PRIMARY SCHOOL-AGED CHILDREN AND FUNDAMENTAL MOTOR SKILLS –
WHAT IS ALL THE FUSS ABOUT?

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ABSTRACT
Fundamental motor skills are assumed to hold a key position on the movement education continuum for primary school-aged children. For example, mastery of fundamental motor skills is considered to be a precursor to their application in sport specific contexts, and conversely a lack of proficiency is lauded as a key reason for attrition from organised sport. The exploration of childrens’ coordination levels and their performance on a fundamental motor skill has revealed a significant relationship between these two movement constructs. Primary school-aged children (n=161) were measured using the McCarron Assessment of Neuromuscular Development (coordination) and their process performance of the two handed sidearm strike (fundamental motor skill). Using the partial credit form of the Rasch analysis (Quest), the ordinal measures of the process performances were transformed into interval data. Consequently, these data were comparable to the Neuromuscular Development Index from the McCarron, by employing multivariate analysis techniques. A significant interaction resulted and this provided a sound methodological basis from which to explore the relationships between coordination and process and product performances on a fundamental motor skill. Implications of this study findings focus on our understanding of movement enhancement.

INTRODUCTION
Fundamental motor skill performances have been the focus of much research within Australia in the recent past (Booth, Macaskill, Phongsavan, Okeley, Patterson, Wright, Bauman & Baur 1997; Thompson, McCormack, Thomas & Woodcock 1995; Walkley, Holland, Treloar & Probyn-Smith 1993; Walkley, Holland, Brown, Temple, Jacobson, O’Connor, Parker & Treloar 2000). The attention focused on Australian childrens’ fundamental motor skill proficiency has been framed within the purported link to physical activity in sport specific environments (Clough McCormack & Trail, 1993; Seefeldt 1979; Ulrich 2000). Investigations of Australian childrens’ motor skills have mirrored
those undertaken in the U.S.A. (Kelley, Reuschlein, Haubenstricker 1989; 1990) and have adopted similar assessment strategies. The outcomes of Australian based research have ultimately provided a culturally-specific indication of skill levels of our school-aged children. Generally, the Australian results reflect those of American studies, namely, that children are not at the most efficient level of performance across most fundamental motor skills.

This paper outlines the benefits of measuring fundamental motor skills and also discusses the challenges associated with the methods and the rationale of such assessment. Ultimately, the focus for researchers engaged in the exploration of what may account for skilled or unskilled performance of fundamental motor skills, is the basis for the research findings presented here. The research question addressed in this paper is concerned with the relationship between performances on a fundamental motor skill and coordination levels of children within the primary school aged period.

Firstly, there is great value in the systematic investigation of motor skill performances for Australian children, as few measures of a comparative nature are available. In contrast, other domains of education have international comparisons for literacy and numeracy (Rothman & McMillan 2003). Given the broad acceptance of the place of fundamental motor skill proficiency in the movement competence of individuals, it is prudent to be supportive of the generation of these data. In the New England area of New South Wales, research has explored the relationships between the sport specific and fundamental motor skills of primary school-aged children (Austin, Haynes & Miller 2004; Miller 2006a; Miller & Dickson 1999; Sprinkle, Wilson, Dickson & Vine 1997). Similarly, studies focusing on pre-school children have identified learning styles linked to gender (Garcia 1994; Miller 1979) as well as the efficacy of fundamental motor skill intervention programs for disadvantaged childrens’ motor skill performances (Goodway & Branta 2003).

Secondly, to question and test assumptions is also encouraged within educational research. For example, the place of fundamental motor skills as a precursor to sport specific or specialized skills is challenged (O’Keeffe 2001). The rationale for this research rests on the exploration of fundamental motor skills as a precursor to more sport specific skills as conceptualized on various motor development continua (Seefeldt & Haubenstricker 1976; 1982; and Gabbard 2004). The most notable model has the ‘proficiency barrier’ located between the fundamental skills and sporting applications found in Seefeldt cited in Nadeau et al., (1979). Such visuals strongly denote an impediment for progress in skilled applications and appear as an unquestionable model.

