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EXAMING SUPINE-TO-STAND AS A MEASURE OF FUNCTIONAL MOTOR COMPETENCE AND HEALTH ACROSS THE LIFESPAN

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DEDICATION

This dissertation is dedicated to my parents, who have raised me to be the person I am today. You have been with me every step of the way, through good times and bad. Thank you for all the unconditional love, guidance, and support that you have given me, helping me to succeed and instilling in me the confidence that I am capable of doing anything I put my mind to.

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ABSTRACT

A person's ability to rise from the floor to a standing position is seen as a precursor for establishing and maintaining physical independence. It also is an important primer for the development of other fundamental movement skills (FMS) and is associated with functional capacity in later life. Thus, the potential importance of developing this movement capability early in life and understanding how it may relate to global function (i.e., motor competence-MC and health-related fitness-HRF) across the lifespan may be underestimated. Limited research has examined components or performance (i.e., time) of supine-to-stand (STS) in children to young adults. Further, no previous research has related overall performance on this task to other later developing movement skills and health-related variables. Thus, understanding the role that the development of STS, as a global measure of functional MC, may have on the development of other critical aspects of motor development and function (e.g. fitness) should be examined.

Therefore, two separate studies were conducted. The first study examined the validity of STS as a developmental measure of functional MC across childhood into young adulthood using a pre-longitudinal screen approach and examining associations between movement components and STS time will provide a secondary measure of developmental validity. As well as to examine the concurrent validity of STS (movement patterns and time) against developmentally valid measures of MC (i.e., FMS) in these age groups. Overall, results indicated STS time can be considered a valid and reliable measure of MC across childhood into young adulthood.

The purpose of the second study was to examine the predictive utility of process- and product-oriented assessments of STS as a predictor of the health-related variables of PA, weight status and HRF across early childhood into young adulthood. This study is unique in that it is the first to demonstrate the strength of association among STS time, as a measure of functional MC, and health-related measures. Results indicate that higher levels of fitness are associated with faster times to stand. Consequently, more PA data is needed to examine the associations among STS time and PA levels. As the development of STS has been noted as a precursor to physical independence in early childhood and the elderly, its consistent link to cardiorespiratory endurance, muscular strength/endurance, and bodyweight status in early childhood into adulthood provides valuable insight for its potential significance as an early lifespan assessment screening tool.

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LIST OF ABBREVIATIONS

AX	Axial Region
BMI	Body Mass Index
CS-PFP	Continuous Scale Physical Functional Performance Test
HRF	Health-Related Fitness
FAR	Functional Axial Rotation
FC	Functional Capacity
FMC	Functional Motor Competence
FMS	Fundamental Motor Skills
FRT	Functional Reach Test
KTK	Köper Koordination Test für Kinder
LE	Lower Extremity
MABC	Movement Assessment Battery for Children
MC	Motor Competence
MVPA	Moderate to Vigorous Activity
PA	Physical Activity
STS	Supine-to-Stand
TGMD	Test of Gross Motor Development
TOMI	Test of Motor Impairment
TUG	Timed up and Go
UE	Upper Extremity
6MWT	Self-paced 6-minute Walk Test

2MWT...Two-Minute Walk Test

CHAPTER 1

INTRODUCTION AND REVIEW OF LITERATURE

The development of motor competence (MC) is suggested to be a causal mechanism that promotes positive lifespan trajectories of physical activity (PA), health-related fitness, and weight status. However, many different assessments are used to measure aspects of MC in different age groups across the lifespan, making it difficult to track changes in MC across the lifespan and compare the strength of associations between MC and health-related variables across time. Specifically, assessments vary dramatically by the type (e.g., gross vs. fine; fundamental movement skills vs. global coordination; object control vs. locomotor) and measurement (i.e., process vs. product) of MC. Most often, MC data (specifically relating to fundamental motor skills) is linked to research with youth. To further complicate the issue, common measures of "functional capacity," as assessed in aging populations, can be viewed as functional measures of MC (i.e., chair stand, 6-min walk, supine-to-stand, timed up and go, balance stands, etc.). In essence, these assessments measure gross coordination and control, which can be defined as the capability of an individual to coordinate and control their center of mass and extremities in a gravity-based environment to effectively complete a goal. Similar to MC, functional capacity measures are linked to health outcomes, but they also are linked to more age-specific outcomes such as physical independence, mortality, and overall quality of life (Rikli, 2005; Kuh, 2007; Smee, Anson, Waddington, & Berry, 2012).

Measures that have been used to assess MC are limited when examining the association of MC with health-related measure across the lifespan. For example, current supine-to-stand (STS) data has limited utility as movement patterns (i.e., developmental sequences) have been assessed up to middle adulthood and STS outcome data (i.e., time to stand) is more limited because this measurement has only been used in elderly populations. Other MC assessments (i.e., KTK, TGMD-2, M-ABC) also are limited in their capability to measure MC over the lifespan as they were developed to assess MC in youth. In addition, many MC assessment batteries were specifically developed to capture developmental delay (TGMD and M-ABC) and can have ceiling effects with normally developing children and during the transition to adolescence. Thus, these batteries of test are designed for particular ages (i.e., youth) and skill levels and are not applicable for testing across the lifespan (Robinson et al., 2015; Stodden et al. 2008). Additional assessment issues noted are related to the measurement of process-oriented or product-oriented data. A major drawback to product-oriented tests is that these assessments only focus on the end result of a movement, which limits the understanding of how the product was produced. The quality of movement that produces an outcome is important from a developmental perspective as the movement pattern provides an understanding of where the individual is developmentally, as well as provide information on how further development should be promoted.

Alternatively, many process-oriented assessments lack developmental validity, are limited in their capability to adequately differentiate skill levels and have ceiling effects (Stodden et al., 2008). Children often are assessed based on how well they measure up to an expert in a particular skill and not based on age-related developmental norms. However, the combination of both a process and product orientation can provide a more comprehensive assessment of skilled movement as it relates to both effectiveness and efficiency of movement (Guthrie, 1952).

Researchers in motor development have yet to establish a measure of MC that is applicable for all age groups (i.e., developmentally valid), can be effectively used to examine motor development and also be used as a predictor variable (e.g., for health). Collectively, these measurement issues are important for future research as an adequate lifespan MC assessment will allow researchers to address the strength of associations between MC and a multitude of health-related variables in youth as well as chronic disease and functional status conditions later in life (Robinson et al., 2015). This testing capability is specifically relevant from a lifespan perspective as the strength of associations between MC and health-related variables such as health-related fitness and obesity have been noted to increase across age in youth (Cattuzzo et al., 2014).

The supine-to-stand test (STS) represents one task that has been used, in different ways, to assess motor development or functional capacity in a variety of age groups. Thus, it has the potential to be a developmentally valid measure of functional motor competence that can be used across the lifespan. The primary purpose of STS from a developmental perspective is to examine movement patterns used by individuals to stand up from a supine position on the floor (process), but very little attention has been placed on the time it takes one to stand (product) as a measure of development. A few studies (Belt et al, 2001; Ng, Conaway, Rigby, Priestman, & Baxter, 2013; Hsue et al., 2014) have examined STS time in relation to how an individual stands, but data was used to provide only a generic understanding that healthy individuals, as compared to individuals with movement disorders, were able to rise faster. No research has explicitly examined STS time in healthy children or adults in relation to how they rise (movement process) from a supine position.

The emergence of more advanced STS movement patterns in early childhood has been documented (VanSant, 1988; Marsala & VanSant, 1991), but it was related to a progression of "motor milestones" (e.g., rolling over, sitting upright and finally, standing with assistance) and not a measure of later functional capacity (i.e., in the elderly), which is aligned to measures of health. One study by Hsue et al. (2014) assessed motor skill performance in the Peabody Developmental Motor Scale in relation to STS movement patterns in children with developmental delays and typically developing children. Results indicated higher levels of motor skill competence were associated with more advanced developmental rising patterns. Additionally, Green & Williams (1992) found that middle-aged individuals self-reported PA was associated with more advanced methods of rising from a supine position. Recent pilot data in four and five year-old children demonstrated that STS time was associated measures of cardiorespiratory endurance and gross motor function in preschool children. Results demonstrated a moderately high inverse correlation ($r = -.66$, $P < .01$) between STS time and the number of PACER laps. Data also revealed a moderately high correlation ($r = -.61$, $p < .01$) between STS time and standing long jump (Nesbitt, Cattuzzo, Molina, Phillips, & Stodden, 2014). These studies provide hints for the idea that the STS test may be a logical choice as a significant predictor of an individual's functional MC over a lifespan. And, it may be a predictor of various health-related variables across age.

In conclusion, researchers have inconsistently assessed the task of STS and have linked it to differential goals and outcomes across the lifespan. Currently there is no information relating how children are able rise from a supine position with the time it takes them to rise. In addition, little information exists that relates STS time or movement sequences to other more widely accepted measures of MC in youth. This lack of research fails to address important potential links between the normally understood concepts of functional capacity, motor competence and health. Thus, the relationship between the development of movement quality and health trajectories might offer insight on how to approach these integrated concepts.

Review of Literature

Motor Competence

Motor competence can be defined as a person's movement coordination quality when performing different motor skills. These movements include the coordination of both fine and gross motor skills (D'Hondt et al., 2009; Henderson & Sugden, 1992; Haga, 2009). Gross motor skills engage large muscle groups that result in the body moving through space and/or the manipulation of objects (Burton and Miller, 1998). Fundamental motor skills (FMS) are basic skills that are an organized series of movements using two or more body segments to accomplish a particular task and consist of both locomotor and manipulative skills (Haywood & Getchell, 2005). The level of motor skill competence has been defined in terms of proficiency in common fundamental motor skills including object control and locomotor skill development (Stodden, 2008), however this term also globally reflects coordination and control of any goal-directed human movement (Robinson, Stodden, Barnett et al., 2015).

Developing fundamental motor skills also is suggested to be a major precursor for life-long physical activity (Clarke & Metcalfe, 2002). Low levels of fundamental movement skills are referred to as phylogenetic skills due to their universal occurrence (Burton and Miller 1998). These FMS are seen as the building blocks for more advanced physical activity and sport skills (Gabbard, 2004). In addition, these more highly advanced skill levels arguably can be defined as ontogenetic in nature.

Fundamental Motor Skills

Locomotor skills are actions that move the body from one place to another such as walking, running, skipping, and hopping (Malina, Bouchard, & Bar-Or, 2004); manipulative/object control skills include throwing, catching, kicking, and striking movements (Haywood & Getchell, 2005). Movement experiences early in a child's life have a significant role in building the foundation of these types of movement patterns. Those children who are delayed in their fundamental movement skills are likely to encounter lifelong problems with movement skills (Ulrich, 2000). Stodden et al. (2008) also states there is a lack of understanding of how to promote physical activity throughout the lifespan and proposes the development of MC has a unique role to promote sustainability of physical activity. The emergence of recent research is addressing how the development of MC and PA, as well as health-related physical fitness, body weight status, and psychological determinants (i.e., perceived competence and self-efficacy), synergistically interact across time (Robinson et al., 2015).

Motor Competence and Physical Activity

Lubans et al. (2010) published the first review article examining associations between MC (specifically FMS) and several health related outcomes in children and adolescents. Results from this review found strong evidence of a positive association between FMS and physical activity among children and adolescents. More recently, Holfelder and Schott (2014) published a systematic review which unlike Lubans, included measures of motor abilities, coordination, and fundamental motor skills. Barnett et al. (2009) demonstrated that childhood object control proficiency was positively associated to the time the child spent in moderate-to-vigorous activity as an adolescent. Children who exhibited a proficient level of object control had a 10-20% higher chance of participation in vigorous activities as they got older. A study conducted by Laukkanen et al. (2013) used metabolic and neuromuscular methods to examine the relationship between motor skills and physical activity in children (5-8 years). The study indicated that gross motor skills are positively associated with habitual PA and negatively associated with sedentary time. Castelli & Valley (2007) stated as a result of their study, children who had low levels of physical activity were most likely inhibited by their lack of motor competence. This suggests that motor competence may be a factor in a child's participation in regular physical activity. Ulrich (1987) examined the interrelationships among perceived physical competence, motor competence, and participation in organized sports in young children. This research revealed that motor competence was significantly related to participation and those who participated in more organized sports had better motor skills than those who did not. Both systematic reviews demonstrated a positive relationship between motor competence and physical activity, but Holfelder and Schott presented evidence of a cause and effect relationship. However, the lack of studies pertaining to motor competence and physical activity in adolescences makes it difficult to infer the association of these variables over time. To complicate the issue even more, measurements of physical activity are operationalized differently which makes it even more difficult to accurately report the relationship among motor competence and variables of physical activity (Robinson et al., 2015).

Motor Competence and Health-Related Fitness

As a result of Lubans et al. (2010) systematic review on fundamental skills in relation to children and adolescents, evidence of a positive association between FMS competency and cardiovascular fitness and an inverse association between FMS competency and weight status was present.

A recent systematic review conducted by Cattuzzo et al. (2014) examined the relationship between motor competence and health-related fitness associated with children and adolescents. Criteria for the review consisted of scientific research published between 1990 and 2013. Results of 44 studies showed strong scientific evidence supporting an inverse association between MC and body weight status along with a positive relationship between MC and aspects of HRF. Among the studies found were Okely, Booth, & Chey (2004) which demonstrated that BMI was a significant predictor for FMS proficiency as well as demonstrated that that FMS proficiency was inversely related to BMI and waist circumference in children grades 4, 6, 8 and 10. Results from this study suggest an important association between various FMS, mainly locomotor skills, and a child’s weight status. D’Hondt et al. (2009) also demonstrated the effects of

BMI on FMS. Children between the ages of 5-10 were assessed using the MABC (manual dexterity, ball skills, and balancing) and their BMI was assessed by means of an electronic scale. Results indicated that children who were classified as obese had lower total MABC scores and poorer general motor skill performance than their non-overweight peers. Stodden, Langendorfer, & Roberton (2009) demonstrated that in young adults (18-25 years old) product scores for motor skills (kicking, throwing and jumping) accounted for 79% of the variance in overall fitness measures (12-min run/walk, BF%, curl-ups, grip strength, and max leg press). This indicated strong evidence that the relationship of motor skills competence and aspects of health-related fitness can aid in the development and maintenance of healthy lifestyles into adulthood. A more recent study by Stodden et al. (2014) examined the dynamic relationships between motor skills and health-related fitness in youth (4-13 years). FMS such as throwing and jumping were significantly associated with health-related aspects for all participants. There was evidence that the association between object control skills (throwing and kicking) and HRF increases as a child reaches middle to late childhood. As a result of this study it was suggested that object control skills as it relates to HRF needs to be further explored and can be an important factor of physical fitness throughout childhood and into adult years.

