

A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship

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Although significant attention has been paid to promoting the importance of physical activity in children, adolescents, and adults, we do not currently understand how to promote sustained physical activity levels throughout the lifespan. We contend that previous research has failed to consider the dynamic and synergistic role that motor skill competence plays in the initiation, maintenance, or decline of physical activity and how this role might change across developmental time. In this article, we present a conceptual model hypothesizing the relationships among physical activity, motor skill competence, perceived motor skill competence, health-related physical fitness, and obesity. We contend that the development of motor skill competence is a primary underlying mechanism that promotes engagement in physical activity.

Obesity and physical inactivity among children and adolescents in our society has been increasing at an alarming rate over the past two decades (American Obesity Association, 2004; U.S. Department of Health and Human Services [USDHHS], 1997, 2004). Despite the fact that research has significantly increased knowledge in this area, we believe the lack of an interdisciplinary and developmental approach has stifled attempts to elucidate this growing crisis. Still unknown are the underlying mechanisms that are causal predictors of obesity and inactivity. Specifically, we believe the limited advancement in solving this complex problem has been the result of the lack of (a) an interdisciplinary and developmental approach in examining physical activity behaviors; (b) consideration that children's motor skill competence plays a highly significant yet varying role in supporting physical activity behaviors; (c) understanding of how perceived motor skill competence, health-related physical fitness, and obesity, as mediating variables, have differential associations to physical activity across developmental time (i.e., early childhood, middle childhood,

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and adolescence); and (d) appropriate measurement of motor skill competence in previous studies. The following sections will address each of these issues within the framework of a unique conceptual model and demonstrate how factors in the model might dynamically interact across developmental time.

Foundations of Motor Skill Development

Current literature in physical activity generally has not focused on the developmental nature of motor skill competence and its role in promoting physical activity across time. In essence, investigators have focused on measuring physical activity in children without an understanding that learning to move is a necessary skill underlying physical activity. In the early childhood years, children begin to learn a group of motor skills known as fundamental motor skills (FMS). FMS are composed of locomotor skills and object control skills. Locomotor skills involve moving the body through space and include skills such as running, galloping, skipping, hopping, sliding, and leaping (Haywood & Getchell, 2005). Object control skills consist of manipulating and projecting objects and include skills such as throwing, catching, bouncing, kicking, striking, and rolling (Haywood & Getchell, 2005). These skills form the foundation for future movement and physical activity (Clark & Metcalfe, 2002; Seefeldt, 1980). In essence, these FMS are the equivalent of the ABCs in the world of physical activity. With respect to the “fundamental patterns period” of development, Clark and Metcalfe (2002) stated, “the overall goal of this period is to build a sufficiently diverse motor repertoire that will allow for later learning of adaptive, skilled actions that can be flexibly tailored to different and specific movement contexts” (p. 176). If children cannot proficiently run, jump, catch, throw, etc., then they will have limited opportunities for engagement in physical activities later in their lives because they will not have the prerequisite skills to be active.

Two models of motor development have emphasized the importance of FMS in later physical activity (Clark & Metcalfe, 2002; Seefeldt, 1980). Over two decades ago Seefeldt suggested that competency in FMS was necessary to break through a hypothetical “proficiency barrier” that would allow individuals to apply these FMS to sports and games. Our experiences with children over the years have led us to share Seefeldt’s perspective, yet there is no empirical evidence to support this developmental view. More recently, Clark and Metcalfe (2002) spoke of the “mountain of motor development” and suggested that FMS are a precursor to context-specific and skillful movement. That is, to reach the “top of the mountain” of motor development and be physically skillful and active, children must first acquire competency in FMS to apply these skills in different contexts (e.g., sports and lifetime activities). Clearly, FMS are an important stepping-stone to motor development and, we believe, lifelong physical activity.

