reflex reactivity, and reflex integration; the musculoskeletal system by way of flexibility, strength, and endurance; and the sensory system by way of proprioception, vestibular control, and vision.\(^2\)

Ample clinically relevant assessment tools exist to evaluate balance in a relatively broad context. There are functionally based tools, specifically for children with known diagnoses\(^3\), as well as specifically for school age children.\(^4\) A wide variety of discriminative measures include balance as a subtest.\(^5\)-\(^8\) There are even several tools that assess only balance in an efficient, functional manner.\(^9\)-\(^13\) Most of these tools are valid and reliable\(^3\)-\(^10,\)^\(^14\) and often utilized in homecare settings, clinics, and schools. They are each valuable in their own right. However, each tool is limited to defining whether or not balance is functioning typically or to measuring change over time; none of these tools assist in discriminating which parts of the balance subsystem may be impaired. If a therapist suspects, based on observational analysis, that the musculoskeletal system is implicated, then, additional assessment is required.
Assessment of Muscular Control Relative to Balance in Children

In the field of Physical Therapy, strength, in the sense of maximal force output, has traditionally been measured using Manual Muscle Testing (MMT) techniques, which have been shown to have low reliability in children.\textsuperscript{15, 16} Hand Held Dynamometry (HHD) has shown promise in measuring maximal strength output in children, but no one has researched a protocol for using HHD to assess the strength of the trunk musculature.\textsuperscript{16-19} Furthermore, both MMT and HHD measure the maximal force output, whereas for trunk muscle control, as it relates to postural control, muscular endurance is likely the more important variable.\textsuperscript{2, 20} So it seems that neither of these methods, though currently used by PT’s in practice, have evidence-based applicability to the assessment of trunk muscle control. How to best measure the muscular control system of the trunk as it relates to postural control in children remains a largely important, unanswered question.

An alternative to manual muscle testing is the use of positional hold tests in supine flexion and prone extension to measure trunk flexor and trunk extensor strength/endurance respectively. This is a common practice among clinicians that, while logical, lacks justification in the literature. Normative research was attempted in the 1980’s for prone extension, though the premise was that the position was an indicator of vestibular function rather than strength.\textsuperscript{21, 22} One researcher looked at the quality and duration of hold for the supine flexion and prone extension tests and compared those variables to clinical measures of static and dynamic balance.\textsuperscript{20} Unfortunately, no one expanded upon this promising work. The only newer evidence that can be found for
normed use of supine flexion is in a rarely used tool, the Clinical Observations of Motor and Postural Skills (COMPS). The only current evidence for the use of prone extension is that a similar position, the “V-up”, is used to assess strength in the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2). This is the closest we have come to justifying our clinical usage of the test, and, unfortunately, this body of work has not been expanded upon in nearly twenty years.

The gap in the evidence is concerning on several levels. First, the research in the 1980’s was far from conclusive; anecdotal tests should not be used in clinical practice to discriminate between populations. Next, most rigorously researched, validated tests are re-normed each decade or so. Furthermore, there is reason to believe that as a result of nationwide changes in infant sleep position from prone to supine (“Back to Sleep”) in 1994, norms for prone extension, in particular, and possibly supine flexion, have changed in the ensuing years. So, it would make sound sense to revisit the topic starting with establishing a correlation between positional hold tests and functional balance skills. If that connection is established, the next step would be to re-establish norms for positional holds in young children.

Summary of Assessing Muscular Control Relative to Balance in Children

Based on the history presented here, it is logical to revisit the use of gross measurements of core muscle control in young children, using timed holds of the prone extension and
supine flexion positions. The following factors are paramount: 1.) A large, two-decade gap in data for trunk strength and how it relates to balance in children; 2.) The complex nature of balance makes it necessary to assess each system individually, yet the muscular system as it relates to balance must be assessed grossly ruling out use of other evidenced based tools such as HHD and MMT; and 3.) The nature of working with young children requires that a tool is quick, non invasive, and able to be incorporated into play.

Prematurity and Development of Muscular Control

Children born preterm (less than 37 weeks), even those considered “low risk”, present with a different developmental course than their full term counterparts, both early in development\textsuperscript{26-29} as well as into the elementary years.\textsuperscript{27,30,31} Because infants born preterm are not in utero long enough to develop physiological flexion, they often rest early in infancy in an extended, biomechanically disadvantaged position from which to learn to move.\textsuperscript{32} In contrast, infants born at full term rest safely in physiological flexion and are able to slowly gain extensor control thanks to the effects of gravity and emerging active movements. The preterm neonate, however, would be attempting extension with the muscles in an already shortened position and without any containment or helpful resistance, effectively being overcome by gravity.\textsuperscript{33} Theoretically, these infants would use their lengthened trunk flexors less and thus an imbalance would develop between the trunk extensors (strengthened, but only in the shortened position) and trunk flexors (overstretched, weakened).\textsuperscript{33} This effect on trunk control may be recognized as delayed attainment of motor milestones or may be subtle enough to go relatively unnoticed for the
early years. However, at school age, this imbalance or decrease in trunk muscle control could become recognizable and possibly even cause functional impairments.34-38

Significance of the Problem

Primacy of Postural Control:
Postural control is “both the anchor and launching pad” for everything that we do.39 We have long understood the supporting role of postural control to distal movement.40-43 It has been a targeted area of intervention for some patient groups. However, we haven’t always trained it in isolation for a large, diverse population, as is currently recommended in fitness circles.

Core training has traditionally been reserved for specific patient groups. Primarily, it has been used for prevention or rehabilitation of low back pain (LBP) and/or low back injuries.44-48 This usage of core training has a strong basis despite some evidence to the contrary.49,50

To move forward with the purpose of finding relationships between core muscle control and functional play skills, the divergent views in the current body of literature must be recognized, yet some assumptions must be made. For the current study, it is assumed that core muscle groups relate on some level to general mobility and overall function.40,41,43 Additionally, it is presumed that core muscle control must be in place for proper
development of gross motor skills. To paraphrase one group of researcher’s assertion of the primacy of trunk control in children: trunk control underlies nearly all functions: head control and thereby visual skills, eye-hand coordination, reach and hand function, respiratory support, and language production. Based on these ideas, it is important, as a standard of care, to assess the strength of these muscle groups in a standardized manner.

Standardized measurement of core muscle control should be of value in pediatric physical therapy practice, not only for diagnostic or evaluative purposes, but also to measure change over time in chronic conditions and furthermore to any condition as it relates to response to intervention. It is largely recognized that young children demonstrate an immense potential for neural plasticity and that early intervention is indeed beneficial. It is, therefore, critical that the profession close the gap in the literature for clinically accessible trunk strength testing between 5 and 8 years of age. Since trunk strength and stability are key building blocks for distal function and an important component of postural control, clinicians are in need of a fast, reliable, and inexpensive way of quantifying core muscle control in children.

**Significance of Prematurity:**

Currently in the United States, 1 in every 8 births is preterm. Preterm birth causes known variances in motor development even under low risk circumstances. It is important to compare the trunk muscle development in children born preterm to their full term counterparts to determine if the known differences in motor development, especially
at school age, are related to trunk muscle control so that timely interventions can be employed. In the preterm population, good postural control in infancy has been shown to relate to higher level of motor skill in toddlerhood, yet other research suggests that decreased motor control in the preterm population compared to full term peers at school age does not relate to functional impairments. Therefore, due to a paucity of evidence, it is important to further investigate the relationships between trunk muscle control and functional abilities in the preterm subset.

**Problem Statement**

Muscular control of the trunk is an important subsystem that likely contributes to postural control and balance. Postural stability and balance in turn are integral to nearly all movement activities. No direct correlations between function and specific measures of core muscle control exist for young children. No reliable and valid method currently exists for assessing trunk or “core” muscle control in children. Research into prone extension and supine flexion hold times, presumably related to trunk muscle endurance, was conducted approximately twenty years ago and has not been updated despite changes in recommended sleep position of infants and changing anthropometric profiles of children, both of which could directly affect what is considered typical in this decade.

Children born at preterm present with special circumstances, which may adversely affect development of trunk muscle control, leading to a decreased level of motor skill at
school age compared to full term peers. The literature has not conclusively established the nature of the relationship between postural control and functional abilities in school age children born preterm.

It is also unclear, based on the current literature, whether levels of core muscle control directly relate to functional balance and motor play skills in typically developing populations born either full term or preterm. Obviously, strength contributes to function; but, is the core, in and of itself, a key area that should be targeted in isolation? Answers to these questions would help to drive treatment programming for all children experiencing difficulties with balance and/or demonstrating impairments in motor skill development.

**Purpose of the Study**

The purpose of this study is to compare core muscle control to balance and functional motor ability within a group of typically developing Kindergarteners (ages: 5-6 years). Measures include: height, weight, Functional Reach Test (FRT), Prone Extension Positional Hold Time, Supine Flexion Positional Hold Time, and Scaled Scores on 3 domains of the BOT-2: Balance, Speed and Agility, and Strength. This project also aims to assess whether preterm birth adversely impacts core muscle control as compared to counterparts born at term.

**Research Questions/Hypotheses**
1. Do the variables of gender, height, weight, and age in a convenience sample of 5-6 year old children affect core muscle control as measured by isometric hold time of prone extension and supine flexion?

2. Does core muscle strength as measured by positional hold times of prone extension and supine flexion relate to functional balance and functional motor skill?

3. Does core muscle strength vary between full term and preterm groups?

Assumptions and Limitations

Assumptions include:

1.) Muscular endurance is more relative to postural control than maximal exertion\(^2\)

2.) The core can be effectively divided into 2 key components: a.) trunk flexion b.) trunk extension\(^{44}\)

3.) Supine flexion hold time grossly measures muscular control of the trunk flexors\(^{59}\) in the absence of an abdominal exercise that comprehensively activates all muscles in the abdominal group\(^{44}\)

4.) Prone extension hold time grossly measures muscular control of the back extensors

5.) The terms “trunk” and “core” and “control” and “strength” will be used interchangeably
Possible limitations include:

1.) Descriptive research can only explore relationships, not show causality

2.) There are confounding variables which will not be controlled for: level of extracurricular activity and early intervention or lack of which may affect development of core control; confounding variables that the study will attempt to control for by matching groups include: age, gender, height, weight

3.) The sample is one of convenience in a suburban school district. The district advertises cultural diversity, but is located in a socioeconomically affluent area.

4.) Each individual principal (n=12) was given power by the participating district to either participate or not participate in the recruitment procedures approved by the IRB; this practice could further bias the sample and/or decrease sample size.
Typically, infants begin moving into extension against the safe containment of physiological flexion within the first month of life. Traditionally, it was understood that the infant develops control of her body following a cephalocaudal progression starting with head control and moving distally to the trunk, arms, and finally the legs. According to a more current, Dynamic Systems Theory approach, it is recognized that development of posture occurs as a result of the interaction of many variables, including: muscle control, anthropometrics, sensory functioning, and the environment. Therefore, while a general sequence of development does occur as a result of biomechanical constraints and forces acting on a system under the constant of gravity, there is not one precise, or even preferred, means to the end.
Within the first year of life, the general sequence of development is that trunk extensor strength is gained and becomes balanced with flexor strength; achieving these gains in force allows for the development of sitting and standing skills. Learning to walk independently, a marked motor milestone, requires mastery of many systems in general, but particularly, dynamic pelvic control. It has been postulated that, with practice, dynamic, articulated control of segments for walking is gained in an ascending fashion: trunk, shoulders, and finally head (at least 1 year after the commencement of independent walking). This would lead some to believe that control of the trunk is the most critical area of development leading to independent walking.

