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A holistic measurement model of movement competency in children

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Abstract
Different countries have different methods for assessing movement competence in children; however, it is unclear whether the test batteries that are used measure the same aspects of movement competence. The aim of this paper was to (1) investigate whether the Test of Gross Motor Development (TGMD-2) and Körperkoordinations Test für Kinder (KTK) measure the same aspects of children's movement competence and (2) examine the factorial structure of the TGMD-2 and KTK in a sample of Australian children. A total of 158 children participated (*M* age = 9.5; *SD* = 2.2). First, confirmatory factor analysis examined the independent factorial structure of the KTK and TGMD-2. Second, it was investigated whether locomotor, object control and body coordination loaded on the latent variable Movement Competency. Confirmatory factor analysis indicated an adequate fit for both the KTK and TGMD-2. An adequate fit was also achieved for the final model. In this model, locomotor (r = .86), object control (r = .71) and body coordination (r = .52) loaded on movement competence. Findings support our hypothesis that the TGMD-2 and KTK measure discrete aspects of movement competence. Future researchers and practitioners should consider using a wider range of test batteries to assess movement competence.

Keywords: *movement competence, fundamental movement skills, body coordination*

Introduction

Movement competency is an integral component of physical literacy, which has been defined as having the movement competence, knowledge, skills and attitudes to live a healthy life and also is an advocate for others to do the same (Whitehead, 2007). Having movement skill competence is important as it has been shown to be an important predictor of regular physical activity and health-related fitness in children (Cattuzzo et al., 2014; Lubans, Morgan, Cliff, Barnett, & Okely, 2010). It is suggested that movement competency is a fundamental aspect of childhood development with a lasting influence on aspects of health across the lifespan (Ahnert, Schneider, & Bös, 2009; Robinson et al., in press; Stodden et al., 2008).

A limitation in the current definition of physical literacy is ambiguity about what constitutes movement competence. However, this has not stopped physical literacy becoming an important focus of physical education curricula (Mandigo, Francis, Lodewyk, & Lopez, 2009) and in the promotion of physical activity (Whitehead, 2001). For example, the physical education curricula of Australia (ACARA, 2011) and England (Department of Education, 2013) aim to promote lifelong participation in physical activity through the development of physical literacy, with a focus on developing movement competence in children and through the development of self and social awareness, self-regulation and responsible decision-making to foster overall personal well-being. The result being a physically educated person with the ability to use these skills in everyday life and developing a disposition towards purposeful physical activity being an integral part of daily living (Castelli, Centeio, Beighle, Carson, & Nicksic, 2014). However, in the effort to create physically literate children, it is important that the concept of movement competency is better understood and defined.

Gallahue, Ozmun, and Goodway (2012) classify movement competence within three distinct holistic categories: locomotion, object control and stability skills and state that there are typical developmental progressions between skills and also between the

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categories. They surmise that children need to master certain stability skills before they can progress onto locomotor skills and that children seem to form rudimentary stability and locomotor skills earlier than they develop object control skills (Gallahue et al., 2012). According to Whitehead, movement competency is multidimensional in nature, containing three interrelated constructs: simple movement capacities, combined movement capacities and complex movement capacities (Whitehead, 2010). Such a multidimensional conceptualisation of movement competence is common in the human movement literature. Dynamical Systems Theory and cognitive psychology both provide a multidimensional taxonomy of movement skills to describe movement competence, though they do offer differing hypotheses of how movement competency is developed (Burton, Miller, & Miller, 1998; Fleishman, 1975).

Overall, there is still a lack of consensus about what movement competence encompasses. An important reason for this disagreement is the variation in measurement methods (Giblin, Collins, & Button, 2014). For example, in North America, the Test of Gross Motor Development (TGMD) (Ulrich, 2000) has been a test battery of choice to examine children's movement competency. The TGMD is a process-oriented test battery that measures competency in a set of motor skills deemed essential for predicting participation in PA and sport. The motor skills are known as fundamental movement skills (FMS) and have been subdivided into two categories called locomotor and object control skills. Confirmatory factor analysis on an American sample has provided evidence for the proposed hierarchical structure of the TGMD-2, suggesting that the TGMD-2 provides a good evaluation of children's gross motor competency (Ulrich, 2000).