Other comprehensive theoretical models have been proposed to address the determinants of physical activity, but these have focused more on social-cognitive and/or expectancy-value-based approaches (Eccles & Harold, 1991; Harter, 1978; Trost et al., 1997). Although these models have contributed greatly to the literature and provide a partial understanding of the underlying factors in physical activity, the focus of these models has been on the psychological dimension

and children's perceptions of their motor competence, mastery attempts, and task persistence. Harter, along with her colleagues, suggests that mastery engagement and attempts build a child's perception of his or her competence, which in turn, influences the child's persistence in a task (Harter, 1978, 1988; Harter & Connell, 1984). In essence, a child's perceptions of competence influence whether a child will maintain engagement in an activity. Eccles and colleagues (Eccles & Harold, 1991; Eccles & Wigfield, 2002; Eccles, Wigfield, & Schiefele, 1998) share a similar perspective suggesting that perceptions of competence in relation to task difficulty influence involvement in an activity (or not). We value and support the views of Harter and Eccles but suggest that an underlying mechanism in these models, not adequately addressed, is the notion of actual motor competence. As we shall discuss further, perceptions of competence are contextually situated. We suggest that across developmental time, if a child does not have actual motor competence, perceptions of competence will drop when that child is better able to evaluate his or her competence level (Goodway & Rudisill, 1997).

A child's perceptions of competence are situated within the difficulty of the task. To use expectancy-value model based terminology, expectancy-related beliefs and subjective task value influence a child's performance, effort, and persistence in a task (Eccles et al., 1983; Eccles & Wigfield, 2002; Eccles et al., 1998). We suggest the notion that task difficulty is not just dependent on self-perceptions of ability. Rather, it is also linked to actual motor competence. A task is only difficult if we do not have the prerequisite skills to be successful in the task. We believe our model is unique in that we contend that actual motor competence interacts with other variables such as perceived competence and is one of the most powerful underlying mechanisms influencing engagement and persistence in physical activity.

One model by Welk (1999) has addressed the area of motor competence but in a different manner than our proposed model. Welk (1999) categorized the five most commonly reported determinants/correlates of physical activity into (a) personal, (b) biological, (c) psychological, (d) social, and (e) environmental. Overall, the most common determinants of physical activity (summarized by Welk) have been self-efficacy, perceived competence, enjoyment, parental influence, and access to an appropriate environment. Welk's (1999) conceptual model suggests that biological factors such as physical skills and fitness act as "enabling factors" that are promoted by physical activity with increased fitness and skillfulness leading to increased persistence in physical activity and enhancement of perceived competence and self-efficacy. However, he indicated that "while direct effects of biological factors are possible, indirect effects through the child's perception of competence are perhaps more likely" (p. 14). Furthermore, he stated, "with respect to competence, evidence shows that children's perceptions (of competence) may be more important than actual ability" (p. 15).

We are proposing that the development of motor skill competence is important in its own right, by either encouraging or discouraging (depending on the level of competence) individuals' physical activity levels. In addition, we believe that the emergent relationship between the development of motor skill competence and physical activity over time is mediated by other factors including perceived motor skill competence, physical fitness, and obesity. Thus, we believe developing motor competence or skillfulness is paramount to understand why individuals choose to be either active or inactive.

A common misconception is that children “naturally” learn FMS; however, a growing body of evidence suggests that many children do not obtain proficiency in FMS development (Goodway & Branta, 2003; Goodway, Suminski, & Ruiz, 2003; Hamilton, Goodway, & Haubenstricker, 1999; Langendorfer & Robertson, 2002a, 2002b). Many of these children might not attain sufficient competence in FMS to be motorically competent as adults (Goodway & Branta, 2003; Goodway et al., 2003; Williams, Haywood, & VanSant, 1991). More recently, a disturbing trend has emerged revealing that low-income Hispanic and African American preschool children in urban Head Start centers start school developmentally delayed in FMS development (Goodway & Branta, 2003; Goodway & Rudisill, 1997; Goodway et al., 2003). It is noteworthy that national data on adolescent physical inactivity mirrors the data on early childhood FMS delays. That is, African American and Hispanic adolescents have lower physical activity than their White counterparts, children raised in low-income environments have lower physical activity than children with higher incomes, and children in urban centers have lower activity levels than those in the suburbs.

It has been suggested that children who participate in sport and achieve greater levels of motor skill competence during childhood and adolescence will remain active participants in physical activity into adulthood (Malina, 1996). In fact, Tammelin, Nayha, Hills, and Jarvelin (2003) provided evidence that participation in sport-related activities as an adolescent was a strong indicator of physical activity into adulthood. The information presented by Malina and Tammelin laid the foundation for hypothesizing the importance of developing motor skill competence as an important approach to impact physical activity and obesity.