However, following the Dynamic Systems approach, it must be recognized that many factors interact to produce movement. So, the primacy of the trunk or order of achievement of segmental control are much less important than the realization that many parts work together to make a whole. Control still must be gained in each part, so, the order may be less important than the interaction between systems. If one system is interacting in a less effective manner, all systems will adapt accordingly. Trunk muscle control ultimately must be effective, and not at only one point in development, but always. The way we measure control tends to drive how we design interventions to improve control. In the context of this study, we are measuring control in a very uni-dimensional manner for simplicity and practicality implying that effective trunk control can be built via rote strengthening. We must also keep in mind that some research reports core strengthening should be more complex i.e. in the context of a dynamic activity with multiple levels of control, at least in the case of young adults.
Between the ages of 3 and 6 years (most observable in 6 year olds), children often use an ‘en bloc’ strategy of the head and trunk, wherein they limit the degrees of joint freedom by maintaining stiffness in the head and trunk while relying on the pelvis, to maintain postural control during walking tasks that involve balance challenges, until adult like strategies of postural control are achieved at around 7-8 years of age.\textsuperscript{57} Two additional authors note a similar age range (4-6 year olds) during which postural responses are, generally speaking, less coordinated.\textsuperscript{2,69} The current study will further investigate this apparently critical time period for trunk control development, but will narrow the focus to the end of the range: from 5-6 years of age.

Muscular control of the trunk is of primary importance in the development of advanced locomotor skills such as running, jumping, and hopping.\textsuperscript{70} The balance between trunk flexion and extension that must occur for the development of sitting balance appears to dissipate by school age, as evidenced by Sinaki and colleagues who observed that across all age groups (n=246; 5-18 years of age) back extensors were stronger than the flexors. The current study will provide further insight into the balance between trunk flexor and trunk extensor strength in the 5-6 year old age group.

\textbf{Existing Tools to Assess Balance in Children}

Balance is assessed in general practice in a functional context. It can be assessed either implicitly or explicitly. For example, the PEDI (Pediatric Evaluation of Disability
Inventory), for populations identified with a diagnosis likely to result in a delay\(^3\), and the SFA (School Function Assessment), for students Kindergarten through Grade 6, target participatory, daily life activities with balance implied as an underlying factor contributing to performance on these measures.\(^3,4\) Other tools, such as the PDMS-2 (Peabody Developmental Motor Scales- 2\(^{nd}\) edition), BSID-3 (Bayley Scales of Infant Development-3\(^{rd}\) edition), BOT-2 (Bruininks-Oseretsky Test of Motor Proficiency-2\(^{nd}\) edition), and Movement ABC-2 explicitly list balance as a stand-alone domain to be tested. These tests focus on assessing development of gross motor milestones as a means to discriminate typical from delayed development.\(^5-8\) Even more explicit are the FRT (Functional Reach Test)\(^9-11\), Pediatric Berg Scale\(^13\) and the timed ‘Up & Go’ (TUG)\(^12\) tests; these tools exist purely as quick clinical assessments of balance abilities without regard to overall development. Any of these tests will produce a similar result in the context of, is balance function within expected parameters or not?

Balance is a complex system with many interrelated component parts. If balance is impaired, trunk strength may be suspected as one piece of the puzzle, but, how can that theory be objectively confirmed? Several tests are helpful in answering this question. The P-CTSIB (Pediatric Clinical Test of Sensory Interaction for Balance) discriminates between the sensory systems (vision, proprioception, vestibular) that contribute to postural control\(^71\), but it can neither confirm nor rule out musculoskeletal or neurological processes relative to balance. So, these variables must be assessed separately. Neurological assessment guidelines exist, such as reflex testing\(^72\), Modified Ashworth Scale for muscle tone\(^73\), and the Tardieu Scale\(^74\) for spasticity. However, like the P-
CTSIB, these tools shed no light on musculoskeletal system function. Range of motion can be assessed simply enough with goniometry to determine if muscle length or flexibility is a factor limiting balance control. As for actual muscle control or strength, many muscles can be quickly assessed with manual muscle testing or dynamometry; however, the trunk muscles as they relate to balance are not conducive to these standard procedures, so other methods must be sought.

**Existing Tools to Assess Musculoskeletal Strength in Children**

There is not currently a gold standard for clinically measuring trunk muscle control in children. \(^{58}\) Manual muscle testing is inadequate to assess the trunk control of children due to reliability issues. \(^{15,16}\) Hand held dynamometry is more reliable \(^{16}\), especially in certain muscle groups. \(^{18,19}\) However, it measures maximal force exertion, which may not be comparable to the type of muscular control needed for postural control. Postural control needed for sitting, standing, or most any sustained, upright positioning against gravity, is more likely relative to muscular endurance. \(^{2}\) Further, even if it were valuable to measure maximal exertion of these muscles, pediatric norms do not exist for the abdominal and back extensor muscle groups. So, the typical measures, MMT or HHD are neither reliable nor currently accessible for assessment of trunk muscle control in children.

Additionally, any measure of muscular control is quite challenging to administer objectively, reliably, and in a play based manner simply due to the emerging
abilities/willingness of young children to maintain attention levels and follow multi-step directions. Importantly, both attention and the ability to follow directions are necessary to obtain scores in standard muscle strength measures, such as manual muscle testing and hand held dynamometry. Classic texts such as Daniels and Worthingham’s Muscle Testing and Muscle Testing and Function put forth guidelines for assessing the strength of the abdominals and back extensors, but only the former reference guide provides guidelines for positioning children for generalized strength assessment. This information provides a helpful guide in the sense that the positions are easy to replicate and conducive to play. To measure trunk flexor strength, the test recommends 4 through 5 ½ year olds do sit-ups and 8 year olds hold a curl position. To measure back extensor strength, the book describes a flying position for 5 year olds that involves the child wrapping her legs around the therapist’s waist. For 8 year olds, the text describes an “airplane” position that is very similar to the prone extension position. These guidelines are a starting point in the quest for practical measure of trunk muscle control in young children with manual, low-tech means that are readily available to clinicians. However, this text lacks reliability studies as well as objective norms for both trunk flexion and trunk extension in the 5 to 8 year old age groups. Without norms it is not possible to discriminate whether scores obtained are typical or not.

As an alternative to the above methods, positional holds of prone extension and supine flexion have been used to grossly measure muscular endurance of the trunk. Norms for prone extension and supine flexion hold times do exist, but were compiled primarily in the 1980’s and are reviewed below. The current study investigates whether
measuring positional hold times, such as prone extension and supine flexion, could provide a new gold standard for measuring trunk strength in young children.

**Evidence for Addressing Core Muscle Control in Isolation**

Core muscle strengthening and core stability training have become buzzwords in fitness circles, and the concept is now affecting how we approach strengthening for all populations, including in pediatric physical therapy, before it has been substantiated by research. In the current literature, the relationship between core muscle control and athletic function is moderate at best. A literature review and some research recognize core training as a key component in the athletic skill level of young adults, even advocating it as an integral part of modern sports training programs. Additionally, case studies have shown a positive correlation in specific populations such as patients status post unihemispheric stroke, and individuals with Multiple Sclerosis (MS). However, another body of research, including a review of the strength and conditioning literature has shown that there is no significant relationship between trunk strength and function neither relative to general measures of static/dynamic balance nor to sport specific performance. There is enough contradictory evidence to judge the benefits of core training on functional athletic performance as inconclusive. On the other hand, case studies that show a relationship between core muscle training and functional outcomes in specific disabilities is promising.
Of the previously discussed research, very few of the studies addressed a correlation between strength and postural control in young children. One project studied a group of typically developing 6-7 year olds (n=30) and reported insignificant correlations between trunk muscle strength and scores on static/dynamic balance measures involving a balance platform. Again, the research that shows a positive correlation is relative to very specific populations. For example, a case study showed that core work improved functional outcomes in children with Developmental Coordination Disorder (DCD), and another showed a positive correlation between a trunk/leg strength program (theorized to support core stability) and walking speed in adolescents with Cerebral Palsy (CP).

There is clearly a lack of research showing correlation in typically developing populations of young children, especially in regard to core muscle control and functional performance, either on the playground or in gross motor skill development. The current study aims to address this gap in the literature.

**Existing Norms for Prone Extension in Children**

Therapists currently use the “superman” or prone extension position in practice as a gross measure of the extensor portion of core muscle strength. The usefulness of this measure is limited to tracking an individual’s progress from baseline measures, because current norms do not exist. There is even disagreement as to what the test actually measures: reflex integration, vestibular function, or muscular control.
The prone extension researchers of the 1980’s primarily sought to collect normative data, to explore the discriminative capabilities of the test, and to standardize the procedures of the prone extension test first described by Ayres. Ayres’ work viewed the prone extension position as a developmental indicator of integration of the tonic labyrinthine reflex. Later, as the reflexive nature of the move was questioned, the test position was used to evaluate integration of sensory information, specifically, vestibular processing capabilities. Ayres proposed that starting at age 6, children should be able to hold the prone extension position for 20-30 seconds, and theorized that an inability to do so likely indicated the child had difficulty processing vestibular information. Most of the prone extension investigators accepted the vestibular nature of the test while one recognized it, as we do today, as a measure of trunk control. Sellers also confirmed that antigravity core muscle activation is related to dynamic postural (balance) control as measured by the ability to walk forward on a balance beam. Additionally, she concluded that prone extension is a reliable, readily accessible means of initial and ongoing assessment of motor control in young children.

One of the prone extension studies explored if the prone extension position could be used to discriminate between children who were typically developing and those who were at risk for learning disabilities. To achieve this, they recorded both the quality of movement and duration of hold time in typically developing children (n=242) to a much smaller group of children identified with learning disabilities (n=10). There is not enough power in that study to determine the discriminative abilities of the test. In the current
project, the position will be investigated as a discriminative measure between groups of kindergartners in regular education (born at preterm or full term).

There is continuity among the studies in how the test is administered, making it easy to replicate.\textsuperscript{20-22} The authors agreed that a subject’s head and upper trunk should be lifted with shoulders abducted to approximately 90 degrees, forearms pronated, and elbows flexed; legs should be fully extended.\textsuperscript{20-22} Harris felt that this motion recruited the shoulder retractors as well as coordinated extensor muscle action of the neck, trunk, and hips, though, in her interpretation these movements were all driven by vestibular function.\textsuperscript{21} For the purposes of the proposed project, Harris’ theory is interpreted using a dynamic systems approach, with volitional muscular control, rather than vestibular system hierarchy, as the driving force. In this case, it seems that the prone extension position is a comprehensive test of the extensor portion of what is now routinely called the core.

Because of the complex nature of this test’s administration, it is valid to consider at what age children can cognitively follow the multi-step instructions as well as physically assume the position. All studies included 4 year olds\textsuperscript{20-22} Based on their results, two authors felt that the test could not be used reliably with four year olds,\textsuperscript{21,22} while one noted that 4 year olds performed differently than 5 year olds and speculated as to the causes, but ultimately they were indeterminable.\textsuperscript{20} For the purposes of the current study, the evidence suggests that prone extension testing should begin no earlier than age 5.
Norms collected by these earlier studies, despite being dated, provide a helpful starting point for current practitioners. Norms relative to the population of the current study: 5-6 year olds are reviewed here. The Harris study did not include 5 year olds; the study by Gregory-Flock and Yerxa found that 5 year olds (n=51) held the position for a median of 30 seconds with a mode of 10 seconds.\textsuperscript{21,22} Other research found that 5 year olds (n=72) could hold the prone extension position for a mean of 9.93 seconds +/- 7.27 seconds.\textsuperscript{20} A benefit of the Gregory-Flock and Yerxa study is that results were presented in quartile ranges. They concluded that scores falling into the lowest quartile ranges (5 yr old: 0-9 seconds; 6 yr old: 0-48 seconds) were indicative of vestibular dysfunction as opposed to the present project’s assertion that it is related to musculoskeletal system control.\textsuperscript{22} Nonetheless, their concept of cut-offs is useful when using the position discriminatively.