Thirdly, the hierarchical nature of the fundamental motor skills as the predecessor to the specialized phase of development in the Gallahue and Ozmun’s heuristic model of motor development (1998) to the subsequent theory of motor development (Gallahue & Ozmun 1998; 2002: 81) provides a frequently referenced link between fundamental motor skill proficiency and its application to sport specific situations. Ages ascribed to the phases of motor developmental also reinforce the precursor status of fundamental movements to specialized skills (Gallahue & Ozmun 2002). Such factors all create an authority of theory and practice which has been widely accepted (Gabbard 2004; Rose & Heath 1990; Seefeldt 1979). The dependence of proficient and efficient movement within the fundamental skills has been the basis for broader applications in the sport specific domain in particular the curricula of schools across many states of Australia (New South Wales
According to Gallahue and Ozmun (2002) children at six years of age should be at the ‘mature’ level of fundamental motor skills performance proficiency. Mature performance of fundamental motor skills can be likened to the most ‘efficient’ or to performances termed as being at the ‘mastery’ level (Booth et al., 1997; Walkley et al., 1993). However such expectations of performance are not being matched by research results (Booth et al., 1997; Walkley et al., 1993).

The fundamental motor phase of development is a period when children are thought to be able to acquire skills through structured and purposeful learning environments. As such, various motor learning factors are considered when skill performances are assessed. The period of time for children when fundamental motor skills are evident is also a phase when the learning environment has become a critical element in performance differences. This latter point implicates the role of curriculum and teaching effectiveness in the primary school education of children.

This paper maintains that the fundamental motor skill phase of development holds a key, or is a crucial period for developing physically competent children. In addition, the assumptions regarding the measurement of skill performances support the investment of resources for this phase of development within the curricula of our primary schools. However, what is less known is the relationship between fundamental motor skills and other measures of whole body efficiency such as coordination. Coordination has, in many cases, been linked to the term motor ability. ‘Motor ability’ has been used in a range of disciplines to describe what is regarded as a finite and pre-determined set of competencies and as such is too confined for the possibility of improvement past the deterministic! As such, this paper will adopt the term coordination.

Coordination can be described microscopically in research centering on the movements of body or limb segments or macroscopically, in terms of the patterning of the body and limb motion relative to environmental objects and events (Magill 1993; Thelen 1989). Motor control literature tends to focus on the former approach with the interrelationship between finite and refined movement often the focus of such research (Walter, Corcos & Swinnen 1998).

The macroscopic view of coordination, such as the whole body, is of particular interest as there is considerable research within the area of poor coordination, usually associated with Developmental Coordination Disorder (DCD). Coordination in this sense is the degree of whole body functioning – in terms of both gross and fine motor tasks, measured using a triangulation of data through both qualitative and quantitative methods.

It has not been only studies of DCD that have ‘coined’ the term coordination. For example Broderick and Newell (1999) moved coordination from a microscopic view of two points on the body in terms of stability or variability in movement, to a broader perspective of a skilled performance.
“In the performance of a movement task, even where the criterion of success is solely an outcome measure and skill level is defined by the outcome of an action, skill level is also a function of the patterns of movement coordination” (Broderick & Newell 1999: 165).

In addition, Gallahue and Ozmun (2002) have employed the term ‘coordinated’ to indicate the continuum of initial, elementary and mature forms of fundamental motor skill performance. Coordination has emerged as a critical element when discussing factors accounting for skilled performance. In specific terms, this paper reports on research based on a broader ‘whole body view of coordination’ and the interaction with the performances of a fundamental motor skill, such as the two handed sidearm strike. The two handed sidearm strike – specifically using a tee-ball stand with the ball placed on the tee was selected because it is a closed skill (Gentile, Higgins, Miller & Rosen 1975). A major benefit of using a skill that is closed is based on the rationale that performance variations in terms of process (levels of efficiency) and product (distance weighted for accuracy) can be attributed to variables associated with the performer, rather than the variations within the environment.

METHOD

The methodology employed in this research includes a quasi-experimental design in which students were tested within the school environment for both coordination levels and their process and product performance on the two handed sidearm strike. The methods are described in terms of participants, instruments and procedures.