It is interesting that even though Welk (1999) suggests that the importance of “actual” competence/skillfulness is overshadowed by an individual’s “perceptions” of competence, he also states “children need to master a variety of physical skills to participate in different physical activities. With a broader repertoire of physical skills, children will have a greater chance of finding activities that they can do well and enjoy” (p. 17). Welk’s comments reflect the basis for our model and the general consensus of the motor development literature (Clarke & Metcalfe, 2002; Haywood & Getchell, 2005; Seefeldt, 1980) that motor skill competence is foundational to engagement in physical activity. Noting the general lack of importance placed on the development of motor skill competence in previous theoretical models pertaining to determinants of physical activity, we have developed an heuristic model representing what we believe are important concepts that have been identified in the literature but have not been integrated and systematically linked to the understanding of why so many individuals are physically inactive (Figure 1).

Relationship Between Motor Skill Competence and Physical Activity

At the heart of our conceptual model is a reciprocal and developmentally dynamic relationship between motor skill competence and physical activity (see Figure 1). Motor skill competence is defined in terms of proficiency in common FMS including object control and locomotor skill development. We suggest the relationship between motor skill competence and physical activity will strengthen over developmental

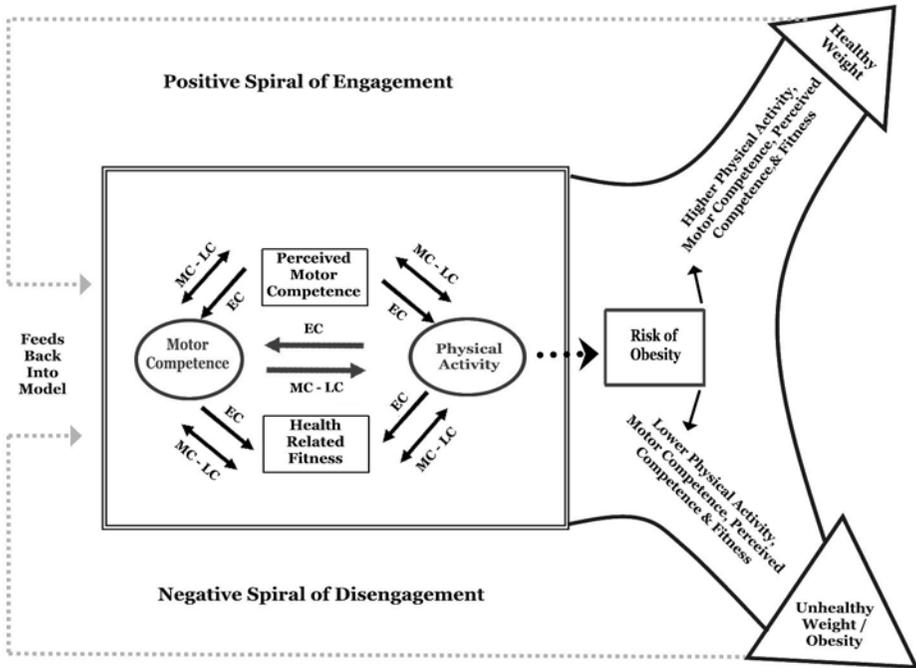


Figure 1 — Developmental mechanisms influencing physical activity trajectories of children.

time. Seefeldt (1980) indicated there might be a “critical threshold” of motor skill competence, above which children will be active and successfully apply FMS competence to lifetime physical activities, but below which they would be less successful and ultimately drop out of physical activities at higher rates. The idea of this critical threshold of motor skill competency has yet to be investigated and empirically defined in the research literature. In their analogy of the mountain of motor development, Clark and Metcalfe (2002) suggest that FMS represent the “base camp” from which children will climb up the mountain of motor development to achieve context-specific motor skills (p. 176). During this time, Clarke and Metcalfe acknowledge that children will follow different “developmental trajectories” in climbing the motor development mountain based, in part, on individual constraints and environmental opportunities. We support this view in our model.