The studies reported huge differences in mean hold time for 6 year olds. Harris’s mean hold time for 6 year olds (n=28) was 28.93 seconds +/- 5.676 seconds.\textsuperscript{21} Gregory-Flock and Yerxa found 6 year olds (n=48) held prone extension for a median of 62.5 seconds and a mode of 60 seconds\textsuperscript{22}, much longer than in the Harris study. However, it should be noted that Harris cut-off the timing at 30 seconds, assuming that was approximately the maximum normal time achievable\textsuperscript{21}, while Gregory-Flock and Yerxa did not use a cut-off time.\textsuperscript{22} Notably, Gregory-Flock and Yerxa had a larger sample size which included a greater proportion of boys, possibly increasing the mean hold time: 50% boys (n=14) to 50% (n=14) girls in the Harris study compared to 58% boys (n=28) to 42% girls (n=20) in the Gregory-Flock and Yerxa study, which could have contributed to the longer hold times found by the latter group.\textsuperscript{21,22}
The present project will fill in the gaps identified in the literature in several ways. First, it will focus only on a peer group known to be able to reliably perform the test: the 5-6 year old age group; and, gender will be investigated as a potential confounding variable. Next, the current study will compare old mean hold times to current ones as a way to explore trends over time. Finally, the current study will compare results between two populations of children, those born at term and preterm, with the goal of having equal participation in groups.

Existing Norms for Supine Flexion in Children

Researchers evaluated trunk flexion norms in groups of typically developing children, using modified manual muscle testing guidelines, to measure force in a modified sit up test.\textsuperscript{59,61} One author investigated the concept in the context of girls only\textsuperscript{59}, while two others researched the use of the position for both genders.\textsuperscript{60,61} Mean muscle strength in 5 year olds ranged from 3.77 +/- 1.48 to 4.3 +/- 1.00 out of 5 \textsuperscript{59,61}, while in 6 year olds the mean was 4.4 out of 5.\textsuperscript{59} Romero added that children under 5 years of age could not coordinate the recruitment of both the neck flexion and trunk stabilizers to complete a sit-up.\textsuperscript{61} A drawback to the generalizability of these results to the general population is that Baldauf et al excluded boys and also excluded subjects who could not fully flex their neck against gravity. By eliminating these potential outliers, they may have obtained skewed results.\textsuperscript{59} A drawback to both studies is that there is documented subjectivity when examiners must distinguish between a Grade 4 (good) and a Grade 5 (normal)
manual muscle test (MMT) score; the subjectivity of MMT introduces potential threats to reliability and warrants caution in generalizing the results.\textsuperscript{15} The proposed project seeks to use an isometric hold time of the supine flexion position as a more objective scoring system than modified manual muscle testing.

Lefkof (1986) examined trunk flexor strength in typically developing children aged 3 to 7 years old using two measures: 1. the number of repetitions completed of the half-hold hooklying sit-up and 2.) duration hold of the supine flexion position.\textsuperscript{60} The first measure is not applicable to the proposed project, because the author found that children were first able to consistently complete hooklying situps at 6 years of age. However, most 3 year olds (95\%) were able to participate in the supine flexion activity to demonstrate isometric strength of trunk flexors.\textsuperscript{60} A similar supine hold position was used in another study of 4-5 ½ year olds\textsuperscript{20}, confirming it as an appropriate means of measuring supine flexion for the population being studied in the proposed project. Combining data from the two studies, 5 year olds averaged between 14.91± 5.52 seconds and 29.5 seconds in the supine flexion hold position; while 6 year olds averaged between 52.0 and 55.4 seconds, respectively.\textsuperscript{20,60}

The Sellers study is the only one that investigated a relationship between performance on the supine flexion and prone extension tests of trunk strength to performance on balance tests. The method of testing balance was simple; the investigators used a 4 point qualitative scale to score one task for static balance (tandem stance) and one task for dynamic balance (balance beam walk). The author interpreted her data to mean that
supine flexion is more important than prone extension to the development of both static and dynamic balance. The proposed project aims to measure balance and functionality using standardized assessment tools to further clarify this relationship.

**Interaction of Anthropometric Features, Age, and Gender**

Many factors, such as age and anthropometrics, may affect measurement of trunk muscle strength. There is conflicting data in the literature, and therefore, a wide range of opinions among researchers about this. In 1984 Baldauf et al found a “very strong” correlation between age, height, and weight; all showed statistically significant relationships to trunk flexion muscle grade, but Romero, who used similar methodology, found that age was the only significant variable tested that affected trunk flexion muscle grade. When measuring trunk flexor strength, using an isometric hold, only height and age positively correlated with trunk flexor strength. Authors that used hand held dynamometry found that just age and weight were significant factors in the ability of children 3.5 through 16 years old to produce force. Other data showed that neither height, nor body weight, nor head circumference relative to height were correlated with trunk flexor strength.

In regard to differences between the sexes, authors almost universally found no significant difference between the sexes at younger ages (4 through 8 years old); the difference is first appreciated in the later elementary years, at around 9-10 years of age.
age, which should not be relevant given the current targeted population (5-6 year olds). One notable exception is the Sellers study, which studied the 4-5 1/2 year old population and showed no difference between strength, but did find a subtle difference in the quality of the prone extension hold and static balance test, with girls performing slightly better than boys.

Because of the conflicting findings with regard to the impact of height, weight, and age on trunk strength, these will be recorded in the proposed project and analyzed as co-variables. To attempt to control for differences among the sexes, the proposed project will attempt to recruit similar numbers of females relative to males. Furthermore, the BOT-2 assessment tool was chosen because it allows for gender specific scaled scores as well as mixed gender group scaled scores.

### Targeted Age Range of Participants

There is a gap in the literature, resulting in no norms reported for trunk flexor or extensor strength in children aged 5 through 8 years old. Most improvements that occur in trunk flexor strength were noted to occur between ages 4 and 5 years. When using the prone extension position, it was found that 4 year olds could not reliably demonstrate the position, but 6 year olds could. While 5 year olds did not participate in that particular study, other research showed that the prone extension test could be used reliably with children starting at 5 years of age; however, they also found that 5 year olds and 6
year olds scored statistically different than one another. So, by age 5, students should have stable performance in both prone extension and supine flexion positional holds, and therefore, be fully capable of participating in this type of testing. But, 5 and 6 year olds may demonstrate statistically significant differences in skill level. However, it should be noted that at the time of these studies, in the 1980’s, many children entering Kindergarten were closer to age 5 than to age 6. That is no longer the case. Children now enter kindergarten well into their fifth year. Subsequently, it is proposed that both 5 and 6 year olds be included in the group of participants. Since both tests are appropriate to administer starting at age 5 and this age corresponds with the beginning of the gap in norms, Kindergarteners, either age 5 or age 6, were determined to be the ideal age level for participation in this study. Including both age groups will allow comparisons to be made within a peer group. Furthermore, in the participating school district, kindergartners do not participate in physical education classes, making kindergartners a group that is convenient for 2 additional reasons, 1.) they may be underserved in regard to motor skill monitoring and 2.) they will be unlikely to be biased by a training effect confounding variable.

**Differences in Development for Children Born Preterm**

Children born preterm (at or before 37 weeks gestational age) develop motor control differently than their full term counterparts. Infants born prematurely are subject to a long list of risk factors for delayed motor development, resulting from neurological immaturity and/or insult. Even preterm infants with VLBW (Very Low Birth Weight)
but no known pathology demonstrated a 23% rate of delayed walking attainment compared to only a 4% rate in a full term group. Why? The immature brain itself is vulnerable and subject to unique neurodevelopmental risks compared to the term brain. While there tends to be an inverse relationship between gestational age and severity of impairment (decreasing gestational age equals increasing levels of impairment), this is not an absolute. Infants born relatively close to term (33-35 weeks gestational age) can demonstrate significant neuromotor delay, and infants born extremely preterm can develop normally. Gestational age, then, is not the primary factor influencing future development. Rather, generally speaking, infants born preterm have different levels of gross motor performance based on their neonatal course, making it useful to consider 2 groups, high risk and low risk. Infants targeted for participation in this study fall into the low risk category.

**Low Risk Preterm Infants**

Infants without known diagnosis in the neonatal period are categorized as low risk. The entire gross motor developmental curve in these “normal” preterm infants has been found to be different than that of typical, full term infants up until 18 months of corrected chronological age. This finding of decreased motor performance compared to full term peers has been constant through the 1980’s and 1990’s despite advanced perinatal and neonatal care in the latter decade. Qualitative descriptions of these differences in behavior between “normal” preterm infants at term age and their full term counterparts include: decreased flexor tone, decreased neck control in sitting, hyperresponsive
reflexes, and asymmetry of movement. In the mobile paradigm, preterm infants, categorized as “low to moderate risk” of developmental delay, demonstrated an increased rate of kicking (note: An increased rate of kicking is a negative finding that has been found to relate to delayed attainment of ambulation), but decreased associative learning, short term memory, and long term memory as compared to age matched full term infants. The aforementioned limitations are noted early in development, but the effects can last for years. Preterm infants show a decreased repertoire of postural control strategies that seem to be functional compensations in early development, but end up being a limiting factor for developing more refined movements, and therefore, may be related to minor neurological dysfunction at school age.

Unfortunately, normal development in infancy did not predict normal neurocognitive development at school age for a heterogeneous group of preterm infants longitudinally followed from hospital discharge until 8 years of age. So, while we are able to predict that early delay will persist, we are unable to predict whether preterm infants with typical development will always be on target, or, if neurological dysfunction may be evident, once these children reach school age. In spite of these findings, Svien discovered a paradoxical relationship. He found that while children born 5 to 10 weeks prematurely did have statistically lower scores on a standardized test of motor development (the BOTMP: Bruininks-Oseretsky Test of Motor Proficiency-1st edition), where 16 of 22 subjects scored 1 standard deviation below the mean), by school age (7-10 years old), compared to a control group, the preterm group did not experience functional limitations, neither in regard to participation in sports (per questionnaire) nor
in overall cardiovascular fitness as measured by a maximal treadmill test. These results are encouraging from an ability perspective, but still leave questions to be answered. For example, the author felt that the BOTMP measured strength and endurance, however, it also looks at postural control and balance, which may have been a large factor, contributing to decreased scores. The current proposed study aims to compare trunk strength and control to balance ability in a functional context at early school age (5-6 years old) to see if a difference exists between full term and preterm infants.

OUTCOME MEASURES:

**Prone Extension Hold Time**

The subjects will complete a timed hold of the prone extension position to measure the extensor portion of core muscle control. It is felt that this position recruits the shoulder retractors as well as coordinated extensor muscle action of the neck, trunk, and hips. The theoretical basis of this test is also supported by research that found that antigravity core muscle activation is related to postural (balance) control and that prone extension is a reliable and accessible means of initial and ongoing assessment of the muscular component of balance control in young children. It is intuitive that muscular control of balance relates to function, but the connection has not yet been made in the current literature.