The Körperkoordinations Test für Kinder (KTK) has been developed in Germany to examine non-sport-specific gross body coordination in children. The KTK has been shown to have good reliability (test–retest reliability between .80 and .96) and factorial structure, where adequate predictive validity has been shown by its ability to distinguish between brain damaged and normal children (Kiphard & Schilling, 2007, 1974).

There is a growing body of evidence that assessment tools should not be used interchangeably. Fransen et al. (2014) compared the KTK and Bruininks-Oseretsky Test of Motor Proficiency (BOT-2; Bruininks & Bruininks, 2005) in primary school children and found only a moderate association between the two tests. These findings are similar to other convergent validity studies (Logan, Robinson, & Getchell, 2011; Smits-Engelsman, Henderson, & Michels, 1998). It is currently unclear whether the TGMD-2 and KTK are measuring the same or different aspects of children's movement competency. If the two test batteries measure different aspects of movement competence, this would suggest key information on a child's movement competency could be missed if only one test battery is used. So the first aim was to explore whether the two test batteries measure different aspects of movement competence. We hypothesise that movement competence includes both locomotor and object control competence and that this is distinct from body coordination. To date, no Australian studies have examined the factorial structure of the TGMD-2. Similarly, no studies examining the KTK, outside of Europe, have reported whether their proposed factorial structure is invariant across samples of different cultural backgrounds. A secondary aim of the present research was therefore to examine the factorial structure of both the TGMD-2 and KTK in a sample of Australian children.

Method

Participants

In total, 158 children aged 6–12 participated in the study (*M* age = 9.5; *SD* = 2.2), 86 (54%) were boys and 72 (46%) were girls. The study was approved by the University Ethics Committee and Victoria Department of Education and Early Childhood Development, and parental consent was obtained for all participants.

Test battery

The TGMD-2 (Ulrich, 2000) assesses proficiency in six locomotor skills (run, hop, slide, gallop, leap, horizontal jump) and six object control skills (striking a stationary ball, stationary dribble, catch, kick, overhand throw, underhand roll). Each participant completes all 12 skills of the TGMD-2 and is given one practice attempt and two assessment trials for each skill. For each skill, skill components are marked as "present" or "absent".

The KTK (Kiphard & Schilling, 2007) is an outcome-based assessment that consists of four non-sport-specific sub-tests that measure gross motor coordination. Reverse balancing requires participants to walk backwards along three different balance beams, with increasing levels of difficulty due to the width of the beams decreasing from 6 cm to 4.5 cm to 3 cm, respectively. Moving platforms requires participants to move laterally for 20 s across the floor using two wooden platforms. Participants step from one platform to the next platform, and then move the first platform to their side in the direction they are travelling and step on to it. Hopping for height requires participants to hop on one leg over an increasing number of 5 cm foam blocks to a maximum of 12 blocks. Participants have to begin hopping 1.5 m away from the foam blocks, hop up to and over the foam block and complete a further two hops for the trial to be deemed successful. The final task is continuous lateral jumping in which participants are required to complete as many sideways jumps as they can, with feet together, over a wooden slat in 15 s.

Training and reliability

A total of 10 Research Assistants (RAs) each received 6 h training in the administration of the TGMD-2 and KTK. At the end of this training period, the RAs administering the KTK assessment tool scores were compared and achieved 94% agreement reliability. Two of the RAs received an additional 3 h training on coding each of the 12 TGMD-2 skills.

These two RAs independently coded videos of 15 children who completed the 12 TGMD-2 skills. To determine the agreement between the two RAs, total scores for each subset (locomotive and object control) were first z-transformed. Next limits of agreement for each subset were calculated based on the mean difference between the two assessor's scores and the respective standard deviation of these differences (Bland & Altman, 1986; Nevill, 1996). The 95% limit above and below the mean for locomotor skills were – 0.7 to 0.7 and for object control skills 95% limit agreements were −0.6 to 0.6. The RAs' 95% confidence intervals are within one standard deviation (1.96) and contains zero, demonstrating that the two RAs have excellent inter-rater reliability.

Procedure

The assessments of TGMD-2 and KTK were carried out in a large sports hall. Groups of four participants rotated around five stations, each manned by two trained RAs, and the TGMD-2 stations were video recorded for subsequent coding. The four KTK assessments were divided into two stations, whereas the TGMD-2 was split into object control and locomotive skills.

