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The relationship of process and product performance of the two-handed sidearm strike

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Background: Many researchers are concerned with the proficiency of children in movement education. They are expressing this concern through the assessment of fundamental motor skills, owing to the established links between the proficiency of fundamental motor skills and subsequent involvement in sport and physical activity. The assessment of fundamental motor skills has predominantly employed a qualitative approach. Another form of assessment involves quantitative measurement; however, the relationship between process and product assessment paradigms is largely unexplored.
Purpose: To investigate the relationship between the movement process and product measures of fundamental motor skill performances for primary school-aged children. The relationship between process and product assessment of fundamental motor skills is at the centre of this research.
Participants: included 161 six to ten year-old children including 86 girls and 75 boys. The primary school-aged children participated in the study after parental permission and university ethics approval for the research were granted.
Research design: involved a cross-sectional design which involved collecting data in an 'ecologically valid' environment—a school playground. Children were withdrawn from class three at a time and individually asked to strike the ball from a batting tee for three warm-up trials. Six trials for each child were measured in terms of process and product performance.
Data collection: occurred in the school. The students were video recorded as they performed six trials of tee-ball striking, responding to the task goal of 'hit the ball as far as you can into the batting V'. These recordings were later coded using a (process) amalgamated striking instrument that is comprised of three levels of efficiency for 10 components of the strike. The components of the process instrument were derived from both the Component Approach and the Total Body Configuration models. The distance or product scores were measured from the batting tee to the resting place of the ball.
Data analysis: The six trials for the 161 children were analysed by firstly taking the process observations and coding them using the amalgamated striking instrument. These process codes were analysed using the partial credit form of Rasch (*Quest*) analysis. Subsequently, *Quest* provided case estimates, transforming ordinal observations to interval data. These process data

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were then compared to other interval measures—the distance measured in metres represented the product of the performance. Process scores (case estimates) were compared to product (metres) data to find the relationship.

Findings: A significant correlation between the process and product measures for each of the six trials ($r = .51 - .66, p < .0001$) indicated there is a positive relationship between the process and product measures of the fundamental motor skill performance of the strike for each of the six trials.

Conclusion: The application of the Rasch model allows for investigation of two different forms of data (ordinal and interval). The exploration of the relationship between process and product performance indicates the significant correlation between the two performances for these data. Choice of assessment technique now is more open, with some confidence in the association established for these two techniques. With considerable variance still unaccounted for, further exploration of this type of investigation would be prudent.

Physical educators and movement specialists measure children's performances of fundamental motor skills. Such assessment of movement has various purposes and therefore varying approaches are employed. In determining the level of proficient performance on a fundamental motor skill, a major challenge for the physical educator resides in selecting from these diverse assessment approaches. There are two broad categories of measurement relevant to the measurement of fundamental motor skills, namely process (qualitative) that is concerned with how the skill is performed, and product (quantitative) that is based on the 'outcome' of the skill performance (Burton & Miller, 1998).

Process and product measurements of motor skill performance differ in two important ways. First, the measures are based on different underlying constructs related to motor skill performance. Process is concerned with the degree to which the execution of a skill compares to its most efficient form, while product measures indicate the outcome of the performance that results from the dynamic execution of components of the skill. The second difference between these two categories of measurement is the data that are generated. Process data tend to be ordinal and product data interval (Wright & Linacre, 1989). Because of these diverse data types, there is a difficulty in statistically identifying the nature of the relationship between process and product assessment measures. Although it has been assumed that there is a relationship between these two categories of assessment, there have only been studies where ordinal data have been compared to interval data (Roberton & Konczak, 2001).

Until recently, comparing measures that are ordinal with those that are interval has been problematic due to the different scales upon which they are based (Wright & Linacre, 1989). A solution to this measurement issue is to transform both process and product measures so that they are both on the same scale. Process measures are centred on criteria and therefore, the data are ordinal. Product measures, in contrast, are predominantly interval as they are concerned with how far, how quickly or how accurately a skill is performed. Parallel to the issue of the relationship between process and product assessments is the need for a more refined process measure of fundamental motor skills.