We suggest that young (early childhood) children’s physical activity might drive their development of motor skill competence. Increased physical activity provides more opportunities to promote neuromotor development, which in turn promotes FMS development (Fisher et al., 2005; Okely, Booth, & Patterson, 2001a, 2001b). Overall, young children demonstrate various levels of motor skill competence primarily because of differences in experience. These differences are the result of many factors including immediate environment, presence of structured physical education, socioeconomic status, parental influences, climate,

etc. (Goodway & Smith, 2005; DiLorenzo, Stucky-Ropp, Vander Wal, & Gotham, 1998; Sallis, Prochaska, & Taylor, 2000). Thus, we hypothesize that young children will demonstrate variable levels of physical activity and motor skill competence that are weakly related at this point in developmental time. As children transition to middle and late childhood, we hypothesize that the relationship among levels of physical activity and measures of motor skill competence will strengthen. That is, the individual and environmental constraints operating during early childhood will compound over time to result in a stronger relationship between physical activity and motor skill competence. In middle and later childhood, higher levels of motor skill competence will offer a greater motor repertoire to engage in various physical activities, sports, and games. At this time we expect that moderately to highly skilled children will self-select higher levels of physical activity, whereas children with less-proficient levels of motor skill competence will engage in lower levels of physical activity. At this point, we believe that motor skill competence drives physical activity levels.

Our hypothesis that the relationship between motor skill competence and physical activity will strengthen over time is a novel concept that has not been addressed in previous literature. Past literature has examined this relationship in various age groups from approximately 3 (Fisher et al., 2005; McKenzie et al., 2002; Sääkslahti et al., 1999) to 16 years (Okely et al., 2001a, 2001b) and into adulthood (Tammelin et al., 2003) with no acknowledgment that the relationships might differ across developmental time. However, results from previous studies have generally shown that the strength of the relationship between motor skill competence and physical activity in children, especially younger children, has been weak in comparison with the data on older children, adolescents, and adults (Fisher et al., 2005; McKenzie et al., 2002; Sääkslahti et al., 1999; Okely et al., 2001a, 2001b; Tammelin et al., 2003).

We also believe there are additional factors that interact with the relationship between motor skill competence and physical activity as it strengthens over time. These dynamic interactions provide additional support for this novel, developmental hypothesis. We suggest that previous investigations that have examined the relationship between motor skill competence and physical activity have generally failed to consider the critical role of mediating variables such as perceived motor skill competence, health-related physical fitness, and obesity, that might interact with and promote/demote this dynamic relationship between motor skill competence and physical activity.

Role of Perceived Motor Skill Competence in the Conceptual Model

A child's perception of his or her motor competence is a developmental phenomenon that changes across developmental time (Harter, 1999). In the early years, young children demonstrate limited accuracy in perceiving their motor skill competence and generally show inflated levels of perceived competence relative to their actual motor competence (Goodway & Rudisill, 1997; Harter, 1999; Harter & Pike, 1984). Specifically, young children do not possess the cognitive skills to distinguish accurately between actual motor skill competence, ability, and effort (Harter, 1999; Harter & Pike, 1984; Nicholls, 1978). Young children under 7 years of age often

perceive higher expenditure of effort or mastery attempts with greater levels of motor skill competence (Harter & Pike, 1984; Nicholls, 1978; Nicholls & Miller, 1983). That is, their perceived competence is tied to mastery attempts and ultimately task persistence (Harter & Pike, 1984; Nicholls, 1978; Nicholls & Miller, 1983). A child might have low levels of actual motor competence but perceive her/himself to be highly skilled. As a result, we expect that perceived motor skill competence will not be strongly correlated to actual levels of motor skill competence nor physical activity during early childhood. In early childhood, however, the inflated perceived motor skill competence might be valuable to drive the acquisition of motor skill competence because children will continue to persist and engage in mastery attempts in activities in which they believe they are skillful.

The transition from early to middle childhood marks an important developmental time when the role of perceived motor skill competence begins to change in regard to the role it plays in the relationship between motor skill competence and physical activity. By middle childhood, children have shifted to higher levels of cognitive development and have a more sophisticated cognitive capacity to begin to more accurately compare themselves to their peers. As a result, their perceived motor skill competence more closely approximates their actual motor skill competence (Harter, 1999). That is, less-skilled children will have lower perceived competence and perceive many tasks as more difficult and challenging. Correspondingly, more-skilled children will have higher perceived competence, perceive tasks as less difficult, and engage in more frequent mastery attempts. Thus, we expect to find stronger relationships between perceived motor skill competence, actual motor skill competence, and physical activity. In fact, Davison, Symons, and Birch (2006) examined the relationship between girls' (ages 9–11) perceived competence and self-reported physical activity using a path analysis and found that perceived motor skill competence explained 27% of the variance in girls' physical activity. Unfortunately, they did not test the girls' actual motor skill competence.