PARTICIPANTS

University ethics clearance was granted as well as permission from the State Department of Education for the research to take place in New South Wales, Australia. Children enrolled in a large primary school (n=630) within a rural city located in the Northern Tablelands of New South Wales were invited to participate in the study. Children were invited to participate in the study based on being 6 - 10 years of age. They were included after gaining both parental and student permission. The age span allowed for two groups of students. These were children whose ages were associated with the later stage of the fundamental movement phase (Gallahue & Ozmun 2002: 46) and the older group who were age-associated with the specialized phase of development.

Children

Of the total number of students available in the targeted age span (n=232), sixty-nine percent agreed to participate (n=161). The profile of the participants included children who were either turning 6 or 7 years of age (n=65) or they were in the group turning 9 or 10 years of age (n=87), a smaller cohort of 8 year olds (n=9) were included. Overall, for the study there were slightly more girls (n=86) than boys (n=75).

Test Administrators

Testers included the principal researcher, a physical education lecturer with over ten years school based teaching experience and four Bachelor of Education/Physical Education students. Training for the administration of the McCarron Assessment of
Neuromuscular Development (McCarron 1997) was designed to collect the most reliable data and as such, test orientation and practice involved intra and inter-rater reliability checks prior to test administrators being permitted to collect data in the school (Miller 2001).

INSTRUMENTS

There are three instruments administered in this research. The first is the McCarron Assessment of Neuromuscular Development (MAND). The MAND consists of ten test items that can be classified as both fine and gross motor tasks. The second instrument is an ‘amalgamated’ process instrument for the two-handed sidearm strike. The process instrument was compiled from relevant features of both the component and the total body configuration approach, specifically for the two handed sidearm strike (Miller 2001; 2004; Miller, Vine & Larkin 2007). The third instrument was a Batting V which was used to measure the distance the ball travelled.

McCarron Assessment of Neuromuscular Development (MAND)

The instrument employed and administered to ascertain the coordination levels of students was the MAND (McCarron 1997). The MAND is a standardised method of assessing psychomotor skills (McCarron 1997: 25) and comprises ten tasks. These tasks are representative of both gross and fine motor actions. In addition, there are both quantitative and qualitative aspects of performances assessed.

Scoring the MAND test involves the compilation of raw scores for all ten tasks, and converting the raw scores to scaled scores using the age-normed tables provided with the instrument. The age norms are provided for six monthly intervals for example, 6 years 0 months and 6 years 6 months and 7 years and 0 months etc. These scaled scores are summed and converted (scaled by age) to form the Neuromuscular Development Index (NDI). The NDI can be likened to a motor quotient and can be considered similar to other quotients, used to assess aspects of development, for example Intelligence Quotient. The NDI is based on a mean of 100 and a standard deviation of 15. Additionally, eight-of-the-ten scaled tasks are grouped in terms of four factors which include Kinaesthetic Integration, Muscular Power, Bimanual Dexterity and Persistent Control. The factors of the MAND are not explored in this paper.

Amalgamated Striking Instrument.

Given that the most current instruments available to assess fundamental motor skills emerged from the I CAN project (Wessel 1976) and were predominantly modified to include the components of the most efficient form of the skill (Kelly et al. 1989; 1990), it was determined that ‘ceiling type of instruments’ currently used in large scale projects were too limited (Booth et al., 1997; Walkley et al., 1993). Instruments based on the total body configuration (TBC) approach were too difficult to use in the research setting. As such, a new instrument was constructed that included aspects of both approaches.

The full detail of the basis of including ten components of the strike and the three levels of efficiency for each of the components is explored fully elsewhere (Miller 2004). The validity of the instrument was assured with the application of the Rasch Latent Trait Scaling Analysis technique. The results of Rasch analysis supported the...
use of the amalgamated instrument which was rigorously investigated prior to its use in a larger investigation (Miller 2004; Miller, Vine & Larkin 2007).