**Supine Flexion Hold Time**
The subjects will complete a timed hold of the supine flexion position to measure the abdominal portion of core muscle control. This positional hold test is more consistently attainable and measurable in young children (3-7yrs) than isotonic hooklying sit-ups and is significantly related to static and dynamic balance in children. The COMPS, (Clinical Observations of Motor and Postural Skills), a screening tool for children with mild motor incoordination, uses this position to grossly measure trunk muscle strength. The position is widely used clinically as an anecdotal tool to differentiate core muscle strength deficits from other deficits in children displaying decreased postural control. This test is quick and simple, but functional relevance needs to be established.

Functional Reach Test

The Functional Reach Test (FRT) will be used to measure balance function for the purposes of comparing core muscle strength to a functional task (dynamic balance). The FRT has been judged to be adequate as a discriminative and diagnostic test of feed forward control of balance. This test was first developed and utilized as a measure for adults. In 1994, the FRT was reported to be of value in the pediatric population by Donahoe et al, who felt that the test procedures incorporate assessment of several systems: strength, biomechanics, sensory function (proprioceptive and vestibular systems), and motor planning. Further, the authors felt that results of this test provide information that is universally relevant to home, school, and recreational activities and/or routines. The authors tested 21 subjects with typical development in the 5-6 year old age
group and found a mean reach of 21.17 cm with a 95% confidence interval of 16.79 cm - 24.91 cm. They also presented scores of “critical reach”, which was 2 standard deviations below the mean and might indicate a delay; for the currently studied age group, the critical reach score was 16.79 cm. The authors felt that variance in scores was a function of age and not related to weight, gender, or arm length. Norris et al also looked at the FRT in 3-5 year old children without disabilities, including 22 children in the 5-year-old age group. In this group, they found a mean reach of 15.7 cm +/- 4.4 cm. The range was 6.8cm to 22.7 cm. Their 95% confidence interval of the mean was 13.8 cm- 17.7 cm. These authors found that weight did explain some of the variance within the group, but admit that this may be difficult to ascertain due to the small population size. The FRT is a quick to administer, clinically relevant tool that will be useful in this study to provide a functional measure of balance.

**BOT-2**

There are several discriminative, norm-referenced tests available which include a balance sub-scale as part of the larger test of gross motor skill development in young children. Of these tests, the BOT-2 was the clear choice for the current study. The test was designed functionally with items on this test selected, not just because they measure underlying motor ability, but also because they represent functional skills. Other valid, reliable discriminative tests of motor development that were considered as similar, but rejected include: 1.) The PDMS-2 (Peabody Developmental Motor Scales), because it has one balance subscale with minimal test items at the 5-6 year age level, making it less
likely to show variance among subjects\textsuperscript{5}; 2.) The Movement ABC-2, because it is not used in clinical practice in this region, and 3.) The BSID-3 (Bayley Scales of Infant Development) because it is not normed for the targeted age range of this project (5-6yrs). The PEDI (Pediatric Evaluation of Development Inventory), while a functional measure, is designed primarily for populations with a known physical impairment\textsuperscript{3} and would not have the capacity to show variance in a population of typically developing children.

The BOT-2 subtests that were selected for this project were: Balance, Running Speed and Agility, and Strength, because items on these tests measured, in a standardized way, the intended target: functional strength and functional balance. The bilateral control section was not chosen, though it combines with Balance to produce an overall “coordination score”, because it focuses more on upper body movements than on functional gross motor play. The proposed study will measure the strength subsystem of postural control and explore whether or not a relationship exists between core strength and functional balance and motor ability.
CHAPTER 3: METHODOLOGY

Research Design

A correlational research approach was used to determine if there is a relationship between anthropometric variables, core muscle control as measured by isometric hold times in prone extension and supine flexion, functional postural control skills/balance, and/or functional gross motor skills. Data was collected cross-sectionally. The two levels of the independent variable were: children born preterm and children born full term. A potential confounding independent variable includes the anthropometric features of the subjects. Dependent variables are: Prone Extension hold time, Supine Flexion hold time, FRT score, and scores on BOT-2 subscales of Balance, Speed and Agility, and Strength.
Hypotheses

1. Scores on the Functional Reach Test will correlate positively with scores on tests of trunk muscle control.
2. Scores on the BOT-2 subtests will correlate positively with scores on tests of trunk muscle control.
3. Children who were born preterm will demonstrate decreased trunk control as compared to those born at full term.

Subject Selection

A convenience sample of students enrolled in Kindergarten was used. Recruitment occurred at Dublin City Schools, a local suburban school district. Projected Kindergarten enrollment for this school district for the 2010-11 and 2011-12 school years was 927 students. Recruitment flyers, which included a brief description of the project as well as inclusion criteria, were available at building curriculum nights. The flyers were also sent home with all Kindergartners per each building principal’s discretion. Subsequently, recruitment occurred at 9 of the 12 elementary buildings within the district.

Inclusion Criteria

Subjects met the following criteria: enrolled in kindergarten, aged 5 through 6 years old, in good health, and parent/guardian provided informed written consent after full
disclosure. Students were asked for verbal assent using an age appropriate script prior to and throughout the testing.

**Exclusion criteria**

Subjects scores were excluded from the study if they had a parent reported history of medical, neurological, orthopaedic (including wore any type of orthotic device), balance, or visual disorders or had ever been treated for neck pain/injury, had any history of back pain/injury (McGill 1998) or had been treated for an ear infection within the past 6 weeks. Subjects may have had a complicated neonatal course. However, subjects’ scores were excluded if they had a formal diagnosis of IVH (Intraventricular Hemorrhage) or PVL (Periventricular Leukomalacia) as reported by parent/guardian. Approval was obtained from the IRB at the Ohio State University and through the office of Student Services at Dublin City Schools.

**Enrollment Procedures**

Parents who made contact with research personnel were given a copy of the Parental Permission for Child’s Participation in Research, the HIPPA Research Authorization Form, and a Student History form. The researcher was available to provide further information and assistance on an as needed basis. All documentation was reviewed one
final time prior to testing. Participants were given an opportunity to voice their consent using an age appropriate assent script prior to as well as throughout testing. Students were tested at their home school building either before or after their AM or PM Kindergarten session. Parent/guardian was able to attend/view testing session if desired. The tests were administered in the following order:

1. Anthropometrics in random order (height, weight)
2. Functional Reach Test
3. Positional Hold tests in random order (Supine flexion and Prone extension)
4. Subtests of the BOT-2 in random order (Balance, Strength, Speed and Agility)

Completion of all tests took 30-45 minutes. All recruitment, testing, and data collection was completed by a single researcher.

**Instrumentation**

Anthropometrics:
Height was measured using a meter stick attached to the wall. Students were asked to remove their shoes and stand facing the researcher looking straight over the researcher’s shoulder. Weight was measured using a calibrated scale. Subjects were asked to remove their shoes and stand quietly on the scale until “their number” appeared.
Prone Extension Hold Time:

This research project utilized the standardized protocol for prone extension adapted by Gregory-Flock & Yerxa from Ayres\textsuperscript{22,90} with the exception of an initial verbal cue that they pretending to “fly like an airplane” paired with a visual demonstration by the researcher. Participants were asked to lie on their stomachs on a mat and were then instructed in the movement in a 3-step sequence with support during the practice trial to avoid fatigue. 1.) Lift the upper body (head, chest, and arms) only with shoulders abducted approximately 90 degrees, forearms pronated, and elbows flexed 2.) Lift the lower body only (knees and hips extended and lifted so legs are off of the surface) 3.) Lift both the upper and lower body simultaneously. The practice trial was followed by a 1-2 minute rest break. For the test trial, subjects were instructed to hold the position for as long as they could. Timing of the test trial began when the subject succeeded in lifting head, chest, arms, knees, and legs off of the floor and was stopped when any of those parts touched the floor. Subjects were scored on the best of 2 test trials.

Supine Flexion Hold Time:

The protocol for measuring isometric trunk flexion was used as described by Lefkof\textsuperscript{60} with the exception that the researcher described the movement to the student as “rolling up like a roly poly bug” paired with a visual demonstration of the position by the researcher. One practice trial was administered with support to prevent fatigue. Subjects started on a mat lying on their backs and were assisted to “hug” themselves (arms crossed over chest) and placed with feet flat on floor, knees flexed to approximately 90 degrees. They were instructed to “roll into a ball” by lifting head and shoulders off the ground and simultaneously bringing knees upward toward their chest. After the practice trial,
subjects were given a 1-2 minute rest. For the test trial, subjects were instructed to hold
the position for as long as they could. When the position was correctly assumed, timing
began. Timing was stopped when the subject’s head, arms, or legs began to drop out of
initial position. Subjects were allowed 2 timed test trials; data was analyzed on the best
of the 2 test trials.

Functional Reach Test (FRT):
The FRT was administered as described by Norris et al.9 Subjects were instructed to
remove their shoes and socks and stand with their right shoulder against the wall and
their feet behind a taped line on the floor perpendicular to the wall. A level yardstick was
attached to the wall at the height of the subject’s acromion process. The subject was
given a visual demonstration paired with verbal instructions and was physically assisted
as needed to get into position: hand fisted, right arm flexed to shoulder height. The
subject was then instructed to reach as far forward as possible without falling or stepping.
The subject was given 2 practice trials. On the test trial, starting and ending
measurements were taken from the third metacarpal; the test trial was considered
unsuccessful and scored 0 if the subject took a step, touched the wall, or needed physical
assistance from the examiner. Successful trials were recorded as the difference between
end position and start position.

Bruininks-Oseretsky Test of Motor Performance- 2nd edition (BOT-2):
The BOT-2 subtests that were administered for this project were: Balance, Running
Speed and Agility, and Strength. The test was administered per standardized testing
procedures described in the test manual. The Balance subtest included: standing on a taped line as well as on a test beam under a variety of conditions: tandem (one foot in front of the other, not touching), heel to toe (one foot in front of the other, touching), and single leg stance. Conditions also included eyes open or eyes closed. Per test protocol, subjects were allowed a second trial if they did not obtain a maximal score on the first trial. The Running Speed and Agility subtest included: 50 feet “shuttle” (down and back) run, stepping side to side over the beam, stationary hopping, hopping side to side over a line, and jumping with both feet together side to side over a line. Per test protocol, these items were only administered a second trial if the subject tripped or fell on the first trial. The Strength subtest included: a long jump (2 footed forward jump measured for distance), sit-ups, push-ups (knee or full), wall sit hold, and V-up hold (similar to prone extension, but shoulders are fully flexed rather than abducted to 90 degrees). Per test protocol, only the long jump test was administered a second time if the child tripped or fell on the first trial.6

Data Analysis

Statistical analysis was completed to accept or reject the null hypothesis. Tools chosen were the Pearson Product Moment Correlation and One-way ANOVA (Analysis of Variance). Level of significance was set apriori at $p < 0.05$. SPSS for Windows, Chicago software was used for generating all statistical analysis.113
Summary

This study evaluated relationships between core muscle strength and functional balance/motor play skills. The study also sought to compare core muscle control in children enrolled in regular education born at full term to peers born at preterm. Information was gathered from each participant’s parent/guardian regarding gestational age at birth and general health of the subject. All subjects participated in measurement of height/weight, timed hold tests of prone extension and supine flexion, the FRT, and 3 subtests of the BOT-2.
CHAPTER 4

DESCRIPTION OF THE STUDY/ARTICLE

Abstract

Development of balance and functional motor skills in children is a complex phenomenon that requires the interaction of many systems. There is not currently one reliable, practical, play-based method to measure the musculoskeletal contribution of the trunk to balance and gross motor function in young children. **AIM:** To investigate relationships between anthropometrics, age, measures of trunk muscle strength, and functional measures of balance and gross motor skill in Kindergarten children enrolled in regular education. **METHODS:** Twenty participants, 7 male, 13 female (mean age: 5yr 8mo), assessed with 1) Prone Extension timed hold test 2) Supine Flexion timed hold test 3) Functional Reach Test (FRT), and 4) three subtests (Balance; Running Speed and Agility; Strength) of the Bruininks-Oseretsky Test of Motor Performance-2\textsuperscript{nd} edition (BOT-2). Anthropometric data was collected for height and weight to be analyzed as possible confounding variables. **RESULTS:** The only variables that were significantly

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correlated were height and weight ($r = .834 \ p < .01$). There was a moderate correlation at a marginally significant level between 2 of the BOT-2 subtests: Running Speed/Agility and Strength ($r = .428 \ p < .06$). **INTERPRETATION:** The positional hold tests may not be valid measures of core muscle strength. There is neither a clear relationship between isometric core muscle control and balance nor isolated core muscle control and overall function. Overall body strength, such as measured by the BOT-2 subtest, may relate more to functional motor performance than isolated core muscle strength.