Functional Capacity

One pathway that hasn't been explored is the relationship of motor competence and functional capacity. Functional Capacity is related to an individual's ability to perform normal daily activities required to meet basic needs, fulfill usual roles, and maintain health and well-being (Leidy, 1994). The term function appears in both motor development literature as well as the medical field; however there are variations in terminology. In the motor development literature, function is defined as a movement that is goal-directed and has both purpose and meaning (Fisher, 1992). Physical and Occupational therapy classify movement function as the ability to perform the activities of daily living that are both required and optional (Burton & Miller, 1995). Both definitions imply purpose and meaning whether it is to throw a ball at a target or get up from a chair. Based on age related difference, motor competence is a concern in young children while functional capacity measures are seen in adults and the elderly populations; there is very little overlap. The key functional capability of the musculoskeletal system is mobility. It can be measured in the laboratory or field by function tests such as walking speed, step test, chair stand, measures of mobility, and balance tests (Vuori, 1995).

The underlying principle to functional capacity is the level of neuromuscular coordination and control. Efficient movement function and the maintenance of balance during dynamic tasks is complex. The neuromuscular system is a combination of the nervous system and muscles working together in order to produce movement. A requirement of being able to perform fundamental movement skills and other meaningful tasks is motor coordination. Motor coordination is the harmonious functioning of body parts (i.e., gross and fine motor movements) that are goal-oriented. It is the body’s ability to control degrees of freedom and movement of different body segments in order to produce a particular outcome (Vandendriessche, 2011). In conjunction with motor coordination, strength and power also play a major role in one’s ability to perform everyday tasks and physical activity. Children who experience difficulties in motor coordination struggle to perform age-related motor skills and/or accomplish developmental milestones. These difficulties are most often categorized as developmental delays. Upon birth, the nervous system begins developing; Up until the first few years of our lives, we are unable to efficiently use our interconnections due to the lack of neurons; this results in poor coordination, poor strength, and poor cognitive abilities. Several major components of the brain contribute to our movement and coordination. Neurons in the motor cortex influence muscle coordination and the body's ability to move a particular limb to a particular point. The motor cortex is also related to function. Like the motor cortex, the cerebellum is also related to coordination and responsible for fine control of the voluntary movements. The cerebellum aids with distribution of motor output by providing adjustments to help the body maintain equilibrium when there are changes in one's environment. Neuron growth rapidly increases after birth until about the age of 13. After this point, the development of neurons is slow. This period in time is crucial for development of motor coordination and control (Vandendriessche, 2011). As an individual gets older, motor performance deficits include difficulty with coordination, issues with balance and walking, and slower movements (Seidler, 2010). Compared to younger adults these types of deficits increase the risk of falls and morbidity.

As we approach late adulthood (roughly 60 years of age) sarcopenia begins to appear. Sarcopenia is the loss of skeletal muscle mass and strength due to age. The decrease in muscle mass ranges from 1-2% per year (Vandervoort, 2001). Research has indicated that regular participation in physical activity throughout the lifespan has the potential to reduce the decline in functional abilities, sarcopenia, and prevent the onset of various risk factors. Lord (1996) stated that older individuals who have higher level of physical activity have better balance and control as well as a better range of sensorimotor function.

Functional Capacity and Physical Activity

Numerous studies have demonstrated that habitual physical activity was associated with less functional limitation. Studies have also indicated that physical activity decreases mortality rates. Living a sedentary life is considered a major risk factor for obesity as well as cardiovascular disease. The amount of physical activity accumulated by an individual is also associated with all-cause mortality risk (Macfarlane et al., 2006). A longitudinal study conducted by Brach et al. (2003) examined the relationship of functional status and physical activity over a 14-year period in community dwelling individuals. At the end of the 14-years, a significant relationship existed between the two which suggested that physical activity plays a role in maintaining functional ability later in life. In addition, Fries et al. (1994) conducted a longitudinal study with adults ranging from 50 to 72 years of age. The purpose of the study was to determine whether vigorous running is associated with the development of disabilities as we age. There was a significant difference in mortality between those who were runners and those who were not. Older individuals who engaged in vigorous activities have slower development of disabilities and lower mortality then those in the general population. Physical fitness may be a useful avenue to explore the relationship between an active lifestyle and physical functioning. Vouri (1995) states that physical activity relates to functional capabilities directly through the components of health-related fitness, and indirectly by influencing the development of functional and degenerative disorders. A decline in motor performance and muscular strength are a result of aging and affects a personal mortality rate as well as physical independence. Physical activity is a modifiable risk factor for overall musculoskeletal fitness (Buchman, 2007).

Functional Capacity and Health-Related Fitness

Several studies have examined the relationship of functional capacity and health related factors in the elderly. Age is an important determinant of functional limitation and therefore functional capacity is generally only examined in older adults. Muscle atrophy is associated with the aging process and has a negative effect on one’s quality of life. A positive relationship has been shown between strength and functional status. A decline in functional ability can be a result of a variety of factors such as loss of muscle or an increase in body weight which is related to the loss of physical independence (Hunter, McCarthy, & Bamman, 2004). Sousa & Sampaio (2005) examined the effects of an Insanity strength training program in the elderly population to two widely used functional tests: the functional reach test (measurement of balance) and the Timed Get-Up-and-Go Test (gait measurement). Results indicated that the strength training program made important improvements to functional task performance as well as aided in the prevention of falls. Foldvari et al. (2000) hypothesized that peak power is associated with functional status in women. The study was part of a 1-year randomized controlled clinical trial. Participants (n=80, mean age 74.8) were eligible if they had previously fallen within the last 12 months or suffered from a functional status impairment. Results indicated that strength for chest press and leg press were significantly related to functional status. Along with muscle power, habitual physical activity level played a role in older women’s functional dependency.

Another useful measurement of strength is grip strength. Taekema (2010) used handgrip strength to predict functional, psychological, and social health in 85 year olds (n=555). Related to functional health, results demonstrated that individuals who had lower handgrip strength were correlated with lower functional scores and were predicted to have a more rapid decline in performing daily life activities.

Motor Competence Assessments

Motor skill assessments serve a variety of purposes which include but are not limited to: categorization or identification of plan treatment strategies, evaluating change over time and the ability to forecast (Burton & Miller, 1998). Many motor skill assessments have been created to identify developmental delays and disorders in infants and young children. In recent years several batteries of tests have been used not only by medical professionals, but also by physical educators. In the physical education setting, teachers use motor skills competence assessments as a way to evaluate students on their ability to perform a task either by process-oriented or product-oriented outcomes. However, motor skill assessments have failed to provide a valid and reliable assessment that combines both process and product scores as well as an assessment that can be used across age including childhood, adolescence and adulthood. Stodden et al. (2008) argued that this disconnect in assessments might underestimate the predictive utility of motor skill competence as it relates to physical activity, health-related fitness and body composition status.

Product & Process Oriented Assessments

Product-oriented assessments evaluate the outcome of a particular movement. These outcomes are quantitative in nature and reflect scores of speed, distance, etc. The most used form of product-oriented assessment that appears in the literature is the Köper Koordination Test für Kinder (KTK). The Köper Koordination Test für Kinder (KTK; Kiphard & Schilling, 1974) is a standardized product-oriented test aimed at assessing children 5 to 15 years of age in a battery of dynamic balance and gross motor skills. The test consists of four items: balance, jumping laterally, hopping on one leg over an obstacle, and shifting platforms. The KTK is appropriate for children with a typical developmental pattern, as well as for children with brain damage, behavioral problems or learning difficulties. It also provides valid and separate normative data for boys and girls. The KTK offers two major advantages. The first advantage is that it is a quick screening of stability and mobility skills. Secondly, it is also considered very reliable with test-retest reliability of 0.90 and 0.97 for the total test battery (D'Hondt, et al. 2013). Unfortunately, norm values have only been established for ages 5-15 and using German norms for other populations might be an adequate representation.

The Movement Assessment Battery for Children (MABC-2) also was originally designed to test motor impairments in children (Henderson & Sugden, 1992). The Movement-ABC test is a revision of the Test of Motor Impairment (TOMI) and originates from the Oseretsky scales for the motor capacity of children (Simons, 2004; Burton and Miller, 1998). In 2007, the second edition was created which included four new items (Henderson, Sugden, & Barnett). It is the one of the most frequently used test of motor impairment in the world. Unlike other movement skill tests which measure the child's strengths and weaknesses over a fairly wide age range, the Movement-ABC is limited to the movement skills of a certain age band. It consists of three components: a standard performance test, a teacher checklist, and a set of guidelines for interventions. The most used component of the M-ABC is the standard performance test (Smits-Engelsman, Fiers, Henderson, & Henderson, 2008). It is a norm-referenced test that examines three subsets: manual dexterity, ball skills, and static and dynamic balancing in children ranging from four to 12 years of age. Croce et al. (2001) found high intraclass correlation coefficients (ICCs) (r = 0.92 to 0.98) for test reliability and concluded that stable values over a one week period were found when using the Movement-ABC. Inter-rater and test-retest correlation coefficients range from r = 0.92 to 1.00 and from r= 0.62 to 0.92 except for one item in the two oldest age bands (Henderson et al., 2007) and test-retest reliability for the total score was excellent, with an intraclass correlation coefficient of 0.97 (Chow & Henderson, 2003). One major attraction to the MABC is that it consists of both a quantitative and qualitative component and it is easily used in the educational setting. A disadvantage of the MABC assessment is amount of time required for set-up and practice to become efficient with administration and scoring.

Process-oriented assessments qualitatively evaluate how a movement is performed. These forms of assessment are suggested to be more useful in terms of identifying specific skill components that may need adjustment, which will promote better performance of FMS (Ulrich, 2000). The Test of Gross Motor Development (TGMD) is a norm and criterion reference test designed for children 3 to 10 years of age (Ulrich, 1985). The TGMD was created to help identify children who were developmentally delayed compared to their peers. It is widely used in the physical education setting and assesses both locomotor and object control subtests. In 2000, Ulrich revised the TGMD to the second edition (TGMD-2). The locomotor assessments (i.e., run, gallop, hop, leap, horizontal jump, and slide) are indicators of a child's ability to translate their center of mass. The object control assessments (i.e., striking a stationary ball, stationary dribbling, catching, kicking, overhand throw, and underhand roll) are related to a child's overall object projection and reception capabilities. TGMD-2 offered greater internal consistency and stability coefficients. Construct validity was later examined by Evaggelinou et al. (2002) to show that the TGMD has good cross-generalizability and has well supported validity. Similar to the MABC, the TGMD-2 includes qualitative aspects of the motor behaviors, but unlike the MABC, it provides information on skill mastering both below and above the skill level of the child. One drawback to the TGMD-2 is the lack of evaluation for fine and stability movement skills; it also has a ceiling effect when testing normal developing children.

The Get Skilled: Get Active was developed by the New South Wales Department of Education and Training (2000) and consists of 12 fundamental skills assessments. The skills are broken into three categories: locomotor skills (run, jump, hop, skip, gallop, leap and dodge), non-locomotor skills (static balance, bend, sway, twist and turn), and manipulative skills (catch, throw and kick). It was reported by the Department of Education (1996) a test–retest reliability of the 11 motor skills over a seven day cycle on 42 primary school children, returning reliability estimates (alpha coefficient method) of $\alpha = .70$ or greater for all skills except the leap and run ($\alpha = .13$ and $\alpha = .17$ respectively). The skills that were added to the original battery of test were validated and showed a god test re-test reliability in children (Barnett et al. 2009).

Functional Capacity Assessments

Functional capacity assessments fall into four major categories: overall function, balance, gait, and basic functional activity measures. These assessments were designed to evaluate and manage physical declines in older adults. Traditionally assessments of fitness and function have been tailored towards younger individuals and are not applicable to frail, older populations due to the physical demands it puts on the body.

One of the most used overall functional capacity measurements is the Continuous Scale Physical Functional Performance Test [CS-PFP]. The CS-PFP consists of 16 household tasks that are performed serially, in a manner of usual function (e.g., in a person's preferred manner rather than in a constrained fashion). Task performance reflects the person's ability because each task is performed at maximal effort within the person's judgment of comfort and safety. CS-PFP was validated on ambulatory older adults with a broad range of physical abilities but without a focus on specific underlying disorder in 1996 (Cress et al.). Cress et al. (2005) established community based excellent test-retest reliability (r = 0.93 - 0.98) for domain and total scores.

The Functional Reach Test (FRT) was designed to measure the limits of stability in an anterior direction in individuals classified as community-dwelling elderly, Parkinson's Disease, and individuals with spinal cord injuries. The maximal distance that subjects can reach forward horizontally while maintaining a fixed base of support is measured (Daubney & Culham, 1999). This test was proven to have excellent test-retest reliability in the community dwelling elderly (Weiner et al. 1992; Duncan et al, 1990). In children, the FRT also has been considered a valid tool to measure balance. However, because children show more variability in their movements than adults and undergo changes in body proportions and size during development, the reliability of various postural control tests in children has been difficult to establish (Volkman et. al., 2007). It appears that the FRT is related to functional mobility and balance and is an indirect measure of strength (Zaino et al., 2004).

Another common balance measure is the “Timed up and Go” [TUG] modified by Podsiadlo and Richardson (1991). It was designed as a clinical measure of basic mobility and assesses individual’s risk for falling. Individuals are given verbal instructions to stand up from a chair, walk 3 meters as quickly and safely as possible, cross a line marked on the floor, turn around, walk back, and sit down. In adults, the TUG has been shown to be correlated to gait speed, postural sway, and the Berg Balance Scale. Hofheinz et al. (2010) obtained excellent test-retest reliability (*r* T1-T2 = 0.98 and *r* T1-T3 = 0.98) in healthy older adults between the ages 60-87. The TUG score also reflects changes in functional abilities as children age. Thus, the TUG is thought to measure components related to gait speed, postural sway, functional mobility, and balance (Zaino et al., 2004).

The self-paced 6-minute walk test (6MWT) is classified to represent the most suitable method to assess the submaximal level of functional exercise capacity in adults. It is a widely used gait analysis assessment. It has been tested in populations with vestibular disorders, Parkinson’s Disease and elderly adults. Individuals in a clinical based setting are instructed to walk for 6 minutes along a 30m unimpeded hallway. This is a useful instrument in physical therapy because it is easy to administer and it mimics everyday activities. Harada et al. (1999) and Steffen et al. (2002) both showed excellent test-retest reliability in the elderly population (r = 0.95) and (ICC = 0.95). The 6-minute walk test (6MWT) is a valuable and practical tool to measure exercise performance on a sub-maximum level in children, reflecting activities of daily living better than any other functional walk test. Excellent reliability and validity of the 6MWT has been demonstrated in healthy normal-weight children (Geiger et al., 2011).