The shift from early childhood to middle childhood marks the beginning of a period of vulnerability during which children who have lower actual motor skill competence will, correspondingly, demonstrate lower perceived motor skill competence and are less physically active. That is, they will opt out of physical activity because (a) they understand they are not as competent as peers (Goodway & Rudisill, 1997; Horn & Weiss, 1991; Weiss & Amorose, 2005), (b) they do not want to publicly display low motor skill competence (Horn & Weiss, 1991; Weiss & Amorose, 2005), and (c) they have a limited motor repertoire and will be less motivated to participate in physical activities that demand high competence levels. Overall, as these variables interact, a child who has low motor competence will find physical activity less enjoyable than their more advanced peers (Halliburton & Weiss, 2002). We believe that most children and adolescents who perceive themselves as having low motor skill competence, and actually demonstrate low levels of motor skill competence, will be drawn into a negative spiral of disengagement (see Figure 1) in which low levels of motor skill competence will be significantly related to lower perceived motor skill competence and, subsequently, lower levels of physical

activity. This will ultimately result in high levels of physical inactivity and will place these individuals at risk for being obese during later childhood, adolescence, and adulthood. Across developmental time, the negative spiral of disengagement compounds resulting in higher levels of physical inactivity and obesity.

We hypothesize an opposite positive spiral of engagement will occur among moderately and highly skilled children. Children with higher perceived and actual motor skill competence will more likely persist in physical activities, especially those they perceive as fun and intrinsically rewarding (Fisher et al., 2005; Weiss & Amorose, 2005). A positive spiral of engagement results in greater physical activity for these higher-skilled children because (a) engagement in physical activity provides more opportunities to further develop their motor skill competence and motor repertoire, (b) engagement in physical activity leads to the development of higher and more accurate perceptions of motor skill competence, and (c) physical activity will be fun and rewarding. As children move from childhood to adolescence, an obvious and significant “physical activity divide” will occur between low-skilled, inactive children who perceive themselves as poorly skilled, and their higher skilled, more active counterparts who find physical activity rewarding and fun.

Only one study has examined the relationship between perceived motor skill competence, actual motor skill competence, and physical activity. Wrotniak, Epstein, Dorn, Jones, and Kondilis (2006) examined the relationship among motor skill competence using the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), children’s self-perceptions of adequacy in performing and desire to participate in physical activity, and physical activity (measured by an Actigraph accelerometer) in 8- to 10-year-old children. Motor skill competence was positively associated with physical activity and perceptions of adequacy in performing and inversely associated with sedentary activity. Southall, Okely, and Steele (2004) assessed the relationship between perceived motor skill competence and actual motor competence in fifth- and sixth-grade (mean age = 10.8 years) overweight and nonoverweight children. They reported that overweight children had significantly lower actual and perceived motor skill competence than nonoverweight children. Physical activity was not measured in this study; however, based on previous literature, we would expect the overweight children to be less active than their nonoverweight counterparts. In contrast, Ulrich (1987) did not find a relationship between perceived motor skill competence and participation in sports in younger children, supporting our contention that this relationship will be different in young children.

These studies provide indirect support for the idea that perceived motor skill competence is a mediating variable that differentially influences the relationship between the development of actual motor skill competence and physical activity over time. We believe, however, that actual motor skill competence is the limiting factor in our model in middle to late childhood because of the fact that perceived competence is, in effect, an indirect measure of actual motor skill competence in older children. Thus, the mediating effect of perceived motor skill competence on physical activity in middle to late childhood is primarily based on the actual level of motor skill competence.

Role of Health-Related Physical Fitness in the Conceptual Model

Health-related fitness might also play a mediating role in the emergent relationship between physical activity and motor skill competence. We believe the acquisition of motor skill competence in FMS in early childhood (2–5 years of age) serves to promote physical fitness, because time spent initially developing these skills promotes increased physical activity and neuromotor development. Again, because of the fact that children will demonstrate variable levels of motor skill competence in early childhood, we do not believe there will be a strong relationship between fitness and motor skill competence or physical activity in early childhood. As children move from early to middle childhood, those children with intermediate to high levels of motor skill competence, and correspondingly more physical activity, should demonstrate greater health-related fitness and higher performance scores. We believe these relationships hold true because the development and performance of many FMS involve ballistic actions by the body, which place an increased demand on the neuromuscular system to generate and transfer momentum optimally through the kinetic link system. These skills require the manipulation of one's entire body mass against gravity with an increased demand for higher strength and power outputs (Enoka, 2002; Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999; Wrotniak et al., 2006).