**Introduction**

When Pediatric Physical Therapists assess the gross motor skills of a young child, they use a top down approach, looking first at overall function/participation, then at impairments, such as balance, and finally at underlying systems. When assessing play skills in young children, balance is nearly always assessed, because, most functional movement activities require postural stability and balance. If balance is impaired, then the musculoskeletal system is assessed since postural control and balance skills require, in addition to other systems, underlying muscular control of the trunk or core.

Despite the intuitive nature of the relationship between core strength and balance, very few correlations have been made in studies between the two. Further, specific measures of core muscle control do not exist for young children. One project studied a group of typically developing 6-7 year olds (n=30) and reported insignificant correlations between trunk muscle strength and scores on static/dynamic balance measures involving a balance
There is other research that shows a positive correlation, but it is relative to very specific populations, such as children with Developmental Coordination Disorder (DCD) and adolescents with Cerebral Palsy (CP).

There is clearly a lack of research showing correlation in typically developing populations of young children, especially in regard to core muscle control and functional performance on the playground or in developmental gross motor skills. In the population of typically developing young athletes, researchers are divided. Some have found that focused training of the core musculature does not correlate with increased functional performance, while others have reported a positive correlation. Despite the lack of strong evidence, programs that specifically train the “core” remain popular in practice.

Further complicating the critical analysis of the relationships between core control and function, is that no reliable and valid method currently exists for assessing trunk or “core” muscle control in children. One solution could be timed positional holds of prone extension and supine flexion, presumably related to trunk muscle endurance, and easily integrated into play. These assessment methods were researched approximately twenty years ago. This body of literature has not been updated despite changes in recommended sleep position of infants, and changing anthropometric profiles of children, and increasingly sedentary lifestyles of youth today; all of which could directly affect what is considered typical in this decade.
Based on the history presented here, it is logical to revisit the use of gross measurements of core muscle control in young children using timed holds of prone extension and supine flexion. The following factors are paramount: 1.) A large, two-decade gap in data for trunk strength and how it relates to balance in children; 2.) The complex nature of balance makes it necessary to assess each subsystem (musculoskeletal, sensory, neurological) individually. However, the muscular system, as it relates to balance, must be assessed grossly, ruling out use of other evidenced based tools such as Hand Held Dynamometry (HHD) and Manual Muscle Testing (MMT); and 3.) The nature of working with young children requires that a tool is quick, non invasive, and able to be incorporated into play.

Methods

A correlational research approach was used to determine if there is a relationship between anthropometric variables, core muscle control as measured by isometric hold times in prone extension and supine flexion, functional balance, and/or functional gross motor play skills.

Participants

A convenience sample of students enrolled in Kindergarten was used. Recruitment occurred at Dublin City Schools, a local suburban school district. Projected Kindergarten enrollment for this school district for the 2010 and 2011 school years was 927 students.
Recruitment flyers, which included a brief description of the project as well as inclusion criteria, were available at curriculum nights as well as sent home with Kindergartners per each building principal’s discretion. Recruitment occurred at 9 of the 12 elementary buildings within the district.

Parents who made contact with research personnel were given a copy of the Parental Permission for Child’s Participation in Research, the HIPPA Research Authorization Form, and a Student History form. The researcher was available to provide further information and assistance on an as needed basis. All documentation was reviewed prior to testing. Participants were given an opportunity to voice their consent using an age appropriate assent script prior to as well as throughout testing. Students were tested at their home school building either before or after their AM or PM Kindergarten session. Parent/guardian was able to attend/view the testing session if desired.

**Instrumentation**

Testing was completed in the following order:

5. Anthropometrics in random order (height, weight)
6. Functional Reach Test
7. Positional Hold tests in random order (Supine flexion and prone extension)
8. Subtests of the BOT-2 in random order (Balance, Strength, Speed and Agility)
Completion of all tests took 30-45 minutes. All recruitment, testing, and data collection was completed by a single researcher.

Anthropometrics:
Height was measured with a meter stick attached to the wall. Students were asked to remove their shoes and stand facing researcher, looking straight over researcher’s shoulder. Weight was measured using a calibrated scale. Subjects were asked to remove their shoes and stand quietly on the scale until “their number” appeared.

Prone Extension Hold Time:
This research project utilized the standardized protocol for prone extension adapted by Gregory-Flock & Yerxa from Ayres\textsuperscript{21,29} with the exception of an initial verbal cue to pretend to “fly like an airplane” paired with a visual demonstration by the researcher. Participants were asked to lie on their stomachs on a mat and were then instructed in the movement in a 3-step sequence with support during the practice trial to avoid fatigue: 1. Lift the upper body (head, chest, arms) only with shoulders abducted approximately 90 degrees, forearms pronated, and elbows flexed 2. Lift the lower body only (knees and hips extended and lifted so legs are off of the surface), 3. Lift both the upper and lower body simultaneously. The practice trial was followed by a 1-2 minute rest break. For the test trial, subjects were instructed to hold the position for as long as they could. Timing of the test trial began when the subject succeeded in lifting head, chest, arms, knees, and legs off of the floor and was stopped when any of those parts touched the floor. Subjects were scored on the best of two test trials.
Supine Flexion Hold Time:

The protocol for measuring isometric trunk flexion was used as described by Lefkor with the exception that the researcher described the movement to the student as “rolling up like a roly poly bug” paired with a visual demonstration of the position by the researcher. One practice trial was administered with support to prevent fatigue. Subjects started on a mat lying on their backs and were assisted to “hug” themselves (arms crossed over chest) and placed with feet flat on floor, knees flexed to approximately 90 degrees. They were instructed to “roll into a ball” by lifting head and shoulders off the ground and simultaneously bringing knees upward toward their chest. After the practice trial, subjects were given a 1-2 minute rest. For the test trial, subjects were instructed to hold the position for as long as they could. When the position was correctly assumed, timing began. Timing was stopped when the subject’s head, arms, or legs began to drop out of initial position. Subjects were allowed two timed test trials; data was analyzed on the best of the two test trials.

Functional Reach Test (FRT):

The FRT was administered as described by Norris et al. Subjects were instructed to remove their shoes and socks and stand with their right shoulder against the wall with their feet behind a taped line on the floor that was perpendicular to the wall. A level yardstick was attached to the wall at the height of the subject’s acromion process. The subject was given a visual demonstration paired with verbal instructions and was physically assisted, as needed, to get into position: hand fisted, right arm flexed to
shoulder height. The subject was then instructed to reach as far forward as possible without falling or stepping. The subject was given two practice trials. On the test trial, starting and ending measurements were taken from the third metacarpal; the difference between the two measurements was recorded. The test trial was considered unsuccessful and scored 0 if the subject took a step, touched the wall, or needed physical assistance from the examiner.

Bruininks-Oseretsky Test of Motor Performance- 2nd edition (BOT-2):

The BOT-2 subtests that were administered for this project were: Balance, Running Speed and Agility, and Strength. The test was administered per standardized testing procedures described in the test manual.31 The Balance subtest included: standing on a taped line as well as on a test beam under a variety of conditions: tandem (one foot in front of the other, not touching), heel to toe (one foot in front of the other, touching), and single leg stance. Conditions also included eyes open or eyes closed. Per test protocol, subjects were allowed a second trial if they did not obtain a maximal score on the first trial. The Running Speed and Agility subtest included: 50 feet “shuttle” (down and back) run, stepping side to side over the beam, stationary hopping, hopping side to side over a line, and jumping with both feet together side to side over a line. Per test protocol, these items were administered a second trial only if the subject tripped or fell on the first trial. The Strength subtest included: a long jump (2 footed forward jump measured for distance), sit-ups, push-ups (knee or full), wall sit hold, and V-up hold (similar to prone extension, but shoulders are fully flexed rather than abducted to 90 degrees). Per test
protocol, only the long jump test was administered a second time if the child tripped or fell on the first trial.\textsuperscript{31}

**Statistical Methods**

Statistical analysis was completed to accept or reject the null hypothesis. Tools chosen were the Pearson Product Moment Correlation and One-way ANOVA (Analysis of Variance). Level of significance was set apriori at \( p < 0.05 \). SPSS for Windows, Chicago software was used for generating all statistical analysis.\textsuperscript{32}

**Results**

This study hypothesized that scores on the Functional Reach Test and BOT-2 would correlate positively with scores on the supine flexion and prone extension tests, but this relationship was not appreciable. Further, the study predicted that children born preterm would demonstrate decreased trunk control compared to those born full term, but could not answer this question. Detailed results and notable trends are discussed below.

A total of 20 students were tested (Tables 1-2). Within this group, 15 were born at full term, 2 were not specified, and 3 were born preterm (Table 1). However, note that none of the participants were significantly preterm; the level of prematurity as reported by parents for the 3 preterm subjects was: 4 weeks, 4 weeks, and 3.5 weeks (Table 1). The
strikingly low participation rate among the preterm group is almost certainly due to a recruiting restriction placed on the study by the participating school district, which required the researchers to recruit all students equally without defining groups.

Mean statistics (Table 3) for the raw data show that stable scores were recorded on all subtests of the BOT-2; FRT scores showed moderate variability (25.00 cm +/- 5.07 cm), and prone extension and supine flexion hold times, SD= +/- 11.54 and SD= +/- 10.72 seconds, respectively, demonstrated large variability.

The only significant correlation in any of the data was the interaction between height and weight (r= .834 p < .01). Height and Supine flexion were moderately correlated (r=.477 p < .033) (Table 4). Additionally, a marginally significant correlation was found between BOT-2 scaled scores in the Running Speed and Agility domain relative to the Strength domain (r=.428 p < .06).

Anthropometric height and weight data was collected for this study (Tables 1-2). These variables and age were compared against all other measurements using Pearson Product Moment Correlations (Table 4). Non-significant correlations were found between anthropometric variables, age, and test variables (FRT, BOT-2, prone extension, supine flexion) with two exceptions: 1.) Age and Height were marginally correlated (r=.436 p < .055) and 2.) Height and Supine flexion, as noted above (Table 4).
Participants were grouped by gender in a One-Way Anova (Table 5). Scores did not vary significantly based on gender. Significance approached an interesting level only for BOT-2 Balance subtest scaled scores (p=.10).