The Two-Minute Walk test (2MWT) was more tolerable than the 6MWT in the frail elderly population (Brooks, Davis, & Naglie, 2007). Similar to the 6MWT Individuals are instructed to walk without assistance for 2 minutes and cover as much distance as they can. Test-retest reliability (ICC = 0.95) was established in older adults by Connelly & Thomas (2009).

The Functional axial rotation (FAR) is a basic functional activity measure. This form of assessment is primarily conducted in community-dwelling older adults or individuals with Parkinson’s Disease. The FAR protocol assesses global axial motion of the trunk, head, and neck (Hillard et al., 2008). The FAR measures are designed to determine how successful a person can be in physically moving the spine as well as in identifying objects to the posterior without consideration for the specific impairments that might limit performance (Schenkman et al., 1995). Schenkman et al (1995) established excellent test-retest reliability for the physical motion portion of the test in adults.

Another test that has been used to assess functional capacity across the lifespan primarily in populations with injuries and disease is the Supine-to-Stand (STS) test.

Supine to Stand

Supine-to-stand is a functional capacity and health assessment generally conducted in the elderly and disabled population. Similar to motor competence test, it is generally a process or product-oriented test and reflects an individual's dynamic balance ability. The supine-to-stand task examines basic "right abilities." Righting abilities are also referred to as developmental milestones in the motor development literature (i.e., rolling to a supine position, sitting up, and standing). One possessing the ability to accomplish certain righting abilities is a key component in establishing and maintaining physical independence. The supine task is one that appears not only at birth but is present until death. In the 1980's VanSant, took the lack of movement descriptions for healthy adults within the field of physical therapy and created descriptive categories. Her assumption was that the movement one uses to stand is age-related and that those movements will change as one ages. Similar to Roberton's (1977) use of a component approach, VanSant divided the body into three components: upper extremity (UE), axial region (AX), and lower extremity (LE) (VanSant 1988). These components gave way to a qualitative method of analyzing movements based on separate body regions. Cross-sectional studies of children and adults have validated the movement categories with the exception of additions of new movement patterns presented by individuals with disorders. VanSant's (1988) original descriptive categories for adults consisted of 5 levels of the upper extremity component which represent levels ranging from the least advance to the most advanced movement form. The upper extremity components were push and reach to symmetrical push (least advanced), push and reach, symmetrical push to reach, symmetrical push, and symmetrical reach (most advanced). The axial region consisted of four levels: full rotation, abdomen up (least advanced), partial rotation, symmetrical, interrupted by rotation, and symmetrical (most advanced). For the final component the lower extremity was divided into four levels. The levels were half kneel (least advanced), asymmetrical squat, symmetrical squat with balance step, and symmetrical squat (most advanced). These categories were eventually expanded and adapted to fit various age groups and individuals with impairments.

Studies by VanSant and Marsala and VanSant (1988; 1998) showed that certain patterns of rising are associated with a particular age group. For example, with adults, there is use of more symmetric movements in all three components. They used a symmetrical push and trunk movement and the lower extremity movement consisted of a symmetrical squat pattern. In VanSant's (1988) study examining children's (ages 4 to 7) movements, more variability was exhibited in the choices of patterns then in the adults. The movements established for adults were used to analyze children's movements and two new movements were presented (jump to squat and full rotation, abdominal down). Grouping by age, showed that movement patterns varied. Younger children used a less advanced movement pattern then those who were in the older group. The most common pattern used by all ages was characterized by an asymmetrical push, forward with rotation for the trunk, and an asymmetrical wide-based squat. Even though this movement pattern was the most occurring pattern, variations of less and move advanced patterns were shown in relation to age. Marsala and VanSant (1988) investigated age-related differences in movement patterns used by toddlers. Modifications to the descriptive categories were expanded once again to allow for two new lower extremity movements (pike and jump to pike). The most frequently used patterns in toddlers were a push and reach to bilateral push for upper extremity, a full rotation, abdomen down and up for the axial region, and a kneel for the lower extremities. The presence of several patterns which were present in young toddlers and older adults provides evidence for a life-span approach. It suggests that they both share similar neuromuscular issues that produce these types of actions.

The supine-to-stand task is most often used to assess development disorders in children. Belt et al. (2001) used VanSant's descriptive categories to see how they compared to children with Prader-Willi Syndrome which is a complex genetic disorder. It is characterized by poor muscle tone and growth, chronic overeating, and delayed development. They compared nine participants with Prader-Willi Syndrome to a healthy individual who was within 10% of their BMI and matched their age. The movement patterns were adapted from VanSant's descriptions of normal individual patterns. The new list of categories included movements that were most often exhibited by individuals with PWS. The upper extremity region consisted of 6 different levels, the axial region 5, and the lower extremity consisted of 7. Results demonstrated that individuals with PWS used a "push and reach to bilateral push" followed by a push on the leg. For the control subjects the movements used where more advanced. The axial region movements for individuals with PWS consisted of "full rotation abdominal up: 91.1% of the trials and "partial rotation." The control group used the "forward with rotation." The lower extremities used by PWS subjects was a "pike," but varied based on age. Those in the control group used a more advanced movement which was an "asymmetrical wide based squat." Accounting for age, neither group's score changed drastically which could be a result of having a small sample size and the variations in age. There was a weak correlation between subject's movement patterns and BMI.

Several questions have been purposed by VanSant and others about the influence of body topography on one's movement patterns however; very little published research has addressed these questions. In relation to body weight, unpublished data by VanSant and colleagues (1990) suggest that carrying an extra 10% of your normal body weight can have an effect on how one stands from the floor due to the extra weight requiring one to use more asymmetrical movement patterns. Physical activity has been examined in relation to movement patterns in adults. Green and Williams (1992) studied the rising patterns of seventy-two adults (30-39 years old) compared to their self-reported physical activity levels. Participants were divided into three groups based on their responses to the survey: those who exercise daily, one or twice a week, and those who rarely exercised. Results indicated that the more active individuals exhibited a more advanced movement pattern when standing. This study suggests that the life-style choices made my adults relate to their ability to stand.

Hsue, Wang, and Chen (2014) compared movement patterns from a supine-to-stand task in children who were diagnosed with mild to moderate development delays to an age-matched healthy child. The Peabody Developmental Motor Scale II (PDMS-2) was used to determine motor performance for both groups. Results demonstrated a high correlation with movement patterns and the lower extremity component and a moderate correlation with the upper extremity and axial region. Participants who had a higher score on the motor performance test demonstrated more advanced levels of rising from the floor. Children with developmental delays overall showed less advanced movement patterns, more variability within trials, and scored lower than their typical developed age-match child. However, children with developmental delays followed similar developmental sequences it took them longer to stand.

Ng et al. (2013) investigated supine-to-stand time and the time it took to run 10 meters in a healthy population of children (n=225) ranging from 2-8 years of age. Participants in this study were asked to perform the supine-to-stand for two recorded trials and then were asked to run a 10 meter distance as fast as possible. Results from this study demonstrated that it took normal children 1-5 seconds to stand with a mean time of 2.08 seconds. There was a strong, negative correlation with time and age indicating that a normal developing child increases the rate of speed in regards to proficiency of the task as they age. There was no significance with time to stand and height, weight, or BMI. Ten meter times ranged from 1 to close to 7 seconds with a mean time of 3.46 seconds. Similar to the supine-to-stand task results, the results showed that times decreased as the participants ages increased. However, unlike supine-to-stand there was a negative correlation with height, weight, and BMI. This study did examine movement patterns in relation to standing times but the movement patterns failed to establish validity. However the movement patterns presented did suggest that faster time standing were correlated with more advanced movements in boys only, not in girls.

Research concerning supine-to-stand has primarily been used to assess functional capacity and health in elderly populations with the focus on movement patterns. Time has been used as a measure of functional capacity however very little is known about how time relates to the movement processes of STS and other MC measures and health in healthy children. Similar to motor competence measures we are lacking a functional capacity test that is a valid process-product measure for predicting health across a lifespan.

Statement of Purpose

The purpose of this study is twofold: (1) to examine STS as a developmentally valid measure of functional MC across childhood, adolescence, and young adulthood. This will be accomplished by using a pre-longitudinal screening approach. Examining associations between movement pattern levels and STS time will provide a secondary measure of developmental validity. Lastly, concurrent validity of STS (movement patterns and time) will be examined relative to other developmentally valid measures of MC (fundamental motor skills) used in these age groups. The second purpose is to examine the predictive utility of process- and product oriented assessments of STS as a predictor of health by examining its association to multiple health-related variables (i.e., PA, weight status, and health-related fitness) across childhood, adolescent and young adult samples. Overall, this study has the potential to impact how future researchers assess MC and its relationship to aspects of health across the lifespan.

Aim 1: Examine the developmental validity of supine-to-stand as a measure of functional MC in individuals aged 4-25.

Examine via a) pre-longitudinal screen (process), b) movement pattern levels with STS time (product) and c) concurrent validity with other MC measures

Hypotheses: a) Prelongitudinal screen (process) will demonstrate appropriate developmental pattern trajectories across age, b) STS time will be inversely associated with component sequence levels, and c) Measures of STS will demonstrate adequate concurrent validity with other valid MC assessments in individuals across age.

Aim 2: Examine the association of supine-to-stand measures to PA, weight status, and aspects of health-related fitness in individuals aged 4-25 years.

Hypothesis: Associations between supine-to-stand measures and PA, weight status and health-related fitness will be moderate to moderately strong across individuals aged 4-25 years.

CHAPTER 2

EXAMINING THE FEASIBILITY OF SUPINE-TO-STAND AS A MEASURE OF FUNCTIONAL MOTOR COMPETENCE[1]

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[1] Nesbitt, D., Molina, S., Sacko, R., Brian, A., Robinson, L., & Stodden, D. To be submitted to the Journal of Motor Learning and Development

Motor competence (MC) is defined as the degree of skilled performance in a wide range of motor tasks (Stodden et al., 2008). Recent research emphasizes that the acquisition and maintenance of motor competence from early childhood into adulthood is a key component to living a healthy and active lifestyle (Robinson et al., 2015), specifically related to health-related fitness (Cattuzzo, 2014) and physical activity (Lubans, Morgan, Cliff, Barnett, & Okley, 2010; Logan, Barnett, Goodway, & Stodden, 2016; Holfelder & Schott, 2014). Research also suggests that MC is both a precursor and a consequence of weight status (Robinson et al., 2015). However, different assessments have been used to assess MC and its association to various aspects of health across the lifespan, making it difficult to track changes across time. For example, many popular motor competence assessments used in childhood and adolescent populations have been designed to detect developmental delay and/or are only applicable up to a certain age (e.g., TGMD-2, M-ABC, BOT, and KTK). These assessments vary dramatically by the type of MC (e.g., gross vs. fine, fundamental movement skills vs. global coordination,) and what aspects of MC they are measuring (i.e., process vs. product, object control vs. locomotor). Thus, the design and intent of these various assessment protocols make it difficult to track changes in motor competence across time, particularly into adulthood.

Similar to MC measures used in children and adolescents, common measures of "functional capacity," as assessed in aging populations can be viewed as measures of MC (i.e., walking speed, supine-to-stand, timed up and go, etc.) (Corsonello et al., 2012; Rikli & Jones, 2001; Volpato et al., 2011). In essence, functional capacity assessments measure gross coordination and control, which can be defined as the capability of an individual to coordinate and control their center of mass and extremities in a gravity-based environment to effectively complete a goal (Stodden, 2009). Tests within these batteries are linked to health outcomes, physical independence, mortality, and overall quality of life (Corsonello et al., 2012; Rikli & Jones, 2001; Smee, Anson, Waddington, & Berry, 2012; Volpato et al., 2011). Similar to the youth assessments, functional capacity measures are used only in adult, mostly elderly, populations.

In contrast to the many youth MC assessments, component developmental sequences have been used to assess changes in movement coordination patterns in fundamental movement skills (e.g., throwing, jumping and hopping) across the lifespan (Halverson, 1982; Haubenstricker & Branta, 1997; Horton & Lipsitz, 2001; Roberton & Konczak, 2001; Stodden, Langendorfer, Fleisig, & Andrews, 2006a, 2006b; Stodden, Langendorfer, & Roberton, 2009; Williams, Haywood, & VanSant, 1991; 1998). Developmental sequences are useful across a wide age range as they were developed to address progression and regression across the lifespan (Halverson, 1982; Roberton & Langendorfer, 1980; VanSant, 1988; 1990; William et al., 1991). However, the relationship of developmental sequences to health-related variables across the lifespan is limited (Lorson, 1980; Vansant, 1988a; 1988b; Williams, 1991).

The lack of MC measures that can be assessed across the lifespan has created a void in understanding not only how movement development occurs, but also in how it relates to health across various ages. Thus, it is logical and necessary to identify developmentally valid and easily administered motor competence assessments that can be effectively and reliably implemented across various age groups. The supine-to-stand test (STS) is one such test that may be a feasible option to test across the lifespan as the ability to independently rise from the ground is demonstrated throughout life (i.e., rising from a bed and regaining posture after a fall) and is a major precursor for establishing and maintaining bipedal physical independence (Bayley, 1936; VanSant, 1998). The time to stand from a supine position has been used as a clinically-based assessment for functional capacity and health in the elderly populations (Bohannnon & Lusardi, 2004; Green & Williams, 1992; King & VanSant, 1995; VanSant, 1998a) and STS component developmental sequences have been examined in children (e.g., Prader-Willi, muscular dystrophy, etc.) (Belt et al., 2001; Ng, Conway, Rigby, Priestman, & Baxter, 2013; Unrau, Hanrahan, & Pitetti, 1994). Thus, as STS would seem to have adequate face validity as a potential lifespan measure of MC, its potential value as a stand-alone assessment is appealing if its movement and performance properties demonstrate adequate developmental validity.