As part of a larger study concerned with the investigation of the process measurement of the two-handed sidearm strike, an innovative and refined process instrument was constructed based on aspects of both the Total Body Configuration approach and the Component Approach to the measurement of motor skill performances. The construction of this process instrument is detailed in the next section.

Process instrument construction

A review of available instruments to measure the process performance of the two-handed sidearm strike resulted in approaches being classified as either emerging from the Total Body Configuration (TBC) orientation or the Component Approach (CA). Both approaches have advantages and disadvantages. For example, TBC has emerged from observational data of both cross-sectional and longitudinal studies, related to the performances of children in early to middle childhood. TBC instruments usually result in three to five stages defined by whole body descriptions that represent a series of 'developmental progressions' (Seefeldt & Haubenstricker, 1982).

In contrast, the Component Approach to assessment emphasises criteria that are defined and represent developmental changes in the 'body-component' parts of a movement such as arm, leg, head and trunk action. The CA has been given more exposure since the 1990s particularly in large-scale studies of children's motor skills (Kelly *et al.*, 1989, 1990; State of Victoria, 1996).

Both TBC and CA approaches eventually led to the development of descriptive criteria that relate the least efficient or 'immature' form of the movement to the most efficient or most 'mature' form of the skill (Roberton, 1978; Kelly *et al.*, 1989, 1990). Although 'mature and 'immature' are terms now less popular with researchers, they are included in this discussion because they were the original terminology used in this work. Currently, the preference in the literature is for the term 'efficiency' rather than notions of generalized maturity. Both TBC and CA methods provide meaningful data for assessing motor skill performance; however, as already discussed, the constructs underpinning the data gathered differ.

An advantage of using the TBC approach is that it provides detail by positioning performance along a continuum from inefficient to efficient performance. A disadvantage of this approach centres on inconsistencies in implementation by the researcher. The major difficulty lies in identifying elements of the performance that can be discretely found in one stage over another and in establishing consistency for each stage for all parts of the body. Roberton (1978) identified the varied nature of progression relevant to TBC measures when she reported that not all segments of the body moved to a new 'phase of development' at the same rate for each motor skill. It was possible for components of body movement to be at different levels of efficient performance at the same time.

An advantage of the CA is that it is relatively easy to implement because the *preparatory*, *contact* and *follow-through* phases associated with it provide a practical means of assessing the performance of a skill, and because the assessment instrument mirrors the order in which the performance occurs. This is helpful in the coding of process performance data. The original use of the instruments associated with the CA rated various levels of performance for each part of the body. In more recent applications, however, the CA has been used to identify the most efficient, or highest, level of performance in the assessment of children in Michigan (Kelly *et al.*, 1989, 1990) and in Australia (Walkley *et al.*, 1993; Booth *et al.*, 1997). One disadvantage associated with this application of the CA is that children are either assessed at the 'mastery' standard, or deemed to have 'failed'. Mastery is when all components are evident in the majority of trials (Kelly *et al.*, 1990; Walkley *et al.*, 1993). This approach has resulted in information being provided for only a minority of performers who are at the 'most efficient' level. Booth *et al.* (1997, 1998) partially addressed this shortcoming by reporting in their assessments another criteria, the 'near mastery' standard of performance. The near mastery standard was defined as that achieved by those who mastered all but one component of the skill, whereas 'mastery' was reached by those who performed all criteria at the most efficient level (Walkley *et al.*, 1993; Booth *et al.*, 1997). This application of the Component Approach has been referred to as a 'ceiling type of instrument' (Miller, 2004, p. 2).