Statistical analysis

Raw scores for each TGMD-2 skill and the four KTK tests were transformed onto the same scale through z-transformation. Following this, data was assessed for violation of the assumptions of normality and for outliers.

Confirmatory factor analysis was used to examine the factorial structure of the KTK and TGMD-2 using AMOS 22. First, a confirmatory factor analysis was conducted to examine whether the individual tests of the KTK served as a good indicator for the latent factor Body Coordination. Following this, two confirmatory factor analyses were conducted to assess the fit of the TGMD-2 skills into locomotor and object control latent factors, respectively. In the instance of an adequate fit, a fourth confirmatory factor analysis was conducted to examine the hierarchical nature of the TGMD-2 by testing whether locomotor and object control loaded on the higher order variable, FMS. If the fit was found to be inadequate, the model was respecified. Finally, if the fit was adequate, it was examined whether the empirical data fitted the hypothesised model in which both FMS and body coordination loaded on the latent variable Movement Competency.

Goodness of fit

Confirmatory factor analysis was conducted with the maximum likelihood method of estimation. In order to specify a model containing latent variables for all factors, error variance was set at zero. Residuals from the observed variables were allowed to co-vary within each specified factor, as indicated by corresponding arrows in path diagrams. Several goodness of fit measures were used to describe the models. In addition to the chi-square (χ^2) statistic, which is influenced by sample size (Ullman, 2006), the following fit indices were considered: Chi-square/degrees of freedom (χ^2/df); Comparative fit index (CFI) (Bentler, 1990); Root mean square error of approximation (RMSEA) (Browne & Cudeck, 1993); Standardised root mean residual (SRMR) (Bollen, 1989); and the P of close fit (PCLOSE) (Hu & Bentler, 1999).

The χ^2 statistic is a measure of overall fit of the model to the data, with a nonsignificant P-value ($P > .05$) indicating a good fit. Also, χ^2 divided by the degrees of freedom (χ^2/df) provides an indicator of fit with values of <2 considered adequate fit. Comparative fit index values of .90 or above indicate an adequate fit. Root mean square error of approximation values of .06 or lower and standardised root mean residuals values of .08 or lower indicate a close fit when these statistics are taken together (Kline, 2011). However, it should be noted that Vandenberg and Lance (2000) have suggested that cut-off values of .08 for root mean square error of approximation and .10 for standardised root mean residuals are acceptable lower bounds of good model fit (Vandenberg & Lance, 2000). Finally, the PCLOSE should be nonsignificant ($P > .05$) (Browne & Cudeck, 1992; Hooper, Coughlan, & Mullen, 2008).

Results

The Mardia (1970) test for multivariate kurtosis was undertaken (Mardia, 1970), following Kline's

Table I. Means and standard deviations for Anthropometric, TGMD-2 and KTK.

Age group	Variables	Boys	Girls
		Mean ± *SD*	**Mean ± *SD***
6–8 years	**N**	**24**	**21**
	Height (cm)	127.7 ± 6.1	124.4 ± 5.6
	Weight (kg)	27.5 ± 4.8	24.9 ± 3.3
	BMI (kg · m^{-2})	16.8 ± 2.3	16 ± 1.2
	Locomotive	32.9 ± 5.3	35.9 ± 4.7
	Object Control	34.2 ± 5.9	30.3 ± 4.7
	Body Coordination	128.9 ± 38.4	142.2 ± 35.7
8–10 years	**N**	**31**	**26**
	Height (cm)	136 ± 7.6	138.4 ± 8.1
	Weight (kg)	32.6 ± 6.8	34.7 ± 9.6
	BMI (kg · m^{-2})	17.5 ± 2.3	17.8 ± 3.2
	Locomotive	35.8 ± 3.8	34.1 ± 4.2
	Object Control	37.3 ± 4.6	35.0 ± 3.9
	Body Coordination	173.5 ± 43.9	176.2 ± 46.7
10–12 years	**N**	**31**	**25**
	Height (cm)	149.4 ± 8.7	152.5 ± 10.2
	Weight (kg)	43.2 ± 10.4	47.2 ± 11.2
	BMI (kg · m^{-2})	19.3 ± 4.1	20.1 ± 3.7
	Locomotive	36.4 ± 5.3	35.4 ± 4.3
	Object Control	41.3 ± 4.3	35.2 ± 4.7
	Body Coordination	209 ± 49.5	202.2 ± 42.5
Total	**N**	**86**	**72**
	Height (cm)	138.5 ± 11.7	139.2 ± 13.9
	Weight (kg)	35 ± 10.2	36.2 ± 12.5
	BMI (kg · m^{-2})	17.9 ± 3.2	18.1 ± 3.4
	Locomotive	35.2 ± 5.0	35.1 ± 4.4
	Object Control	37.9 ± 5.6	33.7 ± 4.9
	Body Coordination	173.8 ± 54.4	175.3 ± 48.1

Note: The means are reported as raw score values.