This new process striking instrument is termed the Miller Amalgamated Striking Instrument (Miller 2004; Miller, Vine & Larkin 2007) and is referred to as the MASI for the remainder of this paper. The detail of the procedure of the instrument has been reported in detail and can be seen in Miller, Vine and Larkin (2007). In summary, one of three levels of efficiency for each of the following ten components of the strike by six trials comprise the process data set. The components are:

1. Preparatory bat position – on shoulder – off shoulder – or at the tee
2. Legs being straight, flexed, or with weight transfer
3. Trunk position with varying positions, from facing the target to side-on
4. Eyes following the ball, or not at all
5. Three distinct degrees of back-swing with the bat
6. Striking phase with arm motion in contacting the ball
7. Grip on the bat with relative hand placement
8. Contact, under or over hit the ball or air-swing
9. Follow through phase with arm angle
10. Trunk rotation to marked sequential hip and shoulder rotation

(Miller 2002; Miller 2004; Miller, Vine and Larkin 2007).

The batting V was set up in the playground using markers and a tape measure that ran down the centre of the V. The tape was used to measure to the nearest metre, the resting place of the ball after it was struck by the participant. The protocols followed in the collection of data and the context within which children were assessed for coordination and tee-ball striking performance is outlined further.

PROCEDURES

Data were collected in the school playground, providing an ‘ecologically valid environment’. This setting addressed the contextual issue of collecting data in a meaningful environment for the students, such that the results of the study could be reasonably applied back into similar learning environments. Children were withdrawn from class three at a time and introduced to the task of the MAND testing. Stations were positioned in such a way as to eliminate distractions for the students. Each child moved around five stations and each administrator assessed two of the ten MAND tasks at each station. All standardised procedures were followed as set out by McCarron (1997).

Within three weeks of the MAND testing, the children were withdrawn for assessment of the two handed sidearm strike. A tee-ball stand was set up in the school playground in a location where children would normally expect to play. After adjusting the tee-ball stand to the waist height of the performer, and using a lightweight ‘nerf-style’ bat, each child was asked to “hit the ball as far into the batting V as possible.” The batting V was a formation used to replicate a baseball field (Miller 2001). Following three practice trials, performances of six trials were recorded. The participants’ process performances were assessed from the video images recorded by a camera placed at a forty-five degree angle to the performer. In particular, the process data involved
identifying one-of-three levels of efficiency for each student on each of the ten components of the MASI for the six trials of the teeball strike.

Following the coding by the principal researcher, inter-rater checks on twenty participants were conducted by an experienced Physical Education teacher. A .90 index of reliability was achieved, which is within the acceptable level of reliability (Anastasi 1988). Product scores were the distance measured in metres from the batting tee to the resting place of the ball.

DATA ANALYSIS
MAND data were compiled using the protocols set out by McCarron (1997). However, based on the exploration of a larger data set in a related investigation, the use of the NDI as a standardized score known as the ZMAND was adopted (Miller 2001). The MAND data were standardised and as such the ZMAND became the anacronym for the coordination score for each student.

Specifically, in addition to the exploration of the larger data set, there was supporting evidence from the literature for the use of raw rather than scaled scores. Larkin and Parker (1995) questioned the factor structure of the MAND, and Cooley, Oakman, McNaughton and Ryska (1997) provided evidence that Australian and American children diverge after seven years of age in performance of motor proficiency. This concurrent evidence provided confirmation of the necessity to be prudent in the use of instruments applied to Australian children that have been age-normed on American populations. This evidence became available after commencing this investigation, and therefore could not be factored into the selection of the motor proficiency instrument.

The process data from the tee-ball strike were analysed using the Rasch Model, as represented in ACER’s Quest software (Adams & Khoo 1993:1). As the fit statistics were of the acceptable level (Hambleton Swaminathan & Rogers 1991; Wright & Masters 1982) in terms of both items (components) and cases (children), the case estimates became the process measure for each child (Miller 2004).

Given that the ZMAND and the case estimates (logits) are both interval level data and not a combination of interval (ZMAND) and ordinal (coded levels of efficiency), a rigorous methodological platform existed from which to explore the relationship between the two sets of data.