The need for an instrument that can combine the advantages, and minimise the disadvantages, of both types of assessment is compelling. The construction of an instrument that is as easy to implement as the Component Approach, yet includes the type of in-depth information about levels of efficiency that the Total Body Configuration offers, is a prerequisite to the provision of meaningful feedback about motor skill performance for all teachers and their students. A central consideration, however, is how to establish and assure the validity of such a combined process instrument? Put another way, would the instrument measure what it is intended to measure, and because it aims to amalgamate elements of two different forms of process instruments, will it still preserve the integrity required to assess the 'varying levels of efficiency' of children's motor skill performance?

To this end, a composite or 'amalgamated' component instrument was constructed and named the Miller Amalgamated Striking Instrument (MASI). To investigate the validity of the MASI, the Rasch Model of Latent Trait Scaling was employed. Rasch analysis was used to provide a method of ascertaining the degree to which the MASI validly measured the varying levels of efficiency of striking inherent in children's performance of the two-handed sidearm tee-ball strike. Further, it was also of interest to develop an instrument that was capable of measuring the performance of a skill and investigate its properties using a 'partial credit form of development'. If the data collected fit the model satisfactorily, then the relationship between process and product scores could be pursued through the use of the MASI.

In summary, this paper is concerned with reporting the application of the Rasch model to both instrument construction and the exploration of the relationship between process and product measures related to the two-handed sidearm strike. As the specific application of Rasch to the MASI has been detailed previously (Miller, 2001, 2004), the emphasis for this paper is on exploring the relationship between process and product measures of the efficiency of motor performance.

Method

Participants

One hundred and sixty-one children ranging from six to ten years of age were recruited from a rural public primary school in New South Wales, Australia. The students were included based on parental and student permission. The students included 75 boys and 86 girls. More specifically, in the 6 to 7 year age range there were 34 boys and 31 girls and in the 9 to 10 age range there were 41 boys and 55 girls. The children selected came from a wide range of ethnic backgrounds, as many of their parents were international students at a nearby university. In addition, approximately 5% of the students in the sample identified as being of Aboriginal and Torres Strait Islander descent. The students also represented a diverse range of socio-economic status groups.

Procedures

Data were collected in the playground of the school providing an 'ecologically valid environment'. This addressed the contextual issue of collecting data in a meaningful environment for the students, such that the results of the study could reasonably be applied back into similar learning environments. Children were withdrawn from class three at a time and introduced to the task of tee-ball batting. After adjusting the tee-ball stand to the waist height of the performer, and using a lightweight nerf-style bat,[1] each child was asked to 'hit the ball as far into the batting V as possible' (refer to Figure 1). Following three practice trials, performances of six trials were recorded. The participants were filmed for later coding of the process data. The product data consisted of a 'distance weighted for accuracy' score.

Instruments

Two instruments were employed. The first was the Miller Amalgamated Striking Instrument for the two-handed sidearm strike (Table 1). The second was the batting V (Figure 1).

MASI. The amalgamated instrument was compiled by selecting relevant measures from existing assessments related to the sidearm strike. The process instrument described in Table 1 was comprised of a number of critical components of the strike. These were chosen from phases or stages of development that represented elements of either the TBC or the CA. There were 10 components, each comprising three levels of efficiency. In some instances the category levels emerged deductively from the data and these were noted as 'category needed'.

Batting V. The batting V was defined by the placement of the ball in relation to the goal of the task. It was designed so it could be replicated in any active field setting with distance markers placed every five metres from the striking area to a maximum of 80 metres. As indicated in Figure 1, the product scores were determined in relation to the tape measure placed down the centre of the striking zone. The apex of the batting V