(2011) suggestion that critical ratio of >3 are of a concern (Kline, 2011). None of the models showed problematic levels of skewness or kurtosis. Mean scores and standard deviations are reported in Table I for all children on both test batteries.

Confirmatory factor analysis for the KTK

The confirmatory factor analysis for the KTK provided an adequate model fit (χ^2 (2df) = 1.49; P = .47; χ^2/df = .75; CFI = 1.00; SRMR = .01; RMSEA = .01; PCLOSE = .60). All four observed measures had a strong effect on the latent variable Body Coordination (see Figure 1).

Confirmatory factor analysis of the TGMD-2

The Confirmatory factor analysis for locomotive skills showed an adequate fit for the overall model (χ^2 (9df) = 9.21; P = .42; χ^2/df = 1.02; CFI = .99; SRMR = .05; RMSEA = .01; PCLOSE = .69). The initial confirmatory factor analysis for object control provided an inadequate fit (χ^2 (9) = 27.54; χ^2/df = 1.34; P = .001; CFI = .80; SRMR = .07; RMSEA = .11; PCLOSE = .02). The modification indices indicated that the error term for the observed variable *Throw* was related to the error term of the observed variable *Strike*. As such, the error terms for these variables were co-varied. The revised model for object control provided an adequate fit (χ^2 (8) = 10.13, P = .26; χ^2/df = 1.26; CFI = .98; SRMR = .04; RMSEA = .04; PCLOSE = .52).

FMS hierarchical model for the TGMD-2 (see Figure 2) showed an adequate fit (χ^2 (52) = 71.07; P = .04; χ^2/df = 1.36; CFI = .86; SRMR = .07; RMSEA = .05; PCLOSE = .52). In this model, object control had more effect (r = .67) than locomotor (r = .39) on overall fundamental movement skill. The catch was found to load very weakly onto object control (r = .08), though it did still contribute to the overall model fit (see Figure 2).

Movement competency structural model

The initial confirmatory factor analysis for the hypothesised movement competency model (see Figure 3) showed an improper solution caused by over specification of the TGMD-2 skills with two second-order factors (locomotor and object control) and the higher order factor FMS both explaining the TGMD-2 skills, therefore, creating an unstable fit. A

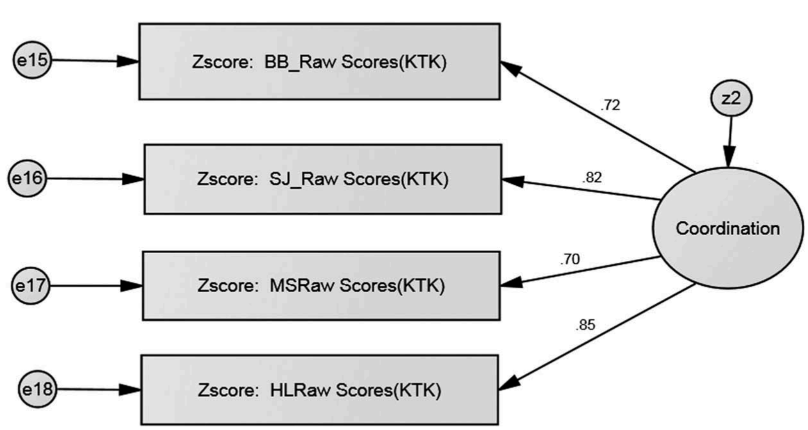

Figure 1. Confirmatory factor analysis for the Körperkoordinations Test für Kinder.