To initially understand developmental patterns of rising from a supine position, VanSant and colleagues conducted three different cross-sectional studies and described movement patterns in toddlers, children, and young adults. Overall, participants in the three different age groups demonstrated mostly similar types of movement patterns, although there were a few different movement descriptors noted across age. These data provided a snapshot of movement categories and potential progression in normally developing individuals (Marsala & VanSant, 1998; VanSant 1988a; 1988b). Component categories were divided into actions of three body regions: upper extremities (UE), axial region (AX), and lower extremities (LE). More advanced movements generally were demonstrated as individuals increased in age with the most advanced movements occurring during the teenage years (VanSant, 1990). Results also demonstrated that both young children and adults use asymmetrical movement patterns to maintain balance (e.g., rotating their trunk to the side and kneeling) when standing, whereas adolescents and young adults demonstrated more symmetrical movements (e.g., the head and trunk flex forward, with or without a slight degree of rotation) when rising from the floor (VanSant, 1990).

As described in the previous section, the use of descriptive categories (process-oriented measures) is important to understand how movement development occurs (i.e., the quality of movement); however, the association of these movements to the time it takes to stand has yet to be examined. Time to stand from a supine position is important because the ability to rise from the floor quickly demonstrates more effective control of coordinated body segment movements (i.e., increased function).Time to stand has been validated as a reliable measure of functional capacity for older adults (Alexander, Ulbrich, Raheja, & Channer, 1997; Bohannon & Lusardi, 2004; Hofmeyer, Alexander, Nyquist, Medell, & Koreishi, 2002; Schenkman, 2000; Ulbrich, Raheja, & Alexander, 2000) and is a predictor of morbidity and fall-related injuries in aging populations (Alexander, Ulbrich, Raheja, & Channer, 1997). However, limited data is available on the time to stand in healthy children or young adults (Ng et al., 2013; Alexander, Ulbrich, Raheja, & Channer, 1997). Ng et al. (2013) found that the average time it took to stand for healthy children was 2.08 seconds; however, this average STS time was averaged among all individuals with only two trials and the descriptive categories used to identify movement patterns were not validated developmentally. In addition, two studies have compared STS time of healthy young adults to older adults demonstrating that younger adults stood up twice as fast as their healthy older counterparts and three times as fast as their community dwelling counterparts (Alexander, Ulbrich, Raheja, & Channer, 1997;

Ulbrich, Raheja, & Alexander, 2000). Although time to stand was assessed for these adults, it was not compared validated movement patterns. To our knowledge only one study (Nesbitt, et al., submitted) has examined the relationship between validated developmental sequences and the time it takes to rise from the floor. Results from a sample of preschool children suggest axial and upper extremity components may be highly constrained and serve as one functional unit to promote rising from a supine position. Results also indicate these two movement components (axial and upper extremity) promote faster standing times, while LE may not be as critical in rising quickly. Examining STS movement patterns and time across additional age groups is needed to confirm these findings.

Based on the aforementioned limitations of current MC measures and the lack of adequate MC measures across the lifespan, STS seems to be a logical assessment to examine an individual’s motor competence across the lifespan. However, the previously developed and adapted movement categories have not been tested via a prelongitudinal screen. The STS test has the capability to track changes in motor development over time (i.e., progression and regression) and thus, will allow researchers to more effectively assess the relationship of MC to aspects of health and function across the lifespan.

The first purpose of this study is to examine the validity of STS as a developmental measure of functional MC across childhood, adolescence, and young adulthood using a pre-longitudinal screen approach (Roberton, Williams, & Langendorfer, 1980). Examining associations between movement pattern levels and STS time will provide a secondary measure of developmental validity. The second purpose is to examine the concurrent validity of STS (movement patterns and time) against developmentally valid measures of object projection and locomotor skills (i.e., throwing, kicking, jumping and hopping) in these age groups.

Methods

Participants

A convenience sample (*N* = 265) of four specific age ranges from early childhood through young adulthood (3-6, 9-12, 13-17, and 18-25 years) was recruited to participate in this study. These age groups were selected because they cover developmental stages of early childhood, middle-late childhood, adolescence and early adulthood. Equal numbers of boys and girls from each age range were recruited from local private and public schools and from a university in the southeast United States (see Table 1 for participant data). Prior to participation, the study was approved by the University's Human Subject Review Board and parental consent and verbal assent from all participants was obtained. Individuals with any physical disabilities or medical conditions that prevented them from completing testing were not included in this study.

Procedures and measures

Prior to testing, individuals performed a general warm-up for each session that included a 3-5 minute jog, followed by static and dynamic stretching exercises. In addition, participants were given three minutes to complete specific warm up trials for each skill performed. Testing was completed in a gymnasium and/or designated outdoor area. Individuals completed testing on five skills (throwing, kicking, jumping, hopping, and STS) with performance of skills assessed via movement patterns (process) and outcomes (product). Each skill was performed at a different station and all skills were video recorded from the side view (Green & Williams, 1992; VanSant, 1988). Participants were instructed to perform with maximum effort, which produces the most advanced movement pattern of ballistic skills (Langendorfer, Roberton, & Stodden, 2011). Participant's throwing, jumping and hopping developmental sequence were analyzed and coded based upon previously established methods for these three skills (Roberton & Halverson, 1984; 1988; Clark & Phillips, 1985; Lane et al., submitted; Halverson & Williams, 1985; Roberton & Langendorfer, 1980). As developmental sequences are normally categorized based on their modal level (Stodden et al., 2006a; 2006b), participants performed five trials for each discrete skill with the exception of the hop. Hopping is classified as a continuous skill with repeated movements that are assessed according to their cyclical movements. Therefore, two trials of hopping on each leg were assessed for each participant with movement patterns and hop distance coded and analyzed at a later time. Maximum throwing and kicking speed (m/s) was calculated using a radar gun (Stalker, Inc.) (Stodden et al., 2006a; 2006b). Maximum standing long jump distance (i.e., distance from the take-off line to the back of the closest heel on landing) was assessed as a percentage of the participant's height (Stodden, Gao, Goodway, & Langendorfer, 2014). Average hop distance was calculated using a minimum of three consecutive hops (4 touches; from weight bearing toe to toe) using Dartfish Video Analysis Software (Version 7.0).

STS was assessed by having participants start in a supine position with their hands by their side in a yoga mat and their feet in line with the edge of the mat. A "go" command prompted participants to stand as quickly as possible and touch a designated spot on the wall. Time between trials was self-selected to minimize fatigue. STS was analyzed using an adapted version of the VanSant and colleagues (1998a; 1988b; 1998) developmental movement categories. The adapted version was used in order to provide a comprehensive range of possible movement patterns for all age groups (see Table 2). Modal component developmental sequences for upper extremity (4), axial (5), and lower extremities (5) (VanSant, 1988a, 1988b; Marsala & VanSant, 1998) were used for data analysis. Modal profiles were identified as the most occurring combination of movements demonstrated across the five trials for each participant. Time was calculated from the first initial movement to the point where the participant touched the designated spot on the wall. The modal profile times for each participant were averaged and used for data analysis.

Developmental sequence coding for all skills was conducted by two trained raters. Modal profiles for each skill were identified using the most occurring movement patterns for each participant, and were used for descriptive data. For each skill inter- (>.80) and intra-rater (>.80) reliability were calculated using Kappa and were deemed acceptable.

Statistical Analysis

An apriori power calculation with alpha set at $p < .05$, and an f^2 of .28 yielded a sample size of 43 with a power estimate of .80. Thus, an oversampling of 60 participants per age group was sufficient to determine significance at $p < .05$ level.

The data were separated by age groups and analyzed in six steps, starting with the pre-longitudinal screen. Observed frequencies of occurrence for each modal level within each component for each age group were calculated and those frequency percentages were plotted against chronological age (Roberton, Williams, & Langendorfer, 1980) to determine the developmental trajectories of each component. Next, Spearman's Rho correlations were calculated to examine the associations between STS time and the three STS components of upper extremity (UE), axial (AX), and lower extremity (LE) by each age group.

Third, L-statistic multiple regression analysis was conducted with STS time as the dependent variable and the STS components as the independent variables while controlling for BMI, for each age group. The L-statistic analysis was conducted due to the non-parametric nature of the STS components. Nonparametric analysis of rank order data are allowed with the use of parametric analysis methods, such as multiple regression, when an L-statistic is calculated by hand (Puri & Sen, 1985) at the outset of the data analysis (Thomas, Nelson, & Thomas, 1999). The L-statistic was treated as an approximation for χ^2 and was acquired from the following equation, $L = (N - 1)\, r^2$. N is equal to the number of participants within a grouping and r^2 is equal to the proportion of true variance (Thomas et al., 1999).

Fourth, Pearson's correlations were calculated to compare performances between STS time and the MC product-oriented assessments of the standing long jump, kick, throw, and hop. Fifth, we conducted Spearman's Rho correlations analysis on the STS component data and the MC product-oriented assessments of the standing long jump, kick, throw, and hop. Finally, Spearman's Rho correlations were calculated to compare performances between STS time and the MC process-oriented assessment data (i.e., developmental sequences) of standing long jump, throw, and hop.

Results

The percentage of trials classified within each step by age is shown for each component in Figures 1, 2, and 3. Cross-sectional data “curves” for the Upper Extremity (UE), Axial (AX), and Lower Extremity (LE) components generally fit the Roberton et al. (1980) hypothetical model curves. The percentage of trials classified within the upper extremity components indicate the frequency of Level 1 (push and reach to bilateral push) was observed most often in the early childhood group and its occurrence declined thereafter. Level 2 (asymmetrical push) showed the most occurrences of any level across all four age groups; however, there was a slight decline during late childhood with the emergence of Levels 3 and 4. The occurrence of Level 2 again began to increase into young adulthood where it was observed in over 80% of the trials. Levels 3 (symmetrical push) and Level 4 (symmetrical reach) generally followed the same pattern across age groups with the occurrence of Level 3 being the most prominent of the two. Both levels increased from early childhood into late childhood but gradually declined thereafter. Similar age-related trends are illustrated in the curves for both the Axial and Lower Extremity levels.

Axial region component levels 1 (full rotation, abdomen down) and level 2 (full rotation, abdomen up) declined across age groups, as would be expected in a developmental progression. Level 3 (partial rotation) also showed a dramatic decrease from early childhood into late childhood, but remained relatively constant across late childhood into young adulthood. Level 4 (forward with rotation) shows the highest percentage of occurrence with approximately 70% during late childhood then declined into adolescence. Trends in Level 4 are followed by an increased occurrence Level 5 (symmetrical) from late childhood (15%) into adolescence (40%). In the young adult group, the frequencies of symmetrical movements (Level 5) decreased back to 18% as the percentage of more asymmetrical movements (Level 4) increase from 45% (adolescent group) to 64% (young adults). According to the Roberton et al. model, Level 1 and 2 would be expected among younger individuals and Levels 3-5 would be observed most often in older individuals.

The data for the lower extremities revealed Levels 1 (jump to squat) and 2 (kneel) were demonstrated less than 5% across all age groups. The occurrence of Level 3 (half-kneel) was most often demonstrated (77%) in early childhood, drastically declined (20%) into late childhood. This trajectory was maintained throughout the remainder of the age groups. Levels 4 (asymmetrical wide-based squat) and 5 (symmetrical narrow-based squat with balance step) began to increase from early childhood into late childhood. The occurrence of Level 4 during adolescence decreased as the occurrence of Level 5 continued to increase. However entering young adulthood, the two levels reversed their trajectories with the occurrence of Level 4 becoming more frequent.

Table 3 presents Spearman's Rho correlations examining the relationships between STS time and the three STS components. The analysis revealed that STS time was inversely related to UE for all groups except 13-17 year-olds (r = -.22 to -.32, $p <$ .05). AX was negatively associated to STS time for all groups except 9-12 year-olds (r = -.25 to -.37, $p < .05$).

Table 4 provides the results for the L-statistic multiple regression analysis with STS time as the dependent variable and the STS components as the independent variables. Body mass index was included as a covariate in the analysis... BMI was a significant predictor for STS time for all of the age groups except 13-17 year-olds (r^2 = .08-.20, $p < .05$). UE and AX were both significant predictors of STS time for the 3-6 year-old group (r^2 = .07 and .12, $p < .05$, respectively). In addition, AX also predicted 8% of the variance ($p < .05$) in STS time for the 13-17 year-old group. The LE component did not account for any of the variance in STS time across all ages.

Pearson's correlations were calculated to compare performances between STS time and the MC product-oriented assessments of the standing long jump, kick, throw, and hop (see Table 5). Standing long jump, throwing speed, hopping distance on the right foot, and hopping distance on the left foot were all inversely associated to STS time for all age groups (r = -.34 to -.60, r = -.28 to -.53, r = -.40 to -.48, r = -.31 to -.46, $p < .05$, respectfully). Kicking speed was negatively associated to STS time for all groups except 9-12 year-olds (r = -.48 to -.54, $p < .01$).

Spearman's Rho correlations analysis were conducted on the STS component data and the MC product-oriented assessments of the standing long jump, kick, throw, and hop (see Table 5). The UE component revealed a positive relationship with standing long jump, throwing, and both hopping distances (r = .37-.42, $p < .01$) for 3-6 year-olds and a positive relationship with both feet on hopping distances (r = .39-.45, $p < .01$) for 9-12 year-olds; however, the UE component showed no significance after late childhood. Correlations were statistically significant for each of the MC product scores and the AX component scores for 3-6 year-olds (r = -.26 to -.44, $p < .05$). Both right and left hopping distances were positively correlated with the AX component (r = .39 - .45, $p < .01$) for 9-12 year-olds. AX component was positively associated with each of the MC product scores (r = .29 - .42, $p < .05$) except hopping distance with the left foot for 13-17 year-olds. The UE and LE component correlations were statistically significant for standing long jump, throwing, hopping distance right foot, and hopping distance left foot for 3-6 year-olds ($p < .05$). After early childhood the LE component was not significantly correlated with any other age groups.

The Spearman's Rho correlations with STS time and the MC process-oriented assessment data varied across the age groups with the greatest amount of statistically significant relationships demonstrated at the youngest age group (3-6 years; see Table 6).

Discussion

The first purpose of this study was to examine the validity of STS as a developmental measure of functional MC across childhood, adolescence, and young adulthood using a pre-longitudinal screen approach (Roberton et al., 1980). Examining associations among movement pattern levels and STS time provided a secondary measure of developmental validity. Results of the pre-longitudinal screening procedure revealed sequences for STS generally met each criterion (Roberton et al., 1980). The findings generally supported the sequential progression and regression of the UE, AX, and LE developmental steps up through adolescence, which demonstrates that one's ability to stand may be characterized by sequential developmental changes in body component actions as a person ages and develops over time. However, there were some instances where the developmental 'curves' did not specifically follow developmental trajectories.