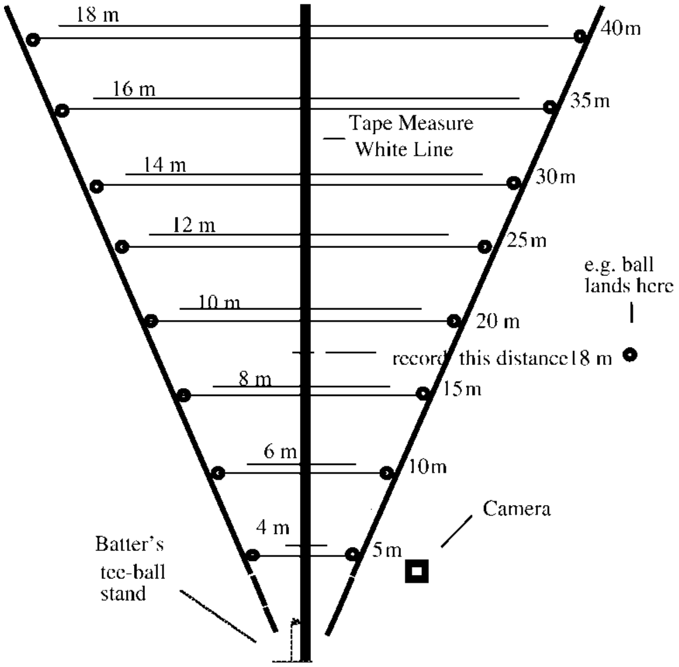

Figure 1. The batting V

was set at zero on the tape measure, that was placed under the tee-ball stand. Regardless of the ball landing within the batting V, the reading was taken directly from the central position on the tape. The distance measure for the execution of the two-handed sidearm strike, then, was not only an outcome of product in terms of how far the ball was hit, but it also reflected accuracy. This approach, in practice, provided a negative weighting for inaccurate or divergent striking from the batting V or central tape measure. A consistent environment was provided for the students by placing the batting V in the same location in the playground on each day of data collection. In terms of ecological task analysis (ETA), the goal of the task for the participants was to 'hit the ball as far into the batting V as possible'.

The ETA framework was adopted as it generally states that the movement form in terms of performance outcomes is the result of: dynamic interaction between the task goal, conditions, environmental situations, and the capabilities and the intent of the performer (Newell, 1986; Davis & Burton, 1991; Bouffard *et al.*, 1998). The ETA provided a multidimensional framework from which to explore motor skill performances and allows for consideration to be given to a wide range of factors or variables that were relevant to a broader investigation (Miller, 2001).

Movement analysis

In the case of the process measures, these were determined by filming the students' performances and later coding them using the MASI. In particular, the process

Table 1. Amalgamated process codes for the two-handed sidearm strike and their sources—Miller Amalgamated Striking Instrument (MASI)

Component number and description	Source of component level
Component 1 Preparatory Phase: Bat Position	
0. bat on shoulder	S&H S1 (TBC)
1. bat at tee	Category needed
2. bat held behind shoulder	Walkley (CA), S&H S4 (TBC)
Component 2 Preparatory Phase: Leg Position	
0. legs straight	Payne IS, S&H S1(TBC)
1. knees flexed & weight transfer	Walkley (CA)
2. weight on back foot & step toward target	Walkley (CA), Payne ES (TBC)
Component 3 Preparatory Phase: Body	
0. trunk faces target	Payne IS, S&H S1 (TBC)
1. trunk 46 degrees to target	category needed
2. body side on to target	Walkley, WA, Ulrich (CA)
Component 4 Contact Phase: Head	
0. eyes not following ball during strike	Category needed
1. eyes partially follow the ball	Category needed
2. eyes fixed on the ball throughout strike	Walkley, WA (CA)
Component 5 Contact Phase: Backswing	
0. $<$ 180 degrees	Payne IS (TBC)
1. 180 degrees	Category needed
2. 180–240 degrees	S&H S4, Payne ES (TBC)
Component 6 Contact Phase: Arm motion	
0. Up/Down motion	Payne IS, S&H S2 (TBC)
1. Horizontal arms bent	S&H S3 (TBC)
2. Horizontal arms straight	Payne IS (TBC)
Component 7 Preparatory Phase: Grip	
0. Dominant hand below non-dominant	
1. Hands apart with dominant hand above	
2. Dominant hand above non-dominant	WA, Ulrich (CA)
Component 8 Contact Phase: Ball contact	
0. no contact with ball	
1. tops or bottoms ball	
2. hits through the ball	WA (CA)
Component 9 Follow Through Phase: Arm motion	
0. up motion homolateral	S&H S1 (TBC)
1. up motion across body	S&H S2 (TBC)
2. horizontal motion across body	S&H S4 (TBC), Walkley, WA (CA)