**Discussion**

These results contrast with others that have found correlations between age and height and supine flexion hold times.\(^{17,18}\) One explanation is that the participants in this study were similarly proportional in size and ability (Tables 5-7). While 14% of the population of boys was considered “overweight” based on Body Mass Index (BMI); that represents only 1 of the 7 boys in the sample (Table 2). Overall, 95% of the sample was considered in the average BMI range (Table 7). It is expected that anthropometrics can be eliminated as a source of variance in measuring functional strength, balance, and motor skills in children of proportional height and weight.

Core muscle strength was measured using prone extension and supine flexion hold times. While these variables did not correlate significantly with any of the functional balance or motor skill measures, as had been hypothesized, general trends are explored. The mean prone extension hold time for 5-6 year olds (5 yrs, n=13; 6 yrs, n=7) in this study was 20.22 +/- 11.54 seconds, with a median of 15.9 seconds (Table 2). Previous studies have reported means for the prone extension test in 5 year olds at a high median of 30 seconds
and as low as a mean of 9.93 seconds +/- 7.27 seconds.\textsuperscript{18} For 6 year olds, a high median of 62.5 seconds was reported\textsuperscript{21} as well as a significantly lower mean of 28.93 +/- 5.676 seconds (but this study cut-off timing at 30 seconds).\textsuperscript{20} In the present study, age did not correlate with positional hold times, possibly due to the narrow age band of participants.

In general, students in the current study showed an overall decreased trend of prone extension hold time compared to studies completed in the 1980’s. The children in the present study seemed to enjoy trying the position, and they appeared to be exerting maximal effort.

It is suspected that several societal trends are also interacting to cause the observed decrease in prone extension hold times. First, infant positioning, relative to decreased prone positioning in play, as an unintended result of the Back to Sleep campaign, could be a factor in this downward trend.\textsuperscript{22,23} It is also relative that parents today place young children in a large variety of equipment such as infant carriers, bouncers, jumpers, exersaucers, instead of on the floor; equipment usage has been shown to correlate negatively with infant development as measured by the Alberta Infant Motor Scale (AIMS).\textsuperscript{33} Furthermore, even as these children grow to preschool age, their opportunities for movement are limited by our increasingly cautious and litigious society, which limits playground design and use, and concomitantly places an increased emphasis on sedentary academic work.\textsuperscript{34}

The mean supine flexion hold time for 5-6 year olds in this study was 17.11 +/- 10.72 seconds, with a median of 14.35 seconds. Previous studies have recorded 5 year olds to
average between 14.91 +/- 5.52 seconds up to 29.5 seconds while 6 year olds averaged between 52.0 and 55.4 seconds.\textsuperscript{17,18}

The trend in the current study of less supine flexor control relative to populations studied in the 1980’s could be representative of the generally speaking, increasingly sedentary lifestyles of children.\textsuperscript{26,27} This type of lifestyle often results in increased time sitting slouched in front of media and decreased opportunities to exercise \textsuperscript{26,27,35}, or specifically, in this case, to develop trunk strength. Increased screen time is compounded by the increasing emphasis our society places on sedentary academic work for children as young as preschool.\textsuperscript{34}

Height, which was shown in previous research, (though not in this research) to correlate positively with supine flexion hold times\textsuperscript{16-18} is not likely to be a factor in the observed downward trend of strength, because the children in this study demonstrated average to above average body size (Table 2, Tables 6-7). The children, overall, responded favorably to this test; they participated willingly and seemed to exert maximal effort.

It has been noted that by age 5 the back extensors show greater strength than the flexors.\textsuperscript{36} It was noted in the present study, when looking at the means, and considering that the standard deviations for each were similar, that the participants held prone extension approximately 3 seconds longer than they held supine flexion. It makes sense, that being upright against gravity all day, even if sitting slouched, would require greater activation of the back extensors than of the flexors. It is still important that a balance exists to some
degree, and likely, that one should not be trained exclusive of the other. Further research could investigate the typical ratio of flexor to extensor strength in a larger, more diverse sample.

Functional balance skills were measured using the FRT. FRT mean reach scores from the current study are 25 +/- 5.07 cm (Table 2). Other reports have found a mean reach in the 5-6 year old population of 21.17 cm and a 95% CI range of 16.79 cm-24.91 cm. The mean reach of students in the current study is several inches greater than in prior research. Possible reasons could be: 1.) an error in administration of the test or 2.) a difference in this population compared to the general population. It is possible, but not suspected, that the students could have moved their toes over the line or leaned against the wall while the single examiner was busy trying to record measurements, thus, giving the students in the current study an advantage. Or, the population could be outside of the norm because the studied group is from a high achieving suburban school district. Without data on extracurricular participation, it is impossible to determine the cause.

Overall, it seems that this test has good reliability in this age group. Though there is one study that found that weight could explain some variance in FRT scores, neither the Donahoe study nor the current study identified variance related to weight, height, or gender. Unfortunately, the validity of the test cannot be corroborated based on the current results. We expected that scores on the balance subtest of the BOT-2 would correlate with scores on the FRT; in this project, they did not. The test does still present a
quick and practical assessment, presumably of dynamic balance, in young children. All children complied with and seemed to understand the test procedures.

Functional motor performance/play skills were measured using scaled scores from three subtests of the BOT-2 (Balance, Running Speed/Agility, and Strength). Two of these subtests, Running Speed and Agility and Strength, were found to correlate at a marginally significant level ($r = .428 \ p < .06$) (Table 4). This could indicate sound test design of the BOT-2. It could also demonstrate that strength is indeed related to functional motor skill performance, but that it is generalized lower body and trunk strength that is important, as measured by this subtest, rather than to the specific area of core muscle strength, as measured by positional hold tests.

One prior research study has shown a relationship between supine flexion hold time, prone extension hold time, and balance in young children. In that study, balance was recorded using one measure of static balance: single limb stance, and one measure of dynamic balance: walking on a beam. To expand on this decades old work, the current study looked at measures purported to be functional in nature. No relationship was observed. Future work could look at 2 varying groups. It is possible that the homogeneity of the current population and small sample size limited the ability to observe variance and draw correlations.
Limitations

One major limitation in our study design is that, due to restrictions in recruitment, there was not a comparison group (it had been proposed to assess a group of students born at term to a group born preterm). Descriptive research can only explore relationships, not show causality. Another limitation, in recruitment procedures, is that each individual principal (n=12) was given power by the participating district to either participate or not participate in the recruitment procedures approved by the IRB, resulting in 9 of 12 buildings participating and a loss of potential participants. A larger sample size could have increased the power of the current findings. Furthermore, the sample, while spread across several buildings, is one of convenience in a suburban school district. The district advertises cultural diversity, but is located in a socioeconomically affluent area, possibly limiting the generalizability of the results.

Finally, a potentially confounding variable was not measured or controlled for: level of extracurricular activity. The level of outside participation in sport could have increased students’ performance on measures of strength, balance, and functional motor skills. Overall, the sample did seem to come from a variety of active lifestyles, and BOT-2 scaled scores showed a nice spread within the average range of 11-19 (Table 3). It is likely that the small sample size and specificity of the selected core tests are the primary factors limiting this study’s ability to observe variance, to draw correlations, and to be generalized.
Clinical Significance

The musculoskeletal system makes a definite contribution to balance\textsuperscript{4} and, obviously, produces movement. Current evidence does not delineate how to measure the contribution of the trunk muscles in children.\textsuperscript{8} The present trend is to accept the core as the prime musculoskeletal contribution to balance, despite the varied evidence in exercise and sport literature.\textsuperscript{10-15} The current project sought and failed to find a relationship between supine flexion and prone extension hold times and functional balance. Further, no relationship was found between generalized strength scores on the BOT-2 and either positional hold test. We cannot validate the use of these positional hold tests to identify musculoskeletal impairments, in general, or as the cause of functional limitations in balance or motor skills.

A conceptual model of disability, the International Classification of Functioning, Disability, and Health, ICIDH-2, recognizes that impairments can be present without activity limitations and vice versa (WHO 2001). For example, a student could have decreased single leg balance scores compared to peers without presenting any difficulty accessing activities at school or participating in the community. A student could have a weak core and still participate fully in physical education class. Or, in reverse a student could have a slower running speed than peers, but have very good balance. All of these considerations occur in the context of the student’s unique environmental and personal factors (WHO 2001), which cannot all be measured. Future studies may consider
including a question regarding extracurricular, sport activities in the questionnaire, as it was noted that some of the students who reported prior experiences with gymnastics, soccer, and dance appeared to hold positions longer than those who did not report regular physical activity. Contextual information could provide another means of analyzing variance.

This study cannot justify use of the prone position or supine flexion posture to measure functional core strength. It supports the idea that core muscles are not the primary system contributing to balance. Instead, there are many other dynamic systems, and all should be trained in an integrated, task specific manner to obtain best results. As in young athletes, focused training of the core musculature does not necessarily lead to increased functional performance.10-12
ID=student identification number, M=male, F=female, FT=fullterm, PT=preterm, NS=not specified, lbs=pounds, sec=seconds, FRT=Functional Reach Test, BOT-2=Bruininks-Oseretsky Test of Motor Proficiency-2\textsuperscript{nd} edition, SS=scaled score, mo=months

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Table 1: Raw Data
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N=number

**Table 2: Descriptive Statistics**

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FRT=Functional Reach Test, BOT-2=Bruininks-Oseretsky Test of Motor Proficiency-2\textsuperscript{nd} edition, N=number

**Table 3: Mean Statistics**
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Table 4: Pearson Product Moment Correlation

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Continued
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*. Correlation is significant at the 0.05 level (2-tailed).

FRT=Functional Reach Test, BOT-2=Bruininks-Oseretsky Test of Motor Proficiency-2nd edition, N=number, SS=scaled score
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<th>Mean Square</th>
<th>F</th>
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FRT=Functional Reach Test, BOT-2=Bruininks-Oseretsky Test of Motor Proficiency-2nd edition, N=number, SS=scaled score, Groups: Males compared to Females, Df=degrees of freedom, Sig.=significance

**Table 5: One Way Analysis of Variance (ANOVA) of Gender**
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ID= Identification, M= male, F=female, BMI= Body Mass Index, BMI %ile=percentile for age

**Table 6: BMI Statistics**
Summary of Children's BMI-for-Age

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<th>Girls</th>
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<td>13</td>
<td>20</td>
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<tr>
<td>Underweight (&lt; 5th %ile)</td>
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<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Normal BMI (5th - 85th %ile)</td>
<td>86%</td>
<td>100%</td>
<td>95%</td>
</tr>
<tr>
<td>Overweight or obese (≥ 85th %ile)*</td>
<td>14%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Obese (≥ 95th %ile)</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

*BMI= Body Mass Index

Table 7: Summary of Children’s BMI-for-Age

References:


32. SPSS for windows. 12.01.2008.


CHAPTER V

SUMMARY AND CONCLUSIONS

This study investigated the relationship between core muscle strength, balance, functional motor skills, and anthropometrics in a convenience sample of typically developing Kindergartners. The study also set out with a second purpose: to explore the differences in core muscle control of two levels of the independent variable: subjects born at full term and subjects born at preterm. Unfortunately, only the first purpose was realized.