Previous research (VanSant, 1998) indicated upper extremity Level 1 (push and reach to bilateral push) is most often demonstrated in toddlers. Since our sample began at age 3, this might have been the cause for fewer incidences of UE Level 1. The most advanced developmental patterns of AX and LE were observed during adolescence, which supports previous research by VanSant (1990). However, our results demonstrated a higher frequency of the asymmetrical push – Level 2 of the UE component than Sabourin's (1989) adolescent data. As secular trends have noted decreases in youth physical fitness and weight status (Malina, 2007; Tremblay, Esliger, Copeland, Barnes, & Bassett, 2008), future research needs to examine the association between STS and fitness and weight status as it may potentially affect children's developmental movement levels in rising from a supine position (Nesbitt et al., submitted) In fact, BMI was associated with component levels in all age groups, with the exception of the 13-17 year old group.

Previous literature shows that individuals with physical impairments and the elderly generate slower STS times than those who are typically developing and younger in age (Alexander, Ulbrich, Raheja, & Channer, 1997; Ulbrich, Raheja, & Alexander, 2000). To our knowledge, Nesbitt and colleagues (submitted) were the first to examine STS developmental sequences and time using a validated assessment. Results from Nesbitt et al. (submitted) study suggest that in early childhood, the use of less advanced UE and AX levels resulted in slower times to stand, which suggest that an individual's ability to control and manipulate their center of mass effectively is important for rising more quickly. The current study expanded upon Nesbitt and colleagues study (submitted) and examined if STS components were associated with time across early childhood to young adulthood. Results from all age groups generally demonstrate that as children age, STS component levels become more advanced and STS times' decrease. In general, weak to moderate correlations were demonstrated across all age groups. Lower extremity movements were not correlated with STS time in any age group suggesting that LE movements are primarily used as a source of balance or stability when standing.

Results from the current study demonstrate the average STS time in 3-6 year-olds (least advanced movement patters) was 2.39 seconds, which was dramatically higher than in late childhood (mean=1.64 seconds) and adolescence (mean = 1.71) where more advance movement patterns were demonstrated. These findings are congruent with previous literature that demonstrates young children present less advanced movement patterns and more advanced movement patterns are seen during late childhood and adolescence (highest). Overall, the adult data demonstrated a less advanced pattern for LE (i.e., Level 5 – symmetrical narrow-based squat to Level 4 – asymmetrical wide-based squat); however, the time to stand did not effectively change (mean =1.73) perhaps reflecting an increase in overall strength. Furthermore, these findings indicate component level trajectories provide sufficient evidence for developmental trends for each of the components used by participants to stand, which are congruent with age-related trends shown in other motor skills (Halverson & Williams, 1985; Keller, Lamenoise, Testa, Golomer, & Rosey, 2011; Messick, 1991).

Results from the current study demonstrated that BMI was a significant predictor for STS time for all of the age groups except 13-17 year-olds, with BMI accounting for the most variance (20%) in the 9-12 year-olds. The positive association among BMI and STS time (*r* = .310- .487) suggest that as individuals gain mass, time to stand increases.

The second purpose of this study was to examine associations of STS (movement patterns and time) to other developmentally valid measures of MC (e.g., fundamental motor skills). Positive associations among STS components and measures of MC and an inverse relationship with STS time suggest that the STS task can be used to assess gross motor skill development, similar to other common MC measures.

STS time demonstrated weak to moderate (*r* = -.282 to -.639) correlations to MC product measures across all age groups; both the STS task and the other skills tested involve large, force-producing muscles of the trunk, arms, and legs (Clark, 1994). Performance of these skills is influenced by a person's ability to effectively coordinate and control his or her body. STS is similar to other fundamental motor skills in that advanced levels of coordination and control involve higher muscle activity levels that impact both strength and power output and the resultant product of the movement (e.g., jumping distance, throwing/kicking speed, time to stand) (Escamilla & Andrews, 2009; Lee, Asai, Andersen, Numome, & Sterzing, 2010; Langendorfer, Roberton, & Stodden, 2013). Therefore, it would be expected that STS time and MC product scores would be associated.

Significant associations among STS component levels and MC product scores were most prevalent during early childhood. The significant associations during early childhood are most likely related to the global level of coordination and control of the trunk and limb segments. The lack of coordination and control of multiple body segments is a major constraint on the effectiveness of resultant force production (i.e., related to STS and MC product scores) and also results in more asymmetry and variability within trials in movement patterns. Positive associations between the AX component and MC product scores during early childhood and adolescence may be explained by changes in body proportions segments during growth. Unfortunately, anthropometric data was not collected for this study; thus, future research is needed to examine if body proportions relative to age is associated with STS components.

In addition, STS time demonstrated weak to moderate (*r* = -.24 to -.63) inverse correlations with MC process scores, indicating more advanced component levels of fundamental motor skills are associated with faster times when standing. Furthermore, STS time was correlated with all developmental sequences for standing long jump in early childhood, though only the arm component at takeoff was significantly correlated to the late childhood, adolescent, and adulthood groups. Similar to the UE components of STS, more advanced arm action during the takeoff phase of the standing long jump provide greater balance and control resulting in improvements in performance (i.e., distance and time to stand) (Ashby & Heegaard, 2002). Additionally, STS time was consistently associated with developmental sequences for hopping for every age group. Single leg hopping involves dynamic balance, with the non-hopping side aiding in both counterbalancing and force production, assisting with the continuous movement of the skill. Both STS and hopping are physical performance measures of function, therefore the inverse relationship to STS time is to be expected. Individuals that demonstrate more advance component levels while hopping were able to rise from the floor faster.

Despite the novelty of this study, several limitations should be noted. Although a pre-longitudinal screen is an important step to establish testable component sequences, longitudinal validation of these sequences is necessary to understand whether they are truly developmental. Another limitation is that the current study only assessed STS from early childhood up to young adulthood. Further examination of STS across the lifespan is needed to understand the progression and regression of MC from a lifespan perspective.

However, the current data supported Sabourin’s (1989) data demonstrating that the advancement of STS component levels peaked during adolescence. Lastly, although this study examined a combination of both object projection and locomotor MC measures (i.e., kicking, throwing, hopping, and standing long jump) further research should examine the associations of STS (sequences and time) to other individual MC skills (e.g., catching, running, etc.) as well as MC test batteries to better understand its predictive utility as a stand-alone or global lifespan assessment of MC.

Conclusion

In conclusion, when compared to validated measures of MC, our results indicate STS time can be considered a valid and reliable measure of MC across childhood, adolescence, and into young adulthood. As, strong evidence indicates that MC is inversely associated with body weight status and positively associated with cardiorespiratory fitness and musculoskeletal fitness across childhood and adolescence (Cattuzzo, 2014), STS represents one task that may be a valuable assessment to understand the impact of MC on health as it is a lifespan measure of functional capacity.

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Table 2.1

Participant Characteristics

		Total		Boys/Men		Girls/Women	
		M	*SD*	*M*	*SD*	*M*	*SD*
3-6 yrs		*N* = 63		*N* = 33		*N* = 30	
	Age (years)	4.8	0.9	4.9	0.9	4.6	0.8
	Height (cm)	109.3	7.9	110.2	8.2	108.3	7.6
	Mass (kg)	19.3	3.2	19.5	3.1	19.2	3.4
	BMI	16.3	2.2	16.0	1.7	16.7	2.6
9-12 yrs		*N* = 74		*N* = 30		*N* = 44	
	Age	10.0	0.8	10.1	0.7	10.0	0.9
	Height	143.9	10.5	141.9	7.9	145.2	11.9
	Mass	41.3	12.9	40.8	13.8	41.6	12.4
	BMI	19.8	4.2	20.1	5.0	19.6	3.7
13-17 yrs		*N* = 53		*N* = 26		*N* = 27	
	Age	14.9	0.9	14.7	0.9	15.0	1.0
	Height	168.9	9.3	173.3	9.0	164.6	7.6
	Mass	62.4	11.0	63.8	12.1	61.0	9.7
	BMI	22.1	3.4	21.6	3.2	22.6	3.6
18-25 yrs		*N* = 79		*N* = 48		*N* = 31	
	Age	20.9	2.0	21.0	2.0	20.7	2.0
	Height	173.1	8.7	177.8	6.4	166.0	6.8
	Mass	82.4	20.7	87.3	18.4	75.1	22.0
	BMI	27.0	5.7	27.6	5.4	26.2	6.2

Note. M = mean. *SD* = standard deviation.

Table 2.2.

Movement Component Categories for Task of Rising from a Supine to a Standing Position (adapted from Marsala & VanSant, 1998; VanSant, 1988a; 1988b)

Upper Extremity Movement Patterns	
Level 1.	*Push and reach to bilateral push.* One hand is placed on the support surface beside the pelvis. The other arm reaches across the body, and the hand is placed on the surface. Both hands push against the surface to an extended elbow position. The arms are then lifted and used for balance.
Level 2.	*Asymmetrical push.* One or both arms are used to push against the support surface. If both arms are used, there is asymmetry or asynchrony in the pushing action or a symmetrical push gives way to a single-arm push pattern.
Level 3.	*Symmetrical push.* Both hands are placed on the support surface. Both hands push symmetrically against the surface prior to the point when the arms are lifted synchronously and used to assist with balance.
Level 4.	*Symmetrical reach.* The arms reach forward, leading the trunk, and are used as balance assists throughout the movement.
Axial Region Movement Patterns	
Level 1.	*Full rotation, abdomen down.* The head and trunk flex and rotate until the ventral surface of the trunk contacts the support surface. The pelvis is then elevated to or above the level of the shoulder girdle. The back extends up to the vertical, with or without accompanying rotation of the trunk.
Level 2.	*Full rotation, abdomen up.* The head and trunk flex and/or rotate until the ventral surface of the trunk faces, but does not contact, the support surface. The pelvis is then elevated to or above the level of the shoulder girdle. The back extends from this position up to the vertical, with or without accompanying rotation of the trunk.
Level 3.	*Partial rotation.* Flexion and rotation of the head and trunk bring the body to a side facing position, with the shoulders remaining above the level of the pelvis. The back extends up to the vertical, with or without accompanying rotation.
Level 4.	*Forward with rotation.* The head and trunk flex forward, with or without a slight degree of rotation. Symmetrical flexion is interrupted by rotation or extension with rotation. Flexion with slight rotation is corrected by counter rotation in the opposite direction. One or more changes in the direction of rotation occur. A front or slightly diagonal facing is achieved before the back extends to the vertical.

Level 5.	*Symmetrical.* The head and trunk move symmetrically forward past the vertical; the back then extends symmetrically to the upright position.
Lower Extremity Movement Patterns	
Level 1.	*Jump to squat.* The legs are flexed and rotated to one side. Both legs are then lifted simultaneously off the support surface and derotated. The feet land back on the support surface with hips and knees flexing to a squat or semi-squat position. The legs then extend to the vertical.
Level 2.	*Kneel.* The legs are flexed and rotated to one side with both knees contacting the support surface.
Level 3.	*Half-kneel.* Both legs are flexed toward the trunk as one or both legs are rotated to one side. Either a kneeling or half-kneeling pattern is assumed. If kneeling occurs, one leg is then flexed forward to assume half-kneeling. The forward leg pushes into extension as the opposite leg moves forward and extends.
Level 4.	*Asymmetrical wide-based squat.* One or both legs are flexed toward the trunk assuming an asymmetrical, crossed-leg or wide-based squat. Internal rotation of the hips may cause the feet to be placed on either side of the pelvis. Asymmetry of hip rotation is common. The legs push up to an extended position. Crossing or asymmetries may be corrected during extension by stepping action
Level 5.	*Symmetrical narrow-based squat with balance step.* The legs are brought into flexion with the heels approximating the buttocks in a narrow-based squat. Stepping action may be seen during assumption of the squat, or balance steps (or hops) may follow the symmetrical rise.

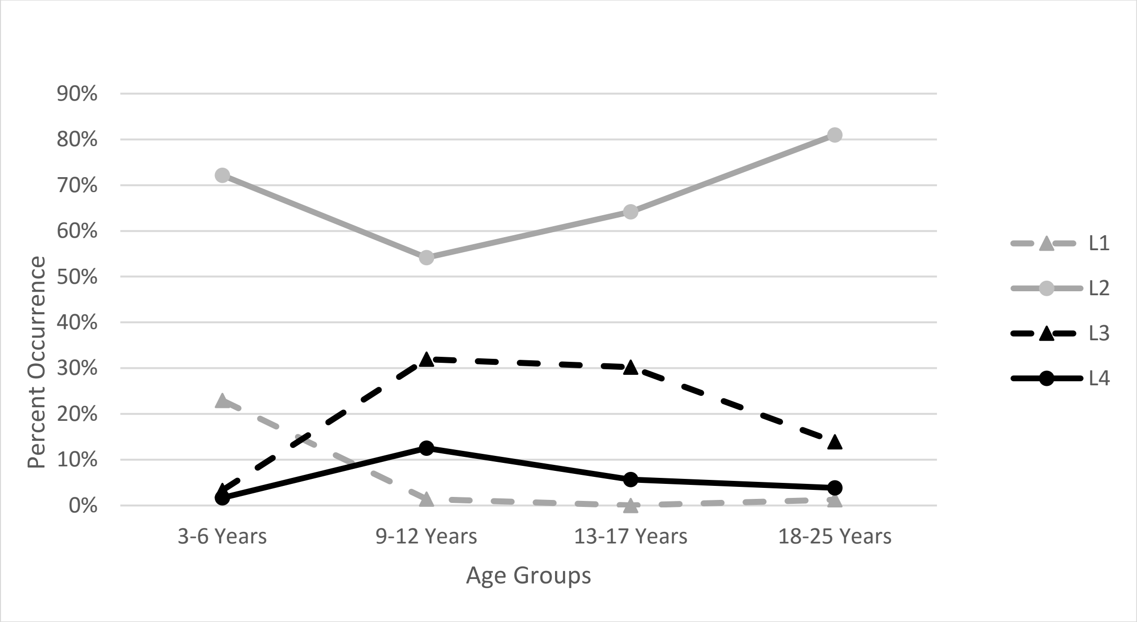

Figure 2.1. Observed frequency of occurrence for upper extremity levels across age groups.