(*Table continued*)

Table 1. Continued

Component number and description	Source of component level
Component 10 Follow Through Phase: Hip–shoulder rotation	
0. no trunk rotation	Payne IS, S&H S1 (TBC)
1. either hip or shoulder rotation	S&H S2 & S3 (TBC)
2. marked sequential hip-to-shoulder rotation	WA, Walkley (CA), S&H S4 (TBC)

Key:
Payne = Payne & Isaacs (1995). IS = Initial Stage; ES = Elementary Stage; and MS = Mature Stage.
S&H = Seefeldt & Haubenstricker (1982). S1 = Stage One; S2 = Stage Two; S3 = Stage Three; and S4 = Stage Four.
WA = Western Australia Fundamental Motor Skill Manual.
Walkley = Walkley *et al.* (1993).
Ulrich = TGMD-2 (Ulrich, 2000).
CA = Component Approach.
TBC = Total Body Configuration.

data involved identifying one of three levels of efficiency for each student on each of the 10 components of the tee-ball strike for six trials. The participants' performances were assessed from the video images recorded by a camera placed at a 45-degree angle as shown in Figure 1. The first author completed all data coding. The coding sessions were limited to a maximum of two hours per day, to avoid fatigue and spurious results. Intra-rater checks on 20 participants were conducted by an experienced physical education teacher and yielded a .90 index of reliability, which is within the acceptable levels of reliability (Anastasi, 1988).

Data analysis

The process data were analysed using the Rasch model, as represented in the Australian Council for Education Research's *Quest* software (Adams & Khoo, 1993, p. 1). Rasch Latent Trait Scaling Technique is based on item response theory (IRT). The rationale for the employment of the Rasch statistical functions centres on the fact that '*Quest* can be used to construct and validate variables based on both dichotomous and polychotomous observations' (Adams & Khoo, 1993, p. 1). Furthermore:

> [with] the Rasch model, (or other IRT models), once variables representing a single specified construct have been identified, and a specific population of examinees has been targeted, the measurement of a subject's ability is independent of the set of items that were administered, and item difficulty is independent of the set of persons used to calibrate the item. (Snyder & Sheehan, 1992, p. 88)

The *Quest* software provides an analysis using a partial credit form of the Rasch model that is appropriate for polychotomously scored data. As there were three levels of efficiency, the data were coded as one of three for each of the 10 components, and the partial credit form was employed.

Because the components of the instrument were gleaned from both the Total Body Configuration and the Component Approach to measuring the strike, the new instrument needed to be confirmed in terms of whether it measured what it purported to measure. In this regard, the Rasch model was particularly useful as it provides statistical evidence of construct validity in terms of item fit indices. Ultimately, case estimates that now represent process measures in the interval form can be compared to product measures of the two-handed sidearm tee-ball strike in correlational analysis.

Results

The Rasch model estimates the fit of the items (components) to the underlying construct (levels of efficiency in the skill of striking). In addition, Rasch also estimates the difficulty of each component and levels within components, thus identifying items that are the most difficult and those that are the easiest. With acceptable levels of fit between the Rasch model and the data, case estimates can be used in subsequent regression analyses.