RESULTS
A detailed exploration of the MASI in terms of Rasch has been reported elsewhere, (Miller 2004) and as such will not be repeated here. The analysis of the relationship between the process measures and the coordination levels (ZMAND) is presented in greater detail in Miller (2006a) and is summarized for this argument. The correlation between ZMAND scores and the average process scores (n=161) was significant (p=<.001) with the Pearson’s r 0.365831. Given the difficulty in the level of confidence and predictability of the correlation (Argyrous 2005), greater exploration of the strength of the relationship between these variables was pursued.
Distance and process measures are highly correlated (Miller, Vine & Larkin 2007). This outcome in a key finding as this relationship between two forms of measurement has not been demonstrated with this skill and with this diverse range of participants. Although it is recognised that different measurement tools measure different constructs, it is noteworthy that performance in terms of distance weighted for accuracy showed a high agreement with the process measure. In addition the data were interval due to the advantage Rasch analysis provided for the process scores (Wright & Linacre 1989).

In order to explore the ways in which these variables are associated, a K-Means cluster analysis was carried out to determine whether a taxonomy of subjects could be identified, and, subsequently, to ascertain if cluster membership was associated with differentiated levels of process performance. For this purpose, ZMAND, (Coordination) PMEAN (process) and DMEAN (distance) were used as classificatory variables in a K-MEANS cluster procedure. A four-cluster solution showing acceptable separation between cluster centres and intra-cluster cohesion was found. Importantly, the four-cluster solution was also considered to have substantive and not merely statistical importance. Cluster membership detail is found in Table 1 which provides a summary of the age, sex, ZMAND, distance and process score characteristics of each cluster.

Table 1: Profile of the ZMAND Cluster Membership for the Participants

<table>
<thead>
<tr>
<th>Clusters</th>
<th>Ages</th>
<th>Girls</th>
<th>Boys</th>
<th>Total</th>
<th>ZMAND Mean</th>
<th>ZMAND SD</th>
<th>Process Mean (logits)</th>
<th>Distance Mean (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 yrs</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5.98</td>
<td>2.05</td>
<td>19.18 D Mean</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6 yrs</td>
<td>7</td>
<td>12</td>
<td>19</td>
<td>.12</td>
<td>1.85</td>
<td>14.53 D Mean</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>9 yrs</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-12.67</td>
<td>.29</td>
<td>5.73 D Mean</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>6 yrs</td>
<td>12</td>
<td>8</td>
<td>20</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Cluster One is the largest group with sixty-four students spanning the age group from six-to-ten years. The majority of students in cluster one are located in the older category of 9/10 years of age. However, there are some boys and fewer girls in this cluster who are at the younger end of the age range, between 6 and 7 years of age. The students in this cluster represent those, on average, with the highest level of coordination and the highest ZMAND mean of 5.98. While there are more girls ($n=36$) than boys ($n=28$), there are more older girls than older boys. The students in Cluster One performing at the highest level of efficiency with a process mean of 2.05 logits also hit the ball further, demonstrating a distance mean of 19.18 metres.

Cluster Two is the next highest level of performers with forty-nine subjects and they are polarised at each end of the age groupings, of six years of age and upper 9/10 years. Cluster Two children have the next level of coordination with a mean ZMAND of .12. There are slightly more boys ($n=27$) than girls ($n=22$). The performance in terms of process, of 1.85 logits, and distance 14.53 metres they represent the next level of performances for the strike. Cluster Two is characterised by a diverse age range, more boys than girls and the second level of performers in terms of ZMAND, process mean and distance mean.

Cluster Three has fifteen students. Fourteen of these students are six years of age, of which nine are girls and five are boys. One boy, was in the 9-10 years of age category. For this cluster, the ZMAND mean is -12.67, the process average is .20 logits and the distance mean is 5.73 metres. Cluster Three represents the lowest level of coordination (ZMAND) and the lowest process means and the lowest mean distance scores.