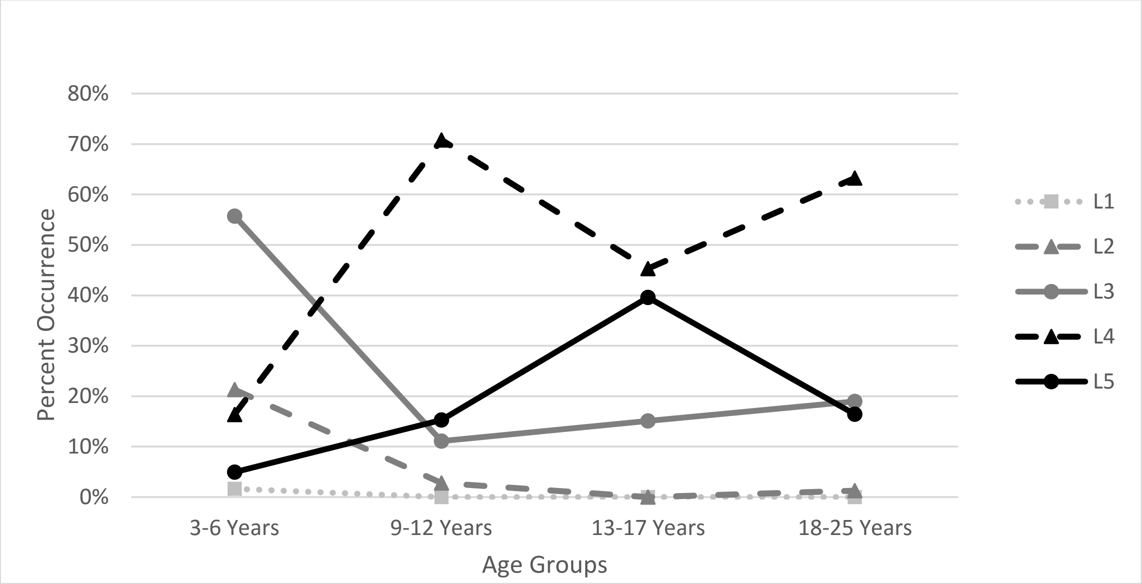

Figure 2.2. Observed frequency of occurrence for axial levels across age groups.

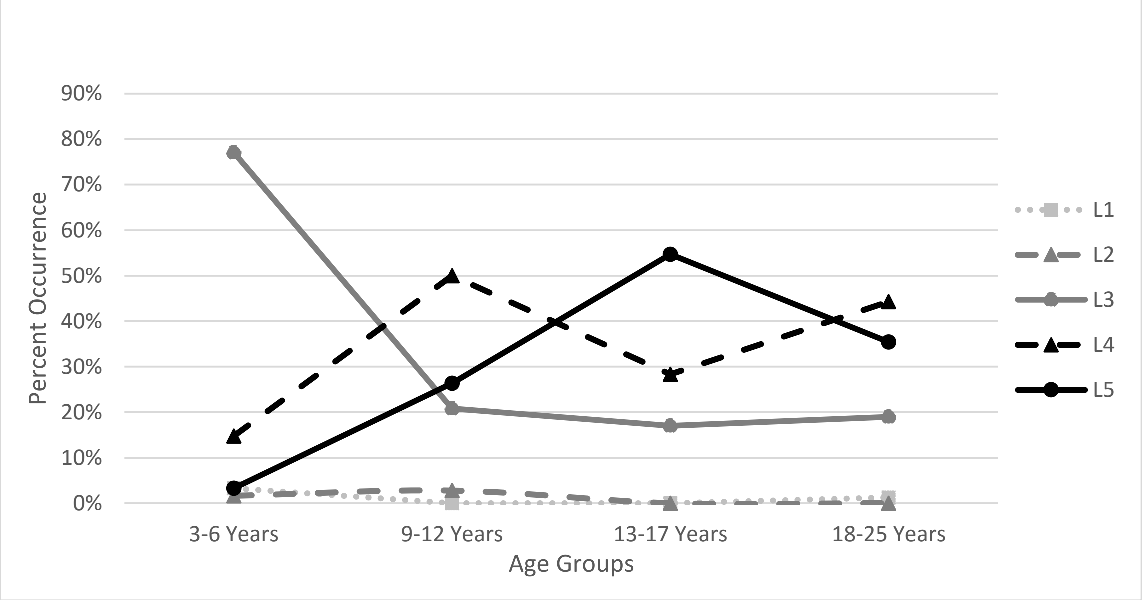

Figure 2.3. Observed frequency of occurrence for lower extremity levels across age groups.

Table 2.3

Whole Group Spearman's Rho Correlations for STS Time and STS Components by Age Groups

Age Group	Variables	STS Time	Upper extremity	Axial
3-6 yrs	Upper extremity	-.32*		
(*N* = 61)	Axial	-.37**	.87**	
	Lower extremity	-.22	.45**	.66**
9-12 yrs	Upper extremity	-.30**		
(*N* = 73)	Axial	-.23	.52**	
	Lower extremity	-.06	.13	.58**
13-17 yrs	Upper extremity	-.18		
(*N* = 53)	Axial	-.32*	.76**	
	Lower extremity	-.08	.12	.42**
18-25 yrs	Upper extremity	-.22*		
(*N* = 79)	Axial	-.25*	.70**	
	Lower extremity	-.02	.20	.62**

Note. **p* < .05. ***p* < .01.

Table 2.4

Regression results by age group for STS components and BMI Using Sex as a Covariate by Age Groups

	Age Group 3-6 (*N* = 60)		Age Group 9-12 (*N* = 70)		Age Group 13-17 (*N* = 53)		Age Group 18-25 (*N* = 78)	
Independent variables	**ΔR^2**	*L*	**ΔR^2**	*L*	**ΔR^2**	*L*	**ΔR^2**	*L*
Upper Extremity	.07	4.25*	.00	0.00	.01	0.68	.02	1.46
Axial	.12	6.79**	.01	0.76	.08	4.21*	.02	1.54
Lower Extremity	.03	1.95	.00	0.00	.00	0.21	.00	0.23
Combined	.12	7.14	.03	1.93	.12	6.24	.06	4.62
BMI	.08	4.72*	.20	14.21**	.04	2.03	.12	8.93**

Note. *$p < .05$. **$p < .01$.

Table 2.5

Whole Group Pearson's and Spearman's Rho Correlations for STS Time and Components with MC Product Factors by Age Groups

Age Group	Variables	SLJ	Kick	Throw	Hop R	Hop L
3-6 yrs	STS Time[†]	-.60**	-.48**	-.53**	-.48**	-.31*
(*N* = 61)	UE[‡]	.37**	.20	.37**	.37**	.42**
	AX[‡]	.40**	.26*	.36**	.44**	.44**
	LE[‡]	.29*	.23	.28*	.37**	.32*
9-12 yrs	STS Time[†]	-.34**	-.07	-.28*	-.40**	-.42**
(*N* = 68)	UE[‡]	.18	.10	-.12	.39**	.45**
	AX[‡]	.17	.11	.09	.30*	.33*
	LE[‡]	.12	.07	-.08	.13	.17
13-17 yrs	STS Time[†]	-.53**	-.54**	-.51**	-.46**	-.45**
(*N* = 53)	UE[‡]	.22	.14	.21	.18	.19
	AX[‡]	.42**	.38**	.41**	.29*	.24
	LE[‡]	.24	.23	.23	.13	-.01
18-25 yrs	STS Time[†]	-.60**	-.54**	-.42**	-.46**	-.46**
(*N* = 79)	UE[‡]	.17	.03	-.14	.07	.01
	AX[‡]	.10	-.01	-.12	.10	.13
	LE[‡]	.01	-.00	-.14	-.01	-.00

Note. *p < .05. **p < .01. [‡] Spearman's Rho. [†] Pearson's Correlation. UE = upper extremity. AX = axial. LE = lower extremity.

Table 2.6

Whole Group Spearman's Rho Correlations for STS Time with MC Process Factors by Age Groups

Variables		STS Time			
		3-6 yrs (*N* = 60)	9-12 yrs (*N* = 74)	13-17 yrs (*N* = 52)	18-25 yrs (*N* = 79)
Throw	Foot	-.24	-.16	-.37**	.02
	Trunk	-.13	-.27*	-.22	-.05
	Humerus	-.36**	.05	-.19	-.20
	Forearm	-.43**	-.19	-.28*	-.07
SLJ	Takeoff legs	-.27*	-.08	.†	-.16
	Takeoff arms	-.47**	-.35**	-.29*	-.37**
	Landing shank	-.42**	-.05	-.13	-.15
	Landing foot	-.34**	-.25*	-.14	-.16
	Landing arms	-.63**	-.16	-.36**	-.24*
Hop	Right leg	-.38**	-.34**	-.43**	-.24*
	Right arm	-.10	-.33**	-.30**	-.21
	Left leg	-.31*	-.39**	-.41**	-.33**
	Left arm	.00	-.49**	-.26	-.32**

Note. **p* < .05. ***p* < .01. SLJ = standing long jump. † Due to a lack of variability in the takeoff legs scores in the 13-17 year-old group, there was no correlation data.

CHAPTER 3

EXAMINING SUPINE-TO-STAND AS A MEASURE OF HEALTH[2]

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[2] Nesbitt, D., Molina, S., Brian, A., Robinson, L., & Stodden, D. To be submitted to the Journal of Physical Activity and Health

The development of motor competence (MC) is suggested to be a causal mechanism that promotes positive lifespan trajectories of physical activity, health-related fitness, and weight status (Robinson et al., 2015; Stodden, 2008; 2009). Different assessments are used to measure aspects of MC in different age groups across the lifespan, making it difficult to track changes in MC across the lifespan and compare the strength of associations between MC and health-related variables across time (Robinson et al., 2015). In addition, the association of MC with long-term health outcomes has not been addressed.

In 2008, Stodden and colleagues introduced a dynamic and synergistic view on the interactions of MC as it pertains to health-related fitness and physical activity. This model hypothesized the influence of MC would strengthen in association across time and may be a key factor in the promotion and sustainability of a healthy lifestyle. For the purpose of this paper, the term MC encompasses a multitude of terms that apply globally to tasks that involve goal-directed coordination and control that can be observed in children to aging populations (i.e., fundamental motor skills, motor skill competence, function, etc.) (Cattuzzo et al., 2014). Many MC measures have primarily been developed for youth to assess developmental delays (i.e., TGMD-2, M-ABC, KTK, BOT-2, etc.); however, a growing emphasis has been placed on the need to promote and examine MC and its association with health in normally developing children and adults (Cantell et al., 2008; Rinne, 2010; Robinson et al., 2015). Research examining the relationship between motor competence and health-related fitness in children and adolescents has escalated over the last two decades (Cattuzzo et al., 2014). Results demonstrate strong evidence for an inverse association between MC and body weight status and a positive relationship between MC and aspects of HRF (Cattuzzo et. al., 2014). In addition, MC research demonstrates positive associations with PA and evidence suggest a cause-effect relationship among the two (Holfelder & Schott, 2014; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). With the majority of literature focusing on children and adolescents, little is known about how MC relates to HRF and PA in adults.

The supine-to-stand test (STS) represents one task that has been used in different ways to assess motor development or functional capacity in a variety of age groups. The STS test is used in physical therapy and with aging populations as a measure functional movement capacity (Bohannon & Lusardi, 2004). It also has been evaluated in children and adults to examine differences in how individuals rise to a bipedal stance at different stages of life (Green & Williams, 1992; VanSant, 1988a; 1988b). The ability to rise from a supine position is suggested to be a valid test for studying lifespan motor development and related to a person's physical independence and functional capacity as they age (Marsala & VanSant, 1998; Nesbitt et al., submitted; VanSant, 1988a; 1988b), but limited data is available to support that claim. Green and Williams (1992) demonstrated middle aged individuals self-reported PA was associated with more advanced methods of rising from a supine position (Green & Williams, 1992). And, functional capacity assessments similar to STS have been linked to health outcomes, physical independence, mortality and overall quality of life (Belt et at., 2001; Green & Williams, 1992; VanSant, 1990)

The development of more advanced STS movement patterns in early childhood is related to a progression of "motor milestones" (e.g., rolling over, sitting upright and finally, standing with assistance) (VanSant, 1988) that are fundamentally parallel to the idea of functional capacity and physical independence that is promoted in literature on elderly populations. The relative chasm that is present between early childhood motor development literature and literature examining elderly health and function may be bridged by examining STS and its association to function and health across the lifespan. Nesbitt et al. (paper 1) recently examined the developmental validity of STS and its relationship between other common MC measures (e.g., kicking, throwing, standing long jump, and hopping) in children to young adults (4-25 years of age). Results showed weak to moderate inverse correlations between STS time and MC product scores (r= -.289- -.639, p<.01) consistently across age groups. Results also demonstrated low to moderate correlations between STS time and component developmental sequences (r= .268- .502, p<.01). These data indicate that the relationship between STS and other developmentally valid measures of MC is consistent across time, suggesting STS time has the potential to be a developmentally valid measure of MC that can be used across the lifespan.

The lack of an appropriate lifespan MC measure is an important issue for future research as a developmentally valid lifespan MC assessment will allow researchers to track the strength of associations between MC and a multitude of health-related variables, chronic disease and functional status conditions across the lifespan (Robinson et al., 2015; Stodden et al., 2008). Therefore, the purpose of this study was to examine the predictive utility of process- and product oriented assessments of STS as a predictor of the health-related variables of PA, weight status and health-related fitness across early childhood into young adulthood.

Methods

Participants

A convenience sample (N=265) that included four specific age groups ranging from early childhood through young adulthood (3-6, 9-12, 13-17, and 18-25 years old) was recruited for this study. We chose to select these age groups because they cover developmental stages of early childhood, middle childhood, late childhood/early adolescence and early adulthood. We recruited equal numbers of boys and girls within each age range from local private, public schools, and a university in the southeast portion of the United States. Descriptive statistics of the sample are reported in Table 1. Prior to participation, the University's Human Subject Review Board provided approval of all procedures. Preceding data collection, we obtained verbal assent from each participant as well as parental consent for minors. Individuals with any physical disabilities or medical conditions that prevented them from completing the testing were not included in this study.

Procedures

Participants were evaluated on STS (component levels and time) and four health-related physical fitness tests that assessed muscular strength (i.e., grip strength, PACER, curl-ups, and pushups). In addition, participants wore accelerometers to objectively assess their physical activity levels. Prior to testing individuals completed a general warm-up routine before participation. General warm-up activities included 3-5 minutes of jogging as well as static and dynamic stretching exercises. In general, participants completed most of the physical fitness testing during one testing session with the exception of the grip strength assessment. Grip strength, body weight status, and the STS task were completed on separate days. All testing was performed in a gymnasium and/or designated outdoor area.