The study did not have sufficient participation from the preterm group, eliminating this component of the research question. The participating school district did not wish for recruitment materials to specifically identify preterm students as a targeted group, so it was finally agreed that all students would be recruited without any mention of the potentially divisive words full term or preterm. It was mutually hoped that the sample would include a relatively balanced number of participants born at full term and preterm.
Given that, on average, 1 in 8 births is preterm (approximately 12.5%)\textsuperscript{54}, it was not practical to expect a balanced sample. Indeed, the statistics played out in this study. Out of a total of 20 participants, only 15\% of the sample was preterm (full term n=15, preterm n=3, and not specified n=2). Failing to define in recruitment materials that two distinct groups were being recruited, very likely limited the number of preterm applicants to a number that corresponds with the typical incidence in the general population. So, this study no longer included an independent variable and instead became a pure correlational, descriptive research design.

This study hypothesized that scores on the Functional Reach Test and BOT-2 would correlate positively with scores on the supine flexion and prone extension tests. However, based on the data obtained, this relationship was not appreciable. Despite the fact that anticipated results were not realized, interesting trends were observed in the data. Detailed results and notable trends are discussed below.

Anthropometric height and weight data were collected for this study. Ironically, the only significant correlation in any of the data was the interaction between height and weight ($r = .834$ p < .01). These results contrast with others that have found correlations between age and height and supine flexion hold times.\textsuperscript{20,60} Perhaps, this is because the participants in this study were proportional in size and within average ranges in ability. It is expected that anthropometrics can be eliminated as a source of variance in measuring functional strength, balance, and motor skills in groups of proportional stature.
Core muscle strength was measured using prone extension and supine flexion hold times. While these variables did not correlate significantly with any of the functional balance or motor skill measures, as had been hypothesized, general trends are explored. The mean prone extension hold time for 5-6 year olds (5 yrs, n=13; 6 yrs, n=7) in this study was 20.22 +/- 11.54 seconds, with a median of 15.9 seconds. Previous studies have reported statistics for the prone extension test in 5 year olds at a high median of 30 seconds as low as a mean of 9.93 seconds +/- 7.27 seconds. For 6 year olds, a high median of 62.5 seconds was reported as well as a significantly lower mean of 28.93 +/- 5.676 seconds (but this study cut-off timing at 30 seconds).

In general, students in the current study showed an overall decreased trend of prone extension hold time compared to studies completed in the 1980’s. This trend is not unique to this study; shuttle run times have increased for the 6-19 year old age group since the 1980’s, showing another decreasing trend in performance. Despite their decreased performance compared to children twenty years ago, the children in the present study seemed to enjoy trying the position. The children also appeared to be exerting maximal effort; so, the test was, at least, practical for current students to replicate.

It is suspected that several trends are interacting to cause the observed decrease in prone extension hold times. First, infant positioning relative to decreased prone positioning in play as an unintended result of the Back to Sleep campaign could be a factor in this downward trend. It is also notable that parents today place developing children in a variety of equipment: infant carriers, bouncers, jumpers, and exersaucers, instead of on
the floor. Equipment usage has been shown to correlate negatively with infant development as measured by the Alberta Infant Motor Scale (AIMS). Furthermore, even as these children grow to preschool age, their opportunities for movement are limited by our increasingly cautious and litigious society, which limits playground design and use, and concomitantly, places an increased emphasis on sedentary academic work even at the preschool level.

The mean supine flexion hold time for 5-6 year olds in this study was 17.11 +/- 10.72 seconds, with a median of 14.35 seconds. Previous studies have recorded 5 year olds to average between 14.91 +/- 5.52 seconds and 29.5 seconds, while 6 year olds averaged between 52.0 and 55.4 seconds. This trend of less supine flexor control relative to populations studied in the 1980’s could be representative of the, generally speaking, increasingly sedentary lifestyles of children. This type of lifestyle results in increased time sitting slouched in front of media and decreased opportunities to gain trunk strength.

Another potential factor is height, which was shown in previous research, though not in this research, to correlate positively with supine flexion hold times. It is not likely to be a factor in the observed downward trend of strength, because it is not likely that the population is becoming shorter. Furthermore, per Body Mass Index (BMI) parameters, 95% of the children in the current study were of average proportion. Based on these findings, height can be eliminated as a source of variance in supine flexion hold times.
Overall, the participants responded favorably to the supine flexion test. They participated willingly and seemed to exert maximal effort. The test is quick, non-invasive, easy to replicate for this age group, and can be incorporated into play.

It is surprising that neither prone extension nor supine flexion positional hold times corresponded with either functional balance or motor skill scores. It was expected that there would be a positive relationship between underlying strength and functional skill. One explanation is that the tests used: the FRT and BOT-2, are objective measures, which do not take into account quality of movement. For example, single leg stance was recorded as time held; factors such as shifting or leaning, which may indicate less refined balance control, were not measured. Therefore, these tests may not be sensitive enough to detect differences in the qualitative area of balance, which may have correlated to core muscle control. Additionally, the students functioned within average ranges, based on scaled scores, on the BOT-2. So, subtle differences in balance in this average group may not have been substantial enough to show a relationship to the more variable supine flexion and prone extension scores. Despite our findings, it is possible that the relationship exists, but was not detected by tests that measure only objective skill level in a group of students functioning within average ranges.

It has been noted that by age 5 the back extensors show greater strength than the flexors. It was noted in the present study, when looking at the means, and considering that the standard deviations for each were similar, that the participants held prone extension approximately 3 seconds longer than they held supine flexion. It makes sense, that being
upright against gravity all day would require greater activation of the back extensors than of the flexors. It is still important that a balance exists to some degree and, likely, that one should not be trained exclusive of the other. Further research could investigate the typical ratio of flexor to extensor strength in a larger, more diverse sample.

Functional balance skills were measured using the FRT. FRT mean reach scores from the current study are 25 +/- 5.07 cm. Other reports have found a mean reach in the 5-6 year old population of 21.17cm and a 95% CI range of 16.79cm-24.91 cm. The mean reach of students in the current study is several inches greater than in prior research. Possible reasons could be: 1.) an error in administration of the test or 2.) a difference in this population compared to the general population. It is possible, but not suspected, that the students could have moved their toes over the line or leaned against the wall while the single examiner was busy trying to record measurements, giving the students in the current study an advantage.

Overall, it seems that the FRT has good reliability in this age group. Though there is one study that found that weight could explain some variance in FRT scores, neither the Donahoe study nor the current study identified variance related to weight, height, or gender. Unfortunately, the validity of the test cannot be corroborated based on the current results. We would have expected for scores on the balance subtest of the BOT-2 to correlate with scores on the FRT; in this project, they did not. The test does still present a quick and practical assessment, presumably of dynamic balance, in young children. All children complied with and seemed to understand the test procedures.
Functional motor performance/play skills were measured using scaled scores from three subtests of the BOT-2 (Balance, Running Speed/Agility, and Strength). Two of these subtests, Running Speed and Agility and Strength, were found to have a moderate correlation at a marginally significant level ($r = .428$ $p < .06$). This could indicate sound test design of the BOT-2. It could also demonstrate that strength is indeed related to functional motor skill performance, but that generalized lower body and trunk strength are important in a broader context, as measured by the BOT-2 subtest. It is possible, then, that the positional hold tests are too narrow in scope to truly represent the core, because they measure only back extensor and trunk flexor control. Kibler et al postulate that the core must include the pelvic musculature and that effective training must include three planes of motion.$^{40}$ A study on core muscle stability in children 9-11 years old with Developmental Coordination Disorder (DCD), used a screening tool that included many muscle groups and all three planes of movement: 20 seconds sit up test, 20 seconds push up test, as well as positional holds of the following positions: plank, bridge, bird-dog, and single leg stance.$^{58}$ Future research could use the supine flexion and prone extension positions with an additional measure of hip flexor control, utilize Kane and Bell’s screen$^{58}$, or could utilize the strength portion of the BOT-2 as more comprehensive indicators of core muscle control.

One prior research study has shown a relationship between supine flexion hold time, prone extension hold time, and balance in young children.$^{20}$ In that study, balance was recorded using one measure of static balance: single limb stance and one measure of
dynamic balance: walking on a beam. To expand on this decades old work, the current study looked at measures purported to be functional in nature.\textsuperscript{6,9,10,14} No relationship was observed. Future work could look at two varying groups. It is possible that the homogeneity of the current population and small sample size limited the ability to observe variance and draw correlations.

Alternatively, future research could examine the research question in reverse. Instead of looking at the question from a top down approach as the current study did, subsequent work could investigate: does training core muscle strength improve balance? It would be interesting to evaluate this question in typically developing children against a comparison group, as the current literature addresses only young adult athletes\textsuperscript{40,68,82,85} and populations of adults\textsuperscript{83,84} and children\textsuperscript{58} with specific disabilities.

The musculoskeletal system makes a definite contribution to balance\textsuperscript{2} and obviously produces movement. Current evidence does not delineate how to measure the contribution of the trunk muscles in children.\textsuperscript{58} The present trend in practice is to accept the core as the prime musculoskeletal contribution to balance, despite the varied evidence in exercise and sport literature.\textsuperscript{40,43,68,82,85,88} The current project sought and failed to find a relationship between supine flexion and prone extension hold times and functional balance. Further, no relationship was found between generalized strength scores on the BOT-2 and either positional hold test. We cannot validate the use of these positional hold tests to identify musculoskeletal impairments in general, nor can we speculate that
lower scores on supine flexion or prone extension tests are a factor in functional limitations in balance or motor skills.

A conceptual model of disability, the International Classification of Functioning, Disability, and Health, ICIDH-2, recognizes that impairments can be present without activity limitations and vice versa (WHO 2001). For example, a student could have decreased single leg balance scores compared to peers without presenting any difficulty in accessing activities at school or in participating in community. Or, a student could have a weak core and still participate fully in physical education class. Reversing that logic, a student could have a slower running speed than peers, but have very good balance. All of these considerations occur in the context of the student’s unique environmental and personal factors (WHO 2001), which cannot all be measured. Future studies may consider including a question regarding extracurricular, sport activities in the questionnaire as it was noted some of the students who reported prior experiences with gymnastics, soccer, and dance appeared to hold positions longer than those who did not report regular physical activity. Contextual information could provide another means of analyzing variance.

This study cannot justify use of the prone extension or supine flexion posture to measure functional core strength. The findings indicate that, perhaps, trunk flexors and extensors are not the primary motor contributors to balance. The pelvic muscles are also important components, and furthermore, the core must be able to work effectively in more than just the sagittal plane. All of the systems that interact to produce balance and movement
should be trained in an integrated, task specific manner to obtain best results. As in young athletes, focused training of the core musculature does not necessarily lead to increased functional performance.\(^{68,85,88}\) This study has several limitations, which may affect the generalizability of the results: small sample size, no comparison group, and a homogenous sample of convenience.

References:


therapy. official publication of the American Occupational Therapy Association.
2002;56:577.


113. SPSS for windows. . 12.01.2008.


APPENDIX A:

Permission Letters, Recruitment, Student History, Assent, Data Collection Sheets
The Biomedical Sciences IRB APPROVED BY EXPEDITED REVIEW the above referenced research. The Board was able to provide expedited approval under 45 CFR 46.119(b)(1) because the research meets the applicability criteria and one or more categories of research eligible for expedited review, as indicated below.

Date of IRB Approval: August 3, 2011
Date of IRB Approval Expiration: July 1, 2012
Expeditied Review Category: 4

In addition, the research has been approved for the inclusion of children (permission of one parent sufficient).

If applicable, informed consent (and HIPAA research authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. The IRB-approved consent form and process must be used. Changes in the research (e.g., recruitment procedures, advertisements, enrollment numbers, etc.) or informed consent process must be approved by the IRB before they are implemented (except where necessary to eliminate apparent immediate hazards to subjects).