In establishing the validity of the MASI, consideration was given to both face and construct validity. In the case of face validity, it was important to have evidence that supports the assumption that the 10 components fit an underlying, unidimensional construct (Hambleton *et al.*, 1991). In practice, this means that a particular version of a strike could be described in terms of component skills that ‘measure’ different but related aspects of the performance.

Construct validity is concerned with establishing whether the three levels within each of the components fit a hierarchical order of performance. The preference for this study was to consider the measure for each component in terms of the ‘relative levels of efficiency’ shown by the students.

Rasch fit statistics for the MASI

The following results report the suitability of the 10 components in measuring ‘levels of efficiency’. The Infit Mean Squares for item estimates were close to 1 (1.01), indicating a good fit of data to the model. The reliability of the estimates for both items and cases is the proportion of the observed estimate variance that is considered true (Adams & Khoo, 1993, p. 24). The item reliability of .97 for item estimates indicated there was a high level of separation between the items. The Infit Mean Square for case estimates was .99, and the case estimate reliability was close to 1 (.81), indicating good separation of cases. The internal consistency index of .86 also indicated that there was a good fit of data to the model. All fit statistics exceeded threshold levels for acceptance. These Rasch results confirmed the MASI was valid in terms of its fit to a construct, and as such, the case estimates could be used for subsequent comparison to product scores. These fit statistics present a macro-view of the fit of the MASI, and the individual components are now detailed in terms of their fit to the model. Additional exploration of the step difficulties is not included here; however, evidence of the hierarchical nature of the three levels of efficiency for each of the 10 components of the MASI has been presented previously (Miller, 2001, 2004).

Unidimensionality of construct

The *Quest* implementation of the Rasch model also produces an item Infit Mean Square map that identifies clearly those items (or components) with Infit Mean Square values that fall outside the interval of 0.7 to 1.3. This is the interval suggested by Wright and Masters (1982) within which components should fall if they are collectively to represent a single underlying construct. Figure 2 contains item Infit Mean Square Maps for the MASI.

Figure 2 provides evidence of the fit of the items to the underlying construct. Items with an Infit Mean Square value of greater than 1.3 indicate items that are implicated in too many reversal patterns suggesting that they may not be elements of the same construct as the better fitting item. Components One and Eight have Infit Mean Square values slightly exceeding 1.30.

Possible reasons for these components either underfitting or being involved in reversals may reside in the following. Component One is derived from instruments where the most efficient level of performance required that the bat be held up off the shoulder and for the ball to be pitched to the performer. In this study, the ball was hit from a batting tee and, consequently, the ball was stationary. To code the levels of efficiency for Component One, the bat position held off the shoulder was coded as most efficient (2); when the bat was lined up at the ball on the tee it was coded at the next level of efficiency (1); and when the bat rested on the shoulder it was coded as the least efficient level (0).

Component One is modified from an instrument that involved different conditions from those used for this study. Consequently, minor misfit may be due to applying criteria to the same skill, but performed in a changed environment, as is the case in this study.

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INFIT
 MNSQ        .53       .63       .77      1.00      1.30      1.60
--------------+---------+---------+---------+---------+---------+---
     item 1                        .         |         .  *
     item 2                      * .         |         .
     item 3                        .         |*        .
     item 4                        .        *|         .
     item 5                        .         |        *.
     item 6                      * .         |         .
     item 7                        .         |       * .
     item 8                        .         |         .    *
     item 9                  *     .         |         .
     item 10       *               .         |         .
===================================================================
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Figure 2. Rasch item fit for 10 components of the two-handed sidearm strike

Component Eight refers to hitting the ball, which also has an Infit Mean Square greater than 1.3. Hitting through the centre of the ball was coded as being the most efficient (2); topping the ball or underhitting the ball was coded at the next level of efficiency (1); and an airswing was coded as the least efficient (0). Although integral to the execution of the propulsion of the ball for the skill of striking (Broer, 1973), this component may underfit the model because it may be more closely associated with the 'outcome' measure and, as a consequence, could be considered to be aligned with the concept of 'product' rather than a measure of process. Alternatively, it is possible that the actual connection with the ball is a critical element, and, hence, it can be equally argued to be a process component of the skill of striking. This component was not found in process instruments prior to the Western Australian Instrument (1997) and the revised Test of Gross Motor Development (TGMD-2) (Ulrich, 2000). In the MASI it was a contentious inclusion (Miller, 2004).