Cluster Four represents the third level of student coordination. Thirty-three students, are in the lower 6-7 years of age category. Eight students are in the upper 9-10 age group. The ZMAND average is -6.01 and the process mean is .87 logits, with distance mean is 11.34 metres for cluster four. This cluster has more girls ($n=19$) than boys ($n=14$). Cluster Four exhibits the third level of performers and, although the spread for age and sex is wide, the majority of the children are in the younger age range.

When these clusters are ranked in terms of descending ZMAND order, they present as: Cluster One; Cluster Two; Cluster Four; and, Cluster Three. The age and sex profile of the clusters is of great interest as there are some younger children in the best coordinated cluster (Cluster One) and some older ones in the least coordinated
cluster (Cluster Three). In addition to the coordination means, the performance of the strike for distance and process measures parallel the coordination grouping.

From this evidence, ZMAND can be seen as not just a proxy for age. The clusters have a wide span of ages of children comprising them. Therefore, given there are no clear parallels between ZMAND and age, there is however for ZMAND, process performances and product (distance) scores.

**DISCUSSION**

There is a general acceptance that the performances for a range of fundamental motor skills reflect a degree of learning to which the individual is exposed. Consequently, the process performance of the strike has previously accounted for an interaction of the integrative capacity of the individual and the opportunities to practice and ‘learn’ the skill. Alternatively, biologically driven growth of coordinative structures during this period may have been less predictive than that induced by the learning of a specific motor skill. However, the inter-correlation of ZMAND and process and product performance is an important result and that provides an opportunity to consider the way in which the movements of primary school-aged children may be influenced. In addition this result also provides a rationale for the school-based learning of fundamental motor skills in the primary school by highlighting the symbiotic relationship between coordination and skilled movement.

This paper began by questioning the place and importance of fundamental motor skills and sport specific applications within the Australian educational context. Rather than engaging in the rationale of proof for the precursor/successor status of motor development models, a suggestion is made that the research presented here provides a platform from which to explore the bi-directional nature of whole body movement, categorized as coordination, or alternatively as an underlying capacity - to the relationship of process and product performances on the two handed sidearm strike.

The nature of the measurements is important to consider. For example, ZMAND is assessed through a range of qualitative and quantitative measures, as is the process data. In addition, the coordination measure is derived from performances on diverse fine and gross motor tasks. Product is measured in metres. At the centre of this result rests the interplay between what is underlying movement quality and which fundamental motor skill assessment factors have the greatest influence.

There are multiple interpretations for the results of this research. Specifically, the relationship between product and process performance indicates a relationship between these two measures of the same performance (Miller, Vine & Larkin 2007). In addition the relationship between process performance on the two handed sidearm strike and coordination (Miller, 2006a), allows for exploration of whole body efficiency and the degree of efficiency in motor skill performance.

In interpreting these outcomes, it should be emphasised that this study focused on children from 6-to-10 years of age, and it may be that during this specific period of motor development the movement outcomes for these children are evidence of them undergoing biologically-driven growth in underlying coordinative structures and the
socially mediated learning of specific motor skills. Stated another way, this result may be evidence of the intersection of the underlying movement capacity of coordination with the learned performance of a motor skill. This bidirectional interaction between the efficiency (process) and effectiveness (product) of a learned skill may ‘translate’ to the integrative capacity of the whole body across the tasks used to assess coordination. Conversely, a well-coordinated mover in terms of neuromuscular development could predispose the body to correspondingly efficient movement in terms of skilled performances of skills such as the two handed sidearm strike.

Ultimately, these findings may best be placed within the framework of Dynamic Systems Theory and provide an empirical basis for the focus on the capacity of the body to self-organise and self assemble and respond to diverse task demands in a similar ‘quality’ manner. The relationship between process measures of the strike and the level of coordination of the students supports the view that movement outcome is a response to varying task demands and an interaction of degrees of freedom within the range of affordances and perturbances (Miller 2006b). Efficiency of movement (process) is related to effectiveness (product) (Miller, Vine and Larkin 2007). Further exploration of these findings by replicating this methodology for a range of fundamental motor skills is one way to test the broader applications of these findings. This approach is currently being undertaken (Miller 2007 in progress).

REFERENCES