This approval is valid for one year from the date of IRB review when approval is granted or modifications are required. The approval will no longer be in effect on the date listed above as the IRB expiration date. A Continuing Review application must be approved within this interval to avoid expiration of IRB approval and cessation of all research activities. A final report must be provided to the IRB and all records relating to the research (including signed consent forms) must be retained and available for audit for at least 3 years after the research has ended.

It is the responsibility of all investigators and research staff to promptly report to the IRB any serious, unexpected and related adverse events and potential unanticipated problems involving risks to subjects or others.

This approval is issued under The Ohio State University’s ORHP Federally Assurance #0006378. All forms and procedures can be found on the ORSP website – www.orsp.osu.edu. Please feel free to contact the IRB staff contact listed above with any questions or concerns.

Karla Zelonik, OD, PhD, Chair
Biomedical Sciences Institutional Review Board
June 10, 2011

To Whom It May Concern:

Brooke Holdgreve is a part-time (.5 FTE) employee of the Dublin City School District. She is employed as a staff Physical Therapist. Dublin City Schools promote research endeavors that investigate current models of practice, develop new models of practice, and/or support staff development. This research project is being conducted to fulfill requirements towards Brooke Holdgreve’s M.S. degree in Allied Health through The Ohio State University. Because this project investigates current trends of practice by Physical Therapists at Dublin City Schools and promotes and also promotes staff development, Brooke Holdgreve, has been granted access to the defined population by the Dublin City School District.

Sincerely,

[Signature]

Michael DeCenzo
Student Services Coordinator
614-760-4385

MD/pjw
Hello!

My name is Brooke Holdgreve. I am working on my thesis requirement for a Master of Science Degree in Physical Therapy at The Ohio State University with my advisor, Deborah Larsen, PhD. I am also employed by Dublin City Schools as a physical therapist.

I am looking for students to participate in my research project and am hoping that you can help me. I plan to evaluate children’s core muscle endurance (strength of the stomach and back muscles) and balance skills. The activities that I have planned should be easy, fun, and take only 30 to 45 minutes to complete.

I would like to evaluate the children at their home school building before or after school hours. This could be accomplished during latchkey hours (if enrolled) or parent/s could bring their student in for an appointment.

The criteria for participation include:

- Enrolled in Kindergarten
- In good health
- Enrolled in general education

Your child’s participation in this study is completely voluntary. Your decision will not affect your current or future relationship with Dublin City Schools. All personal information and individual data/test results will be confidential.

I would be glad to answer any questions you may have. If you have questions or are interested in enrolling your child in this study, please contact me.

Thank you!

Brooke Holdgreve, PT, OH#9460

Home Ph: 614-766-4914
Cell Ph: 614-352-6143
Email: holdgreve.8@osu.edu
The Ohio State University
School of Allied Medical Professions
Physical Therapy Division
614-292-2397
Brooke Holdgreve, PT

_____ YES, I would like my child to take part in this research project

Student Information

Name: ____________________ Male/Female (circle one)

Date of Birth: ___/___/____  Due Date: ___/___/___ full term/preterm

1.) Is your child in good health? Yes/No (circle one)
   List any areas of concern: ______________________________

2.) Has your child ever been diagnosed with a neurological condition? Yes/No
   Please describe: ______________________________

3.) Does your child have ear tubes or a history of ear tube placement? Yes/No
   Please explain: ______________________________

4.) Has your child ever had an IEP (Individualized Education Plan)? Yes/No

Parent Information

Parent 1: __________________  Parent 2: __________________

Best way to contact you? Home phone/Cell phone/ Email (circle one)

Home phone# ____________  Cell phone# ____________  Email _______________

Parent Signature: ________________________ Date: __________________
The Ohio State University Parental Permission
For Child’s Participation in Research

Study Title: CORE MUSCLE ENDURANCE AND ITS RELATIONSHIP TO BALANCE IN KINDERGARTENERS BORN AT FULLTERM AND PRETERM

Principal Investigator: Deborah Larsen, PhD

Sponsor: School of Allied Medical Professions, The Ohio State University

• This is a parental permission form for research participation. It contains important information about this study and what to expect if you permit your child to participate. Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to permit your child to participate.

• Your child’s participation is voluntary. You or your child may refuse participation in this study. If your child takes part in the study, you or your child may decide to leave the study at any time. No matter what decision you make, there will be no penalty to your child and neither you nor your child will lose any of your usual benefits. Your decision will not affect your future relationship with The Ohio State University. If you or your child is a student or employee at Ohio State, your decision will not affect your grades or employment status.

• Your child may or may not benefit as a result of participating in this study. Also, as explained below, your child’s participation may result in unintended or harmful effects for him or her that may be minor or may be serious depending on the nature of the research.

• You and your child will be provided with any new information that develops during the study that may affect your decision whether or not to continue to participate. If you permit your child to participate, you will be asked to sign this form and will receive a copy of the form. You are being asked to consider permitting your child to participate in this study for the reasons explained below.

1. Why is this study being done?
This study is being done to determine if the core (abdominals/stomach and back muscles) endurance of children in Kindergarten relates to balance and participation in play activities. The study will also investigate if there is a difference in the overall core muscle endurance of students born at preterm compared to those born at full term.
2. **How many people will take part in this study?**
   The investigators anticipate participation of a minimum of 30 students; the study will be capped at a maximum of 100 students.

3. **What will happen if my child takes part in this study?**
   You will be asked to provide information regarding your child’s birth, medical history, and development. Your child will participate in the following assessments: measurement of height and weight, timed hold of the supine flexion position (“curl” or “bug”), timed hold of the prone extension position (“airplane” or “superman”), the FRT (a measure of standing balance), and the BOT2 – Subtests 5,6,8 (a test of motor skill). The administration of all of these tests should take 30-45 minutes.

   The FRT (Functional Reach Test) involves standing and reaching with an outstretched arm as far forward as possible without stepping or falling. The BOT2 (Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition) is a standardized assessment tool. Subtest 5 (Balance) involves items related to standing still as well as walking on a line and balance beam, some items require eyes open and some request voluntary closure of eyes. Subtest 6 (Running Speed and Agility) involves running, sidestepping, and hopping. Subtest 8 (Strength) involves jumping, push-ups, sit-ups, wall sit, and v-ups.

4. **How long will my child be in the study?**
   Your child will only participate in one testing session lasting 30-45 minutes. After all children are tested and the data is analyzed, results will be shared with you and your child, if requested.

5. **Can my child stop being in the study?**
   Your child may leave the study at any time. If you or your child decides to stop participation in the study, there will be no penalty and neither you nor your child will lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

6. **What risks, side effects or discomforts can my child expect from being in the study?**
   Risks: Your child may experience mild fatigue during or for a short period of time after the assessments.

7. **What benefits can my child expect from being in the study?**
Benefits: Your child will learn about core muscle control, balance, and will practice some fun motor play skills.

8. **What other choices does my child have if he/she does not take part in the study?**
   You or your child may choose not to participate without penalty or loss of benefits to which you are otherwise entitled.

9. **Will my child’s study-related information be kept private?**
   Efforts will be made to keep your child’s study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your child’s participation in this study may be disclosed if required by state law.

   Also, your child’s records may be reviewed by the following groups (as applicable to the research):
   - Office for Human Research Protections or other federal, state, or international regulatory agencies;
   - U.S. Food and Drug Administration;
   - The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
   - The sponsor supporting the study, their agents or study monitors; and
   - Your insurance company (if charges are billed to insurance).

   If this study is related to your child’s medical care, your child’s study-related information may be placed in their permanent hospital, clinic, or physician’s office records. Authorized Ohio State University staff not involved in the study may be aware that your child is participating in a research study and have access to your child’s information.

   You may also be asked to sign a separate Health Insurance Portability and Accountability Act (HIPAA) research authorization form if the study involves the use of your child’s protected health information.

10. **What are the costs of taking part in this study?**
   There are no specific costs associated with this study.

11. **Will I or my child be paid for taking part in this study?**
   There are no monetary incentives to participate in this study. By law, payments to subjects are considered taxable income.
12. What happens if my child is injured because he/she took part in this study?

If your child suffers an injury from participating in this study, you should notify the researcher or study doctor immediately, who will determine if your child should obtain medical treatment at The Ohio State University Medical Center.

The cost for this treatment will be billed to you or your medical or hospital insurance. The Ohio State University has no funds set aside for the payment of health care expenses for this study.

13. What are my child’s rights if he/she takes part in this study?

If you and your child choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights your child may have as a participant in this study.

You and your child will be provided with any new information that develops during the course of the research that may affect your decision whether or not to continue participation in the study.

You or your child may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

14. Who can answer my questions about the study?

For questions, concerns, or complaints about the study you may contact: **Brooke Holdgreve @ 614-352-6143 or Deborah Larsen @ 614-292-5645.**

For questions about your child’s rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If your child is injured as a result of participating in this study or for questions about a study-related injury, you may contact: **Deborah Larsen @ 614-292-5645.**
Signing the parental permission form

I have read (or someone has read to me) this form and I am aware that I am being asked to provide permission for my child to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to permit my child to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

Printed name of subject

Printed name of person authorized to provide permission for subject

Signature of person authorized to provide permission for subject

Relationship to the subject

Date and time

AM/PM

Investigator/Research Staff

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

Printed name of person obtaining consent

Signature of person obtaining consent

Date and time

AM/PM

Witness(es) - May be left blank if not required by the IRB

Printed name of witness

Signature of witness

Date and time

AM/PM

Printed name of witness

Signature of witness

Date and time

AM/PM
April 7, 2011

Protocol Number: 2011HO116
Protocol Title: **CORE MUSCLE ENDURANCE AND ITS RELATIONSHIP TO BALANCE IN KINDERGARTENERS BORN AT FULLTERM AND PRETERM**

Age Appropriate Assent Script:

“Hi! My name is Mrs. Holdgreve. I’m trying to find out how well children can use their stomach and back muscles and how well they can balance.

I have a couple of tests that I would like for you to try. The first thing we will do is to check your height and weight using a scale and a measuring stick.

Then, I want to see how strong your back muscles are, so we will try to hold a superman position for as long we can. Some people call it the airplane test—it looks like this (demo). We will lie on our bellies and hold our head, arms, and legs up like this (demo) and I will use a timer to see how long you can hold yourself up.

Next, I want to see how strong your stomach muscles are, so we will curl up like a bug on our backs (demo). I want to see how long you can stay like that with your head, arms, and legs up; I will use a timer to time you.

Then, I want to see how well you can balance. I have 2 tests for that. The first one is pretty quick. You will stand beside the wall like this (demo) and reach forward like this (demo). I want to see how far you can reach without stepping or falling. The last balance test is made up of a lot of quick games. We will try standing and walking on a line. Sometimes I will ask you to try with your eyes open and sometimes I will ask you to try with your eyes closed. We will also practice games like jumping, hopping, standing on one leg, and we will try some exercises like sit-ups, push-ups, and v-ups.

There are a lot of things to do, so we will take little rest breaks to be sure we have enough energy. You can tell me if you feel tired.

Is this something that you would like to try?”
Student ID#______________________

Male/Female

Term/Preterm:____________________

Height:______________

Weight:______________

Prone Extension Hold: sec sec (1 practice) sec sec 
Trial 1 Trial 2

Supine Flexion Hold: sec sec (1 practice) sec sec 
Trial 1 Trial 2

Functional Reach Test (2 practice trials): cm

BOT2:

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<th>Scale Score</th>
<th>90% CI band</th>
<th>Age Equiv.</th>
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<tr>
<td>Running Speed and Agility</td>
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<td>Strength</td>
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