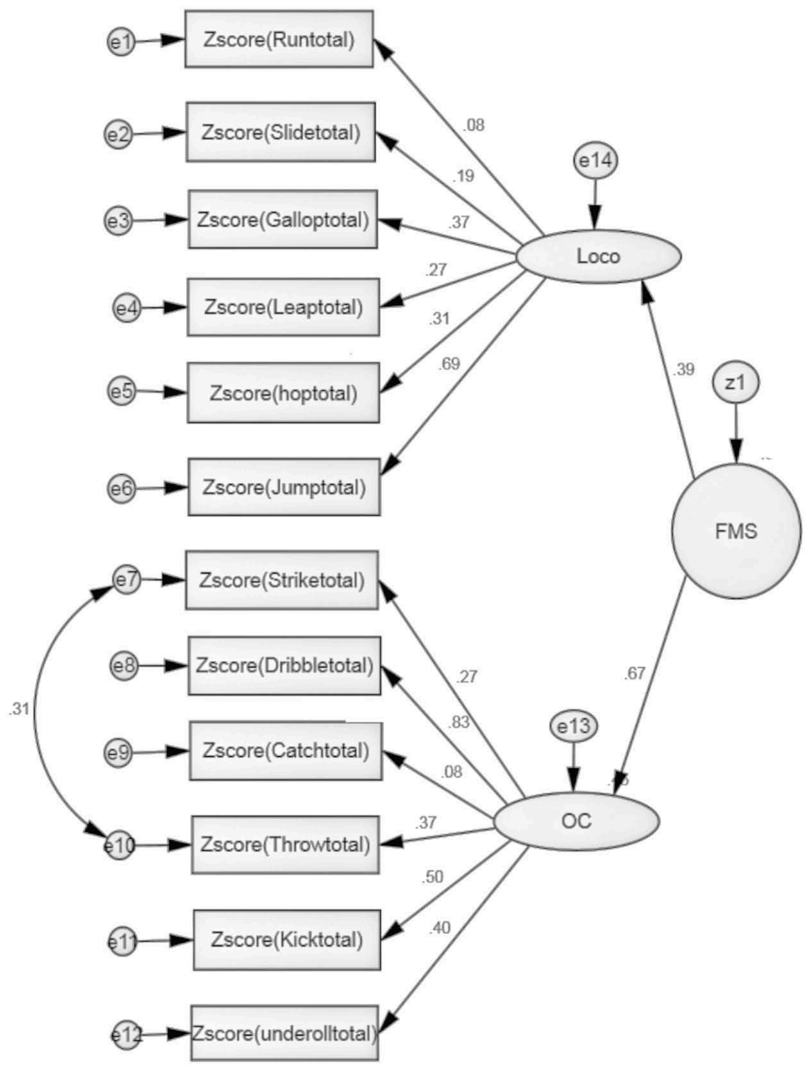

Figure 2. Fundamental movement skill hierarchical model for the test of gross motor development 2.

second confirmatory factor analysis for movement competence was carried out (see Figure 4). The FMS latent variable was dropped from the movement competency model to avoid over specification of the TGMD-2 skills. The three second-order latent variables, coordination, object control and locomotor, now loaded directly into movement competency. An adequate fit was achieved (χ^2 (102) = 155.40; P = .001; χ^2/df = 1.52; CFI = .89; SRMR = .09; RMSEA = .06; PCLOSE = .24). In this model, locomotor (r = .86), object control (r = .71) and body coordination (r = .52) loaded on movement competence. The catch also now provided a higher loading on object control.

Discussion

This study examined the relationship between the TGMD-2 and the KTK and tested its factorial structure in a sample of Australian children. Both the TGMD-2 and KTK, when examined independently, showed good model fit in our sample. In addition, findings support our hypothesis that the TGMD-2 and KTK measure discrete aspects of the movement competency construct.

The proposed movement competency model in this study suggests that both object control and locomotor skills of the TGMD-2 and the body coordination skills of the KTK are related to the overall concept of movement competency. The final model provided an adequate fit and there did not appear to be any redundancies. An important implication of this finding is that, if used individually, these commonly used assessment batteries provide only a limited view of the overall movement competence of children. To obtain a more holistic picture of the movement competencies of children, future research should examine both FMS and body coordination skills.