Three fundamental aspects involved in the development of muscular strength include (a) the ability to effectively recruit motor units, (b) the ability to increase motor-unit firing rates, and (c) a decreased level of coactivation of muscle agonists and antagonists (i.e., coordinated muscle recruitment). All three of these factors are part of developmental neuromuscular adaptations that occur as children acquire FMS. These aspects of neuromuscular development are generally discussed in the realm of strength and resistance training but are also critical for the development of any goal-directed movements (i.e., motor skills). In middle to late childhood, higher levels of motor skill competence in FMS allow individuals to persist in activities long enough to demonstrate more consistent improvement in motor skills and be more successful. Children who are more physically fit later in childhood will be more likely to maintain physical activity for longer periods of time and continue to improve motor skill competence. In effect, the relationship between motor skill competence and physical fitness becomes more reciprocal in nature during late childhood and adolescence.

In later childhood and adolescence, during which the culture of sport becomes increasingly important for many individuals in the United States (Pate, Trost, Levin, & Dowda, 2000), more advanced levels of motor skill competence ought to be strongly related to greater health-related physical fitness and physical activity levels. In fact, persistence in sport activities that demand high levels of motor skill competence for successful participation during adolescence has actually been associated with high levels of adult physical activity (Tammelin et al., 2003).

Children who do not have adequate levels of motor skill competence will not continue to be physically active into middle and later childhood and, therefore, will not further develop or maintain aspects of health-related physical fitness. Low fitness levels will negatively influence a child's ability to persist in physical activities that require adequate levels of physical fitness and will limit further development of

motor skill competence. Thus, physical fitness acts as a mediating variable with the relationship among physical fitness, motor skill competence, and physical activity, increasing in strength over developmental time.

Role of Obesity in the Conceptual Model

The relationship between physical inactivity and obesity is well established in the literature (Anderson & Butcher, 2006; Centers for Disease Control and Prevention, 2000; Freedman, Khan, Serdula, Galuska, & Dietz, 2002). What is not clear are the underlying mechanisms resulting in that relationship. Overweight children have greater difficulty performing motor skills, especially locomotor skills, because of their increased overall mass (Goodway & Suminski, 2003). That is, higher mass results in lower locomotor competence. Consequently, they are less likely to be physically active throughout childhood (Bandini, Schoeller, & Dietz, 1990; Berkey, Rocket, Gillman, & Colditz, 2003), and when they do attempt physical activities, they will experience less success. McKenzie et al. (2002) and Okely, Booth, and Chey (2004) found body composition to be significantly associated with motor skill competence levels. In addition, Okely et al. (2004) indicated that intervention strategies stressing increased motor skill proficiency (especially in locomotor skills) might be a key component to prevent “unhealthy” weight gain in children and adolescents.

As demonstrated in our model, we believe that there is a dynamic and reciprocal relationship between obesity and the four factors within the model (physical activity, motor skill competence, perceived motor competence, and physical fitness). We propose that, over time, there will be a positive spiral of engagement with high motor skill competence, higher perceptions of motor skill competence, greater physical activity, and higher levels of health-related physical fitness promoting a healthy weight status. Concurrently, there is a negative spiral of disengagement in physical activity with low motor skill competence, low perceptions of motor skill competence, less physical activity, and poor health-related physical fitness leading to increased weight and obesity. Increased obesity levels will then feed back into the model and continue to negatively load on these factors as part of the spiral of disengagement. Thus, obesity is both a product of the interaction of variables and a mediating variable in how it interacts within the model, as described by the positive or negative spiral of engagement/disengagement. On the negative end, high levels of obesity will have a greater impact on the spiral of disengagement. We believe these synergistic relationships compound over time, perhaps accounting for the increase, maintenance, or decrease in physical activity during adolescence and into adulthood.