Measures

Motor competence measure. Participants were evaluated individually on STS time and sequences. Participants were instructed to lie down in a supine position with their hands by their sides and their feet together. When given the "go" command, participants stood up as fast as they could and touched a marked spot on the wall in front of the participant that was shoulder height from the floor (VanSant, 1990). Research staff provided verbal encouragement for each participant to complete the task as fast as possible, but no instruction on how to stand was provided. Participants completed five consecutive trials of the supine to stand test and all trials were videotaped from the side view using digital video cameras (HDR-CX380, Sony, China). STS component sequences and time to stand were coded from the video at a later time.

Health-related fitness measures. Body composition measures included height, weight (used to calculate BMI), and body weight status. Height was accessed using a physician’s scale and measured to the nearest 0.5 cm. Body weight status (i.e., %body fat and BMI) was accessed using a Tanita Bioelectrical Impedance scale (SC-331s; Tanita, Illinois). Body weight was measured to the nearest 0.1 kg and body mass index was computed as (BMI, weight kg/[height m]^2).

Health-related fitness was assessed using FITNESSGRAM protocols (Meredith & Welk, 2005) for PACER, curl-ups and push-ups. The PACER was conducted using a 15-m (4-6 year-olds) or 20-m shuttle run (9-25 year-olds) at a specified pace that increased every minute. The original PACER test protocol was adapted for the 3-6 year-old group by having research staff run individually with children or in groups of two or three children until the end of the test to provide an adequate pace (Stodden et al., 2014). This method has demonstrated to have high reliability ($r = .84$, $p < .001$) (Burgi et al., 2011). Curl-ups were performed to a cadence on a CD while fingers slid forward across a 7.6 cm (4–9 year olds) or 12.7 cm (10–25 year olds) rubber strip. The recorded score was the maximum number performed or until two form breaks occurred. 90° pushups were performed to a cadence on a CD (i.e., “up; down”). The recorded score was the maximum number performed or until two form breaks occurred. Instruction and modeling for all participants was provided prior to testing. Participants were asked to practice each fitness test movement once to demonstrate adequate technique and were informed of the purpose of each fitness measure. Children also were prompted to demonstrate correct technique, if possible, on curl-ups and pushups before the actual testing. It is important to note the curl-up and pushup test are not recommended for the early childhood group due to FITNESSGRAM recommends that formal testing of these measures not be tested until fourth grade (Meredith & Welk, 2005). The lack of total body coordination and control at this age makes it difficult to delineate the contribution of muscle strength and coordination to the number completed (Stodden et al., 2014).Total body strength was measured using grip strength (IOM, 2012). Grip strength was measured using an adjustable hand grip dynamometer (Jamar digital handgrip dynamometer (Bolingbrook, IL)). The best score of three trials for each hand was averaged and used for data analysis (Stodden et al., 2014).

Physical activity. Daily PA levels were assessed using Actigraph GT3X accelerometers (Pensacola, FL), which are valid and reliable to measure different intensities of PA among children and adults in free-living settings (Lee & Macfarlane, 2010). Each participant was provided with written instructions regarding care and placement of the accelerometers. For the preschool aged children, instructions also were provided as part of the consent form to their parents/guardians. Participants were instructed to wear the accelerometers on the right hip, attached by an elastic belt, during awake hours for 7 consecutive days (5 weekdays and 2 weekend days). Activity counts were set at 1-second epoch. Counts were classified into sedentary, light, moderate, and vigorous categories. The following cut points were applied in this study: children's PA (sedentary: 0 to 100; light PA: 101 to 2295; and MVPA: 2296 and above) (Evenson, 2008) and young adults (sedentary: 0 to 99; light PA: 100 to 2019; and MVPA: 2020 and above) (Troiano, 2008). Participants' average percentages of time engaged in light PA and MVPA was used as the outcome variables.

Data Reduction

STS. A modified version of STS component developmental sequences, adapted from Vansant, 1988a, 1988b; Green & Williams, 1992; Marsala & VanSant, 1998, were used for this study (see Table 2) Upper extremity (UE, 4 levels), axial (AX, 5 levels) and lower extremity (LE, 5 levels) components were coded by two experienced raters. The modal level of the five trials for each component was used for data analysis. If an individual had a bimodal component level, the higher of the two levels was used. STS time was calculated using Dartfish-7 video analysis software (Dartfish USA, Alpharetta, GA). Time was calculated from the first initial movement of the individual to the point when the participant touched the mark on the wall. The average time from the modal profile, which was noted as the most occurring movement combination of components, was used for data analysis.

Statistical Analysis

An apriori power calculation with alpha set at $p < .05$, and an f^2 of .28 yielded a sample size of 43 with a power estimate of .80. Thus, an oversampling of 60 participants per age group was sufficient to determine significance at $p < .05$ level.

The data were separated by age groups and analyzed in seven steps. Pearson's correlations were calculated to compare performances between STS time and BMI, grip strength, pacer, curl-ups, and pushups. Next, as sequences are ordinal data, Spearman's Rho correlations were conducted on the three STS components of upper extremity (UE), axial (AX), and lower extremity (LE) and the BMI, grip strength, pacer, curl-ups, and pushups. Third, Pearson's correlations were calculated to compare performances of pacer and STS time with the two physical activity (PA) factors (light PA and MVPA).

Next, an L-statistic multiple regression analysis was conducted with each of the three STS components as the dependent variable and BMI as the independent variables while controlling for sex for each age group. The L-statistic analysis was conducted due to the STS components consisting of ordinal data which is not normally distributed. Nonparametric analysis of rank order data are allowed with the use of parametric analysis methods, such as multiple regression, when an L-statistic is calculated by hand at the outset of the data analysis (Thomas, Nelson, & Thomas, 1999). This nonparametric analysis was founded on the Puri and Sen (1985) L-statistic, which was treated as an approximation for χ^2. L is acquired from the following equation, $L = (N - 1) r^2$. Within that equation, N is equal to the number of participants within a grouping and r^2 is equal to the proportion of true variance (Thomas et al., 1999).

L-statistic multiple regression analyses were calculated for each age group on each of the three STS components as the dependent variables and the combination of HRF product scores (grip strength, pacer, curl-ups, and pushups) as the independent variable (Stodden et al. 2009; Stodden et al., 2014) while controlling for sex. Sixth, multiple regressions were conducted for each age group with STS time as the dependent variable and the combination of the HRF product scores as the independent variable while controlling for sex. Seventh, multiple regression analysis was calculated for STS time as the dependent variable and BMI as the independent variable while controlling for sex across each age group. Lastly, two multiple regression analysis were calculated for STS time as the dependent variable and light PA and MVPA as the independent variable while controlling for sex.

Results

Participant demographic characteristics for each group are provided in Table 2. Pearson's correlations were calculated to compare performances between STS time and BMI, grip strength, pacer, curl-ups, and pushups (see Table 3). The PACER generally was the strongest fitness measure associated with STS time at every age group (r = -.33 to -.56, $p < .05$). Grip strength, pushups, and curl-ups were inversely associated to STS time (r = -.24 to -.48, $p < .01$) across age groups. BMI also was positively associated to STS time for all age groups except 13-17 year-olds (r = .31 to .49, $p < .05$).

Spearman’s Rho correlations analyses examined associations between the upper extremity (UE), axial (AX), and lower extremity (LE) component sequences and BMI, grip strength, pacer, curl-ups, and pushups (see Table 3). The UE component demonstrated a positive relationship with HRF measures (r = .29 and .45, $p < .05$, respectively) across the age groups. BMI for 9-12 year-olds (r = -.42, $p < .01$) demonstrated an inverse relationship with the UE component. The AX component was positively associated with grip strength, pacer, curl-ups, and pushups (r = -.29 to -.38, $p < .05$) across age groups. The AX component was inversely associated with BMI for 9-12 year-olds and 18-25 year-olds (r = -.34 and -.38, $p < .05$, respectively). The LE component was significantly associated with PACER and curl-ups for 3-6 year-olds (r = .27 and .31, $p < .05$, respectively) and with BMI for 9-12 year-olds and 18-25 year-olds (r = -.25 and -.35, $p < .05$, respectively).

Results of the L-statistic multiple regression analysis conducted with each of the three STS components as the dependent variable and BMI as the independent variables while controlling for sex for each age group are provided in Table 4. BMI was a significant predictor of the AX and LE components only in the 18-25 year-old age group (r^2 = .11 and .09, $p < .05$, respectively).

Table 5 provides results of the L-statistic multiple regression analysis calculated for each of the three STS components as the dependent variables and the combination of HRF product scores (grip strength, pacer, curl-ups, and pushups) as the independent variable while controlling for sex. The combined HRF product scores was a significant predictor of the UE, AX, and LE components in only in the 3-6 year-olds (r^2 = .19, .18 and .16, $p < .05$, respectively).

Table 6 provides results of the multiple regressions conducted for each age group with STS time as the dependent variable and the combination of the HRF product scores as the independent variable while controlling for sex. In all of the age groups, the combination of HRF product scores were statistically significant ($p < .01$) and predicted 18 – 40% of the variance in STS time.

Results of the multiple regression analysis calculated with STS time as the dependent variable and BMI as the independent variable while controlling for sex across each age group are provided in Table 7. The combination of HRF product scores were a significant predictor of STS time in all of the age groups except 13-17 year-olds ($r^2 = .08$-$.25$, $p < .05$).

Table 8 provides the results of the correlations to compare performances of STS time with the two physical activity (PA) levels (light and MVPA). STS time was inversely associated with light PA for 3-6 year-olds ($r = -.54$, $p < .05$) and with MVPA for 18-25 year-olds ($r = -.48$, $p < .05$, respectively). Results of the first multiple regression analysis that was conducted with STS time as the dependent variable and light PA while controlling for sex in the 3-6 year-old group demonstrated that light PA was a significant predictor for STS time at this age group ($R^2 = .32$, $F(21, 19) = 4.471$, $p < .01$). Results of the second regression analysis calculated with STS time as the dependent variable and MVPA as the independent variable while controlling for sex demonstrated that MVPA predicted 13% of the variance in STS time for the 18-25 year-old group ($R^2 = .13$, $F(2, 26) = 5.431$, $p < .01$).

Discussion

The purpose of this study was to examine associations of STS (time and sequences) and aspects of health-related variables (i.e., weight status, health-related fitness, and PA) across early childhood into young adulthood. Our data provides evidence for a positive association between both STS time and components and health-related fitness variables across from 4-25 year olds. Not surprisingly, STS time generally demonstrated stronger and more consistent associations with fitness measures than components. Significant associations between STS time and PA were exhibited only in the adult sample. These data provide evidence on the usefulness of STS to examine the link between MC and health-related variables and provide preliminary evidence for STS being a lifespan assessment for this same purpose.

STS and Health-Related Fitness

Findings in this study support previous research demonstrating the link between MC and fitness level across childhood, adolescence and young adulthood (Cattuzzo et al., 2014; Stodden et al., 2009).There was a moderate amount of explained variance between STS time and health-related fitness outcomes when controlling for sex, (18-40%). Effective performance of HRF measures inherently demand a high level of coordination and control that has to be learned, as many HRF tasks involve complex movements. Acquiring more advanced levels of HRF skills demands more effective manipulation of an individual's entire body mass against gravity and higher strength and power outputs (Fleisig et al., 1999). Similar to HRF measures, a person’s STS performance (i.e., time to stand) involves multi-segment movements, which requires an increased demand on the neuromuscular system to generate and transfer energy optimally through the kinetic link system (i.e., optimizing control and coordination) (Fleisig et al., 1999). The similarities in neuromuscular demands provide rationale for the link between both STS and multiple HRF performances.

Results demonstrated that sex significantly influenced STS time starting at adolescence and into young adulthood. These findings are expected since physical characteristic of boys and girls are very similar prior to puberty (Thomas & French, 1985). The transition from middle to late childhood and adolescence is an important time where children's' biological age may impact MC and HRF (Thomas & French, 1985). Biological characteristics such as body type and composition as well as leg length have been noted to potentially influence motor skill ability (Malina, 1984; Thomas & French, 1985); however, the current study did not examine the effects of maturation. Further research needs to be conducted in order to examine the extent that maturation may effect STS time.

STS components generally demonstrated weak inverse associations with HRF measures (Table 3). Regressions revealed that after controlling for sex, STS components (UE, AX, and LE) accounted for 9-11% of the variance in HRF scores only in 3-6 year olds. The explained variance of HRF during early childhood, and not in later years, may be due to the lack of experience, strength, and/or coordination and control at this age. These factors may have influenced the ability to effectively demonstrate adequate technique in tests such as curl-ups and pushups as they require complex coordination of multiple segments as well as simultaneous concentric, isometric and eccentric muscular contractions across different segments of the body during the movements (Stodden et al., 2014). Several children demonstrated the capacity to complete several reps of both pushups and curl-ups, while others could not complete a single correct repetition of either. As STS, push-ups, curl-ups and PACER all are complex multijoint movements that require high levels of coordination and control to produce a successful movement outcome, it is logical that in early childhood they would be more strongly related to STS component sequence levels as opposed to older age groups, where physiological development of muscular endurance (push-ups, curl-ups) and cardiorespiratory endurance (PACER) is not as directly linked to the development of coordination. Alternatively, the development of strength and power is more directly linked to the development of coordination and control (Enoka, 2008; Ramsay et al., 1990; Ratamess, 2008; Raynor, 2001). Grip strength, noted as a global measure of total body strength (IOM, 2012), was more consistently related to STS time across age groups (see Table 3) than components. This further demonstrates that a total body coordinative outcome (i.e., STS time), is more predictive than individual components.

While not significant across all age groups, results from the current study demonstrated that BMI was associated with STS time and component developmental levels (see Tables 3 and 7). An increased rate of adiposity has an inverse effect on both balance and the application of strength in movement performance (Malina, 1995). Since rising from the floor is a whole body action, excess body weight imposes constraints on movement and may negatively effects balance and coordination (Teasdale, 2007). Results generally demonstrate that increased body weight status has a negative impact on STS time. Component developmental sequence levels, while not as consistent as STS time, also demonstrated an inverse association with BMI in the 9-12 and 18-25 year old age groups. Thus, BMI may also have influenced movement choices to stand in these age groups, as well as how those movements are coordinated during standing.

There were inverse associations with STS time for moderate-to-vigorous physical activity (MVPA) levels for young adults and with light PA for 3-6 year-olds. Regression analysis demonstrated MVPA accounted for 23% of the variance in STS time in 18-25 year olds, indicating that young adults who were engaged in more MVPA could stand more quickly. This finding aligns with previous data on MC and PA higher MC, which is linked to higher fitness, results in greater success and persistence (Robinson et al., 2015) and lower levels of fatigue that may consequently lead to greater amounts and intensity of physical activity (Wrotniak et al., 2006).