If the Mean Square value is less than 0.7 it suggests the item does not discriminate between persons with similar levels of ability, that is, persons with different ability levels get the same score on an item. Such an occurrence involves the very easy items, or it may indicate that it is too easy or too difficult. This is the case for Components Nine and Ten. Component Nine is concerned with the plane in which the bat travels after the ball is struck and Component Ten is the degree of sequential hip-to-shoulder rotation.

Component Nine refers to the bat position during the follow through. When the bat followed through across the body, it was coded as the most efficient (2); when the bat travelled upward across the body it was coded at the next level of efficiency (1); and when the bat travelled up on the homolateral side of the body this was coded as the least efficient (0). Component Nine may underfit the model as the degree of upswing or across the body swing was difficult to assess at the fine-grained level from the video evidence. For example, the rule of coding employed was that the bat had to be travelling in an angle parallel to the ground to be coded as the most efficient (coded 2), and this became difficult when the ball was struck with a parallel bat pattern, and then the bat would travel upward away from the ground in the final follow-through phase of the strike. Consequently, this was a component more often coded closer to 1 than 2. These situations requiring decisions of when to differentiate between the levels of efficiency represented difficult and challenging issues for the study.

Component Ten is the most underfitting of all items. Very few of the participants were coded as having sequential hip-to-shoulder rotation. This is a difficult component to exhibit, as noted by Walkley *et al.* (1993). Sequential hip-to-shoulder rotation was the last component to be mastered by primary school-aged children (aged 9) as evidenced by Walkley, employing a larger sample (1182 participants), with a wider age range of 8 to 14 years, (J. Walkley, personal communication, 1996). More recently, Booth *et al.* (1997, p. 61) reported fewer than 10% of boys and 3% of girls in year 4 (approximately 10 years of age) performed sequential hip-to-shoulder rotation. With 5518 participants, older children of year 10 (16 years of age), 38% of boys and 10% of girls mastered this component of the strike. In comparing our study with the larger New South Wales survey conducted by Booth *et al.* (1997) using an age range of approximately 10 to 16 year olds, it is understandable that this component proved to be too difficult for the predominantly younger participants in this study.

Although the fit of Component Eight is of some concern, overall item and case fit statistics are substantially better than the threshold usually considered acceptable, as are the reliability and consistency indices. It is defensible, therefore, to use the case ability estimates as measures of subject process performance in any subsequent multivariate and correlational analyses.

The process scores for all 161 students were the case estimates for each of the six trials. The product scores were the 'distance weighted for accuracy' scores of how far the ball travelled measured back to the centre tape. The relationship of distance with process scores in the form of correlation coefficients is presented in Table 2.

Examination of Table 2 indicates the correlations between process and product measures for each trial range from .51 (trial 6) to .66 (trial 2), all of which are significant at $p < .0001$ level. The correlations between process and product scores for each of the six trials indicate that not only is there a significant relationship between these measures, but that there is consistency for each trial, that is, there is no one trial that is markedly different than the others. This evidence provides a basis for expectations that the relationship between measures that represent process and product performance is consistent.

Conclusion

The use of the MASI as an instrument that measures the 'levels of efficiency' of the two-handed sidearm strike provided a sensitive and informative assessment of process efficiency. The Rasch model provided a technique for validation of the instrument and for transforming ordinal observations to interval measurements. This allowed for meaningful comparisons between process and product data to be made. The significant relationship between process and product for this study represents an extension to the current focus on measurement of fundamental motor skills. Replication of the methods undertaken in this research is recommended for application to other fundamental motor skills.