Lack of Developmental Assessment of Motor Skill Competence and the Relationship to Physical Activity

A number of studies have examined the relationship between motor skill competence and physical activity (Fisher et al., 2005; McKenzie et al., 2002; Okely et al., 2004; Okely et al., 2001a, 2001b; Wrotniak et al., 2006). We believe meaningful relationships between these variables have not been evidenced as a result of the

nondevelopmental manner in which motor skill competence was evaluated. In these studies, motor competence was evaluated by either assessing ability in individual skills or by using a test that purportedly measured the construct of motor skill competence. Within each of these approaches, scores represented either an inappropriate “product” or resultant of the child’s movement, such as the number of successful catches or number of “hits” recorded for throwing at a target, or a description of the child’s “process” or way of moving (see Fisher et al., 2005; McKenzie et al., 2002; Okely et al., 2004; Okely et al., 2001a, 2001b; Wrotniak et al., 2006). The difficulty with many product measures specifically used in these studies is that they did not examine the developmental movement process that resulted in the movement product. For example, in the BOTMP a child can have the same number of “hits” throwing at a target with no step and a chop arm motion, or they could throw with a more developmentally sophisticated pattern (opposition of arm to leg, arm wind up, and segmented trunk rotation). Thus, the score has no relationship to the child’s motor development or the ability to apply that movement skill, such as throwing, to the real world of physical activity.

The difficulty with studies that have used a process-oriented approach to examine motor skill competence (Fisher et al., 2005; McKenzie et al., 2002; Okely et al., 2004; Okely et al., 2001a, 2001b; Wrotniak et al., 2006) is that none have related the movement description to a developmental continuum. Rather, they have focused on whether the child’s movement approximated the movement of an expert performer. When the movement is not the same as the expert, the child’s score reflects some unspecified distance from the expert model. Two children can receive the same score for quite different “distances,” neither of which represents the children’s actual level of motor development. For example, Fisher et al. (2005) examined the relationship between motor skills and physical activity in 400 preschool children (mean age = 4.2 years). They administered the Movement Assessment Battery consisting of 15 motor tasks that were simply scored yes/no, indicating either they were “skilled” or “not skilled.” Children also wore accelerometers for 6 days. The correlation between the motor skill performance and physical activity was .1. In discussing their results, the authors wondered if a developmental, process-oriented assessment of the motor tasks would have correlated more highly with activity. In addition, McKenzie et al. (2002) combined product scores for lateral jumping, catching a ball, and balancing on one foot. The authors indicated that their skill assessments might have been inappropriate and that a restricted range of measurement levels (0–2 for balance, 0–6 for catching) might have been a factor as to why motor skill competence in early childhood did not predict physical activity in later childhood. Furthermore, they wondered whether skills involving speed and power would have better predictive validity for adolescents. Okely et al. (2001a, 2001b) used process-oriented assessment checklists to examine the relationship between motor skill competence in six fundamental motor skills including running, vertical jumping, catching, overhand throwing, forehand striking, and kicking and cardiorespiratory endurance and physical activity. Overall, the relationship between the six motor skills and cardiorespiratory endurance explained a low to moderate amount of variance in 8th and 10th grade boys and girls ($r^2 = .13-.28$). Unfortunately, these same motor skills explained only 3% of the variance in physical activity as assessed by a uni-axial accelerometer. As in the McKenzie et al. (2002) article, the authors

wondered if their process-oriented assessments were inappropriate. They also noted that the restricted range in components for the skills was a limitation.

In short, previous research that has considered the relationship between motor competence and physical activity has questionable developmental validity, not only by our standards, but also by those of the researchers themselves. When using the criterion of comparing a child to an “expert” performer, the movement patterns of an expert can be overly simplistic, often resulting in ceiling effects that are incapable of distinguishing between intermediate and advanced motor skill competence. In addition, comparison with the expert performer might result in floor effects that do not distinguish between a child with low-level skills and a child who is more skilled. For example, if the criterion for an expert thrower is a contralateral step, one child might demonstrate a throw with no foot action (the most rudimentary form), whereas another child might step with an ipsilateral (same hand same foot) step, showing a more advanced developmental pattern. Despite these developmental differences in performance, both would score a zero when comparing them with the expert performer. Our proposed model adds to the literature in that it recognizes the process-oriented and dynamic nature of motor skill development. New research in this area clearly needs to use developmentally valid measures of motor skill competence.

Another challenge relates to the validity and reliability of physical activity measurement. Many direct and indirect measures of physical activity have been used to examine various aspects of physical activity, such as accelerometers (uni-triaxial), pedometers, and self-report assessments. Concern relating to validity and reliability is an ongoing process, with entire journals dedicated to this specific topic (Measurement of Physical Activity, 2000; Troiano, 2005).