Although statistical significance was not found across all age groups, there was an inverse trend for STS time and MVPA levels in the 3-6 and 9-12 year old groups (see Table 8). Unfortunately, poor compliance of individuals wearing their accelerometers led to only 39% of the total sample having acceptable PA data, which resulted in very small sample sizes per age group. Thus, larger sample sizes are warranted to understand associations of STS time and PA.

Several major limitations of the current study must be noted. First, we did not assess sexual maturity or skeletal maturity in this sample and biological maturation effects would likely provide additional insight on the dynamic relationships among measures of MSC and HRF, specifically during the transition from childhood to adolescence. Second, due to the lack of individual’s compliance wearing accelerometers, the analyses were underpowered to adequately address associations among STS time and

PA levels. Lastly, the current study only assessed STS from early childhood through young adulthood. Further examination of STS and its relationship to multiple health-related variables across the lifespan is warranted to understand its potential predictive utility as an important estimation of functional motor competence and health across the lifespan.

Conclusion

This study is unique in that it is the first to demonstrate the strength of association among STS time, as a measure of functional MC, and health-related measures. Results indicate that faster times to stand are consistently associated with higher levels of fitness across 4-25 years of age. Additional PA data is needed to examine the associations among STS time and PA levels across age. As the development of STS has been noted as a precursor to physical independence in early childhood and the elderly, its consistent link to cardiorespiratory endurance, muscular strength/endurance, and bodyweight status from early childhood into adulthood provides valuable insight for its potential significance as an early lifespan assessment screening tool. Additional cross-sectional data and longitudinal studies are needed to provide an improved understanding of the relationship between STS and factors related to physical fitness beyond young adulthood.

Practical Applications

Implications of this research could inform future assessment protocols in both a clinical and physical education setting. The STS task as a measure of MC is unique in that this assessment is cost-effective, less time consuming then most fitness time (i.e., FITNESSGRAM), and has the capability to predict a person’s general health status.

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Table 3.1

Participant Characteristics

		Total		Boys/Men		Girls/Women	
		M	*SD*	*M*	*SD*	*M*	*SD*
3-6 yrs		*N* = 63		*N* = 33		*N* = 30	
	Age (years)	4.8	0.9	4.9	0.9	4.6	0.8
	Height (cm)	109.3	7.9	110.2	8.2	108.3	7.6
	Mass (kg)	19.3	3.2	19.5	3.1	19.2	3.4
	BMI	16.3	2.2	16.0	1.7	16.7	2.6
9-12 yrs		*N* = 74		*N* = 30		*N* = 44	
	Age	10.0	0.8	10.1	0.7	10.0	0.9
	Height	143.9	10.5	141.9	7.9	145.2	11.9
	Mass	41.3	12.9	40.8	13.8	41.6	12.4
	BMI	19.8	4.2	20.1	5.0	19.6	3.7
13-17 yrs		*N* = 53		*N* = 26		*N* = 27	
	Age	14.9	0.9	14.7	0.9	15.0	1.0
	Height	168.9	9.3	173.3	9.0	164.6	7.6
	Mass	62.4	11.0	63.8	12.1	61.0	9.7
	BMI	22.1	3.4	21.6	3.2	22.6	3.6
18-25 yrs		*N* = 79		*N* = 48		*N* = 31	
	Age	20.9	2.0	21.0	2.0	20.7	2.0
	Height	173.1	8.7	177.8	6.4	166.0	6.8
	Mass	82.4	20.7	87.3	18.4	75.1	22.0
	BMI	27.0	5.7	27.6	5.4	26.2	6.2

Note. M = mean. *SD* = standard deviation.

Table 3.2. Movement Component Categories for Task of Rising from a Supine to a Standing Position (adapted from Marsala & VanSant, 1998; VanSant, 1988a; 1988b)

Upper Extremity Movement Patterns	
Level 1.	*Push and reach to bilateral push.* One hand is placed on the support surface beside the pelvis. The other arm reaches across the body, and the hand is placed on the surface. Both hands push against the surface to an extended elbow position. The arms are then lifted and used for balance.
Level 2.	*Asymmetrical push.* One or both arms are used to push against the support surface. If both arms are used, there is asymmetry or asynchrony in the pushing action or a symmetrical push gives way to a single-arm push pattern.
Level 3.	*Symmetrical push.* Both hands are placed on the support surface. Both hands push symmetrically against the surface prior to the point when the arms are lifted synchronously and used to assist with balance.
Level 4.	*Symmetrical reach.* The arms reach forward, leading the trunk, and are used as balance assists throughout the movement.
Axial Region Movement Patterns	
Level 1.	*Full rotation, abdomen down.* The head and trunk flex and rotate until the ventral surface of the trunk contacts the support surface. The pelvis is then elevated to or above the level of the shoulder girdle. The back extends up to the vertical, with or without accompanying rotation of the trunk.
Level 2.	*Full rotation, abdomen up.* The head and trunk flex and/or rotate until the ventral surface of the trunk faces, but does not contact, the support surface. The pelvis is then elevated to or above the level of the shoulder girdle. The back extends from this position up to the vertical, with or without accompanying rotation of the trunk.
Level 3.	*Partial rotation.* Flexion and rotation of the head and trunk bring the body to a side facing position, with the shoulders remaining above the level of the pelvis. The back extends up to the vertical, with or without accompanying rotation.
Level 4.	*Forward with rotation.* The head and trunk flex forward, with or without a slight degree of rotation. Symmetrical flexion is interrupted by rotation or extension with rotation. Flexion with slight rotation is corrected by counter rotation in the opposite direction. One or more changes in the direction of rotation occur. A front or slightly diagonal facing is achieved before the back extends to the vertical.

Level 5.	*Symmetrical.* The head and trunk move symmetrically forward past the vertical; the back then extends symmetrically to the upright position.

Lower Extremity Movement Patterns

Level 1.	*Jump to squat.* The legs are flexed and rotated to one side. Both legs are then lifted simultaneously off the support surface and derotated. The feet land back on the support surface with hips and knees flexing to a squat or semi-squat position. The legs then extend to the vertical.
Level 2.	*Kneel.* The legs are flexed and rotated to one side with both knees contacting the support surface.
Level 3.	*Half-kneel.* Both legs are flexed toward the trunk as one or both legs are rotated to one side. Either a kneeling or half-kneeling pattern is assumed. If kneeling occurs, one leg is then flexed forward to assume half-kneeling. The forward leg pushes into extension as the opposite leg moves forward and extends.
Level 4.	*Asymmetrical wide-based squat.* One or both legs are flexed toward the trunk assuming an asymmetrical, crossed-leg or wide-based squat. Internal rotation of the hips may cause the feet to be placed on either side of the pelvis. Asymmetry of hip rotation is common. The legs push up to an extended position. Crossing or asymmetries may be corrected during extension by stepping action
Level 5.	*Symmetrical narrow-based squat with balance step.* The legs are brought into flexion with the heels approximating the buttocks in a narrow-based squat. Stepping action may be seen during assumption of the squat, or balance steps (or hops) may follow the symmetrical rise.

Table 3.3

Whole Group Correlations for STS Time and Components with Health Related Fitness Factors and BMI by Age Groups

			HRF factors			
Age Group		BMI	Grip Strength	PACER	Curl-ups	Pushups
3-6 yrs	STS Time†	.31*	-.37**	-.47**	-.25*	-.21
(N = 61)	UE‡	.08	.36**	.22	.29*	.23
	AX‡	.04	.32*	.30*	.29*	.18
	LE‡	-.15	.16	.27*	.31*	.14
9-12 yrs	STS Time†	.49**	.04	-.56**	-.28*	-.48**
(N = 68)	UE‡	-.42**	.10	.45**	.18	.06
	AX‡	-.34**	.17	.36**	.16	.17
	LE‡	-.25*	.10	.18	.20	-.02
13-17 yrs	STS Time†	.23	-.42**	-.33*	-.29*	-.43**
(N = 53)	UE‡	.11	.05	-.01	.15	.29*
	AX‡	-.11	.26	.16	.22	.37**
	LE‡	-.16	.08	.19	.26	.16
18-25 yrs	STS Time†	.45**	-.35**	-.53**	-.20	-.24*
(N = 79)	UE‡	-.09	-.07	.12	.08	-.04
	AX‡	-.38**	-.13	.24*	.14	-.06
	LE‡	-.35**	-.13	.18	.12	.05

Note. *p < .05. **p < .01. ‡ Spearman's Rho. † Pearson's Correlation. UE = upper extremity. AX= axial. LE = lower extremity.

Table 3.4

Regression results by age group for STS Components and BMI Using Sex as a Covariate

		Sex		BMI		
Age Group	Dependent variables	ΔR^2	*L* Stat	ΔF	ΔR^2	*L* Stat
3-6 yrs	Upper extremity	.00	0.12	0.06	.00	0.06
(*N* = 60)	Axial	.00	0.12	0.09	.00	0.12
	Lower extremity	.02	0.89	1.66	.03	1.65
9-12 yrs	Upper extremity	.05	3.41	0.25	.00	0.21
(*N* = 72)	Axial	.05	3.27	0.67	.01	0.64
	Lower extremity	.04	2.49	1.25	.02	1.21
13-17 yrs	Upper extremity	.02	0.99	0.26	.01	0.26
(*N* = 53)	Axial	.17	8.84*	0.19	.00	0.16
	Lower extremity	.04	2.24	0.94	.02	0.94
18-25 yrs	Upper extremity	.02	1.39	0.22	.00	0.23
(*N* = 78)	Axial	.01	0.85	9.14	.11	8.24*
	Lower extremity	.00	0.08	7.04	.09	6.62*

Note. $*p < .05$. $**p < .01$. ΔF = *F*-ratio change for the model.

Table 3.5

Regression results by age group for STS Component and Combined Health-Related Fitness Factor Using Sex as a Covariate

		Sex		HRF		
Age Group	Dependent Variables	ΔR^2	*L* Stat	ΔF	ΔR^2	*L* Stat
3-6 yrs	Upper extremity	.00	0.12	3.25	.19	11.46*
(*N* = 61)	Axial	.00	0.12	2.96	.18	10.62*
	Lower extremity	.03	1.62	2.74	.16	9.72*
9-12 yrs	Upper extremity	.05	3.28	0.63	.04	2.48
(*N* = 68)	Axial	.05	2.81	0.32	.02	1.27
	Lower extremity	.03	2.61	0.38	.02	1.54
13-17 yrs	Upper extremity	.02	0.99	0.98	.08	3.90
(*N* = 53)	Axial	.17	8.84*	0.13	.01	0.47
	Lower extremity	.04	2.24	0.60	.05	2.39
18-25 yrs	Upper extremity	.02	1.46	0.74	.04	2.96
(*N* = 79)	Axial	.01	0.85	2.53	.12	9.36
	Lower extremity	.00	0.08	1.63	.08	6.40

Note. $^*p < .05$. $^{**}p < .01$. ΔF = *F*-ratio change for the model.

Table 3.6

Regression results by age group for STS Time and Combined Health-Related Fitness Factor Using Sex as a Covariate

		STS time	
Age Group	Independent variables	ΔF	ΔR^2
3-6 yrs	Sex	2.89	.05
	HRF	4.37**	.23
9-12 yrs	Sex	0.20	.00
	HRF	10.22**	.40
13-17 yrs	Sex	7.37**	.13
	HRF	3.05*	.18
18-25 yrs	Sex	10.24**	.12
	HRF	6.84**	.24

Note. $*p < .05$. $**p < .01$. ΔF = F-ratio change for the model.

Table 3.7

Regression results by age group for BMI and STS time Using Sex as a Covariate

		STS time	
Age Group	Independent variables	Δ*F*	ΔR^2
3-6 yrs	Sex	3.35	.05
	BMI	5.00*	.08
9-12 yrs	Sex	0.28	.00
	BMI	23.11**	.25
13-17 yrs	Sex	7.37**	.13
	BMI	1.98	.03
18-25 yrs	Sex	9.85**	.12
	BMI	27.94**	.24

Note. *$p < .05$. **$p < .01$. Δ*F* = *F*-ratio change for the model.

Table 3.8

Whole Group Correlations for STS Time and PA Factors by Age Group

Age Group		PA factors			
		Light	*p*-value	MVPA	*p*-value
3-6 yrs (*N* = 22)	STS Time	-.54*	.01	-.31	.16
9-12 yrs (*N* = 36)	STS Time	-.23	.17	-.23	.18
13-17 yrs (*N* = 16)	STS Time	.43	.10	-.07	.81
18-25 yrs (*N* = 29)	STS Time	.00	1.0	-.48**	.01

Note. **p* < .05. ***p* < .01.

CHAPTER 4

DISCUSSION

The purpose of this research project was to examine the feasibility of Supine-to-Stand as a measure of functional motor competence and health from early childhood into young adulthood. Two separate studies were conducted. The first study (see Chapter 2) examined the validity of STS as a developmental measure of functional MC across childhood, adolescence, and young adulthood using a pre-longitudinal screen approach and examining associations between movement components levels and STS time will provide a secondary measure of developmental validity. In addition, the second purpose was to examine the concurrent validity of STS (movement patterns and time) against developmentally valid measures of MC (i.e., kicking, throwing, hopping, and standing long jump) in these age groups. Overall, results indicated STS time can be considered a valid and reliable measure of MC across childhood, adolescence, and young adulthood. As, strong evidence indicates that MC is inversely associated with body weight status and positively associated with cardiorespiratory fitness and musculoskeletal fitness across childhood and adolescence (Cattuzzo, 2014), STS represents one task that may be a valuable assessment to understand the impact of MC on health as it is a lifespan measure of functional capacity.

The second study (see Chapter 3) examined the predictive utility of process- and product oriented assessments of STS as a predictor of the health-related variables of PA, weight status and health-related fitness across early childhood into young adulthood. This study is unique in that it is the first to demonstrate the strength of association among STS time, as a measure of functional MC, and health-related measures. Results indicate that higher levels of fitness are associated with faster times to stand. Consequently, more PA data is needed to examine the associations among STS time and PA levels. As the development of STS has been noted as a precursor to physical independence in early childhood and the elderly, its consistent link to cardiorespiratory endurance, muscular strength/endurance, and bodyweight status in early childhood into adulthood provides valuable insight for its potential significance as an early lifespan assessment screening tool.

Further examination of STS across the lifespan is needed to understand the progression and regression of MC from a lifespan perspective. In additional, more cross-sectional data and longitudinal studies are needed to provide an improved understanding of the relationship between STS, MC measures and factors related to physical fitness beyond young adulthood.

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