The application of the Rasch model to the MASI allowed for comparing process observations to the product scores. The significant correlation between process and

Table 2. Summary of correlations between distance and process scores, within trials (n = 161)

Relationship of distance and process scores on:	Pearson's r	p value
Trial 1	0.572758	$< .0001$
Trial 2	0.659598	$< .0001$
Trial 3	0.612973	$< .0001$
Trial 4	0.625471	$< .0001$
Trial 5	0.620184	$< .0001$
Trial 6	0.505815	$< .0001$

product is new for comparing the same type of data. However, comparisons between process (ordinal) and product (interval) measures of the same performance have been reported previously (Roberton & Konczak, 2001). Similar findings for the distance the ball travelled and process measures of the overarm throw have been previously reported by Miller and Dickson (1999). Rasch was applied to children's performances of motor skills for varying forms of the strike (Sprinkle *et al.*, 1997) and the overarm throw (Miller & Dickson, 1999).

The Rasch model has been applied in related research of motor competence (Zhu & Kurz, 1994) and gross motor skills (Zhu & Cole, 1996). More recently, Hands and Larkin (2001) applied the Rasch model to confirm a range of fundamental motor skills to measure the construct of 'motor ability' of primary school-aged children. The method of construction and exploration of the MASI with the use of Rasch analysis provides another aspect to motor ability and gross motor skill exploration. The findings of this research have both theoretical and practical implications.

Theoretical implications

The theoretical implications of this study rest with the use of the Rasch model to transform ordinal observations to interval measurements that can be subsequently used in multivariate analyses (Sprinkle *et al.*, 1997; Miller & Dickson, 1999; Miller, 2001, 2004). The Miller Amalgamated Striking Instrument is an advance for the more fine-grained assessment of process performance. A more in-depth approach has been formulated and is a tool in the analysis of movement as it is practical to use and can be assessed for construct validity. The Rasch model was central to this validation process.

Practical implications

There are three practical implications of this study. The first is that there is the potential to measure the movement process for the striking skill at a more fine-grained level. The second is that there is a relationship between two forms of measurement of a fundamental skill. This finding confirms that there is an efficient form of the strike and if used, a corresponding increase in distance (and accuracy) can be reasonably predicted and expected. Conversely, as one moves along the continuum from most to least efficient performance, there is a corresponding decrease in the goal-directed distance the ball travels. The third implication relates to the inferences that may be made from one form of assessment to another. Process measurements are very time-consuming and difficult for many practitioners to implement due to the methods required for the collection of data, the coding of the movement and the concluding assessment of development (Orlich, 2002). It is prudent at this point to emphasise that the correlations reported in this research relate to an *association* between the two dependent variables of product and process and do not infer a 'cause and effect' between the two (Sanders, 1990). Previously, the practitioner may have had difficulty with assessing the developmental levels of his/her students, but it is now possible to construct a process instrument and test its potential validity with the confirmation of fit statistics from the application of the Rasch model. With caution, product measures may assist teachers with inferences of related efficient performance for their students.

Additionally, in exploring the unaccounted variance in the correlations between product and process measures, the ecological task analysis may provide a relevant basis of further exploration. The ETA factors include: interpretation of the task goal, unpredictable conditions of the study, complexity of the environmental situations, and the intent and capability of the performer. For example, arm speed may be one factor associated with the 'capability' or the coordination of the performer (Miller, 2006).

The procedures described in this paper can be replicated with other fundamental motor skills. Overall, this study reports on an important methodology in the measurement and interpretation of the process and product performances of a fundamental motor skill, specifically, the two-handed sidearm strike.

Note

1. A nerf-style bat is a well-recognised light-weight foam coated bat with a plastic core for strength. They are used for children as they are lighter and less dangerous than wood or metal.

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