In summary, attempts to relate physical activity data collected from different, and sometimes inadequate, physical activity assessment tools to inappropriate motor skill competence measures lead us to question the results of previous work and the conclusion that there is a relatively weak relationship between motor skill competence and physical activity. We argue that the relationship between motor skill competence and physical activity will emerge from early to late childhood and will continue to gain strength during adolescence. We also believe this relationship will continue to gain strength into adulthood. This emergent relationship will be recognized if developmentally appropriate motor skill competence measures are used in conjunction with appropriate physical activity assessments.

Current Evidence for the Model

Recent cross-sectional data have provided promising results on the relationship between aspects of health-related physical fitness and motor skill competence in both young adults and children. Stodden, Langendorfer, and Roberton (in press) evaluated 79 men and 109 women 18 to 25 years of age on three FMS and six health-related physical fitness measures. This study used product scores of throwing and kicking maximum speed and maximum jumping distance to assess motor skill competence. This study also tested participants on six fitness measures (12 min run/walk, curl-ups, grip strength, leg press, percent body fat, and sit-and-reach flexibility). The motor skill product scores were moderately to highly correlated to five

of the fitness measures ($r = .48-.74$), with the exception of sit-and-reach flexibility ($r < .167$). The five moderately to highly correlated measures were combined in a factor analysis and regressed on the motor skill scores. Results from the multiple regression indicated that the three motor skill scores predicted 79% of the variance in the physical fitness factor. Overall, women generally scored lower in fitness and demonstrated lower product scores; however, the individual regression slopes for both men and women were approximately equal.

Additional pilot data on 253 children (ages 5–14 years) have also been recently examined (Stodden, Langendorfer, & Robertson, 2007). FitnessGram protocols were used for testing aspects of physical fitness (PACER, push-ups, curl-ups, and percent body fat). Grip strength was included as an additional measure of upper-body strength. The same procedure, as just mentioned, was used to examine competency in the same three motor skills. As with the adult data, motor skill product scores (throwing and kicking speed and distance jumped) were regressed on the construct of physical fitness. Again, as our model would predict, product scores did not significantly predict physical fitness for 5 to 6 or 7 to 8 year old children. However, throwing and jumping predicted significant amounts of fitness variance in 9 to 10 (28%), 11 to 12 (23%), and 13 to 14 (46%) year old children, respectively. As a whole, these pilot data on children and young adults provide support for our conceptual model with respect to the emerging relationship between motor skill competence and health-related physical fitness.

Although our previous argument stated that product scores are generally not a valid developmental measure of motor skill competence, we believe resultant product scores such as ball speed in kicking and throwing and jumping distance are valid because of the ballistic nature of these types of skills. All three of these skills share a similar fundamental characteristic that involves optimally generating and transferring linear and angular energy through the kinetic link system ultimately leading to a resultant product. Robertson and Konczak (2001) and Stodden, Langendorfer, Fleisig, and Andrews (2006a, 2006b) provide compelling evidence that throwing speed is strongly associated with component developmental levels and their associated kinematic descriptors. This argument must be validated in kicking and jumping, as well as other ballistic skills (e.g., striking) that share similar complex coordination characteristics.

Concluding Comments

It is clear that the problem of physical inactivity and increasing obesity in our society is multifaceted, with many factors influencing these disturbing trends. We believe the information presented in this article provides a scientifically grounded basis to stimulate research on the notion that the degree of motor skill competence is a critically important, yet underestimated, causal mechanism partially responsible for the health-risk behavior of physical inactivity. We also believe that the dynamic and developmental nature of our conceptual model, which describes differing relationships among the previously mentioned variables across developmental time, provides a unique perspective on this important issue. Furthermore, the need to focus on the positive or negative developmental trajectories of physical activity and the antecedent-consequent mechanisms of why individuals choose to be either active

or inactive is critical. We recognize that these relationships are embedded in and influenced by other contextual factors (environment, family, peers, socioeconomic status, culture, nutrition, self-efficacy, etc.) that affect an individual's opportunity to be active. Thus, there is one additional question to ask: Will the strengths of these relationships continue to increase over the lifespan (i.e., throughout adolescence and adulthood)? Or, will other factors change the nature of these relationships as we age? As multidisciplinary teams attempt to elucidate the underlying mechanisms influencing physical activity, we urge them to consider the dynamic and developmental issues proposed in our conceptual model.

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