The KTK is a product assessment test battery with each skill outcome being assessed quantitatively (i.e., number of jumps completed in a specific time). In contrast the TGMD-2 provides a qualitative assessment of skill execution (i.e., whether a child does or

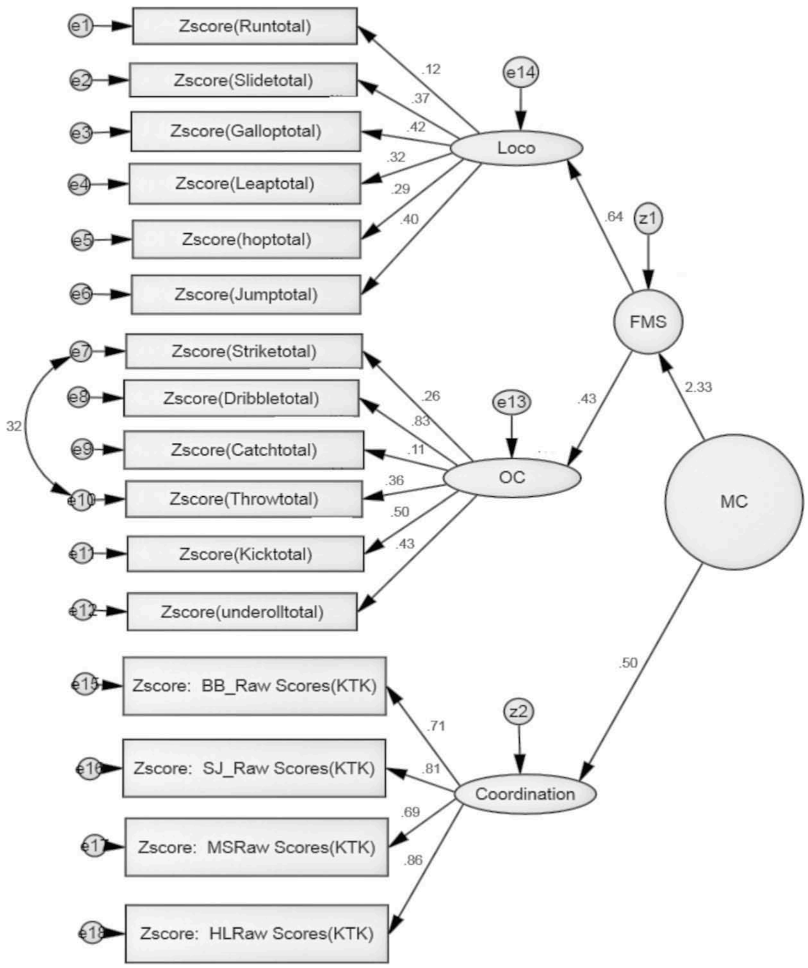

Figure 3. Movement competency model.

does not demonstrate specific component). Although the TGMD-2 does not measure the outcome of a given movement sequence, it is implicitly assumed that the underlying process is associated with successful outcomes. Indeed, empirical evidence suggests strong associations between skill process and skill outcomes. Miller, Vine, and Larkin (2007) investigated the correlation between process and product scores of a two-handed sidearm strike in children. A significant relationship was found between the product and process scores for each trial (correlations ranging from r = .51 to .66) demonstrating a consistent association between technique and outcome. Roberton and Konczak (2001) compared the product and process of the overarm throw and reported a significant correlation between quantitative (ball velocity) and quality of performance in primary school children (Roberton & Konczak, 2001). Both these studies provide evidence for a positive relationship between process and product FMS measures.

The separation of product and process measurement of movement competence has been questioned (Stodden et al., 2008). The choice of a process or product test battery, in this respect, might be indicative of theoretical beliefs on how movement competence is formulated. For example, in general terms, an ecological dynamics theorist may favour a process-orientated approach, whereas a cognitive psychologist may adopt a product approach. Our analysis suggests that both assessment strategies provide a useful assessment of movement competence and that both strategies should be used concurrently to obtain a more holistic assessment of the movement competence of children.

Two recent systematic reviews and meta-analyses have provided evidence that FMS interventions can be successful in motor skill development in children (Logan, Robinson, Wilson, & Lucas, 2012; Morgan et al., 2013). These interventions only focused on aspects of FMS development rather than development of FMS *and* body coordination. The results of the present study and work by Ericsson (2008) suggest that children's movement competency encompasses a number of additional components besides FMS and that interventions based solely on the development of FMS might not provide adequate development of body coordination, resulting in a lack of overall movement competence in the long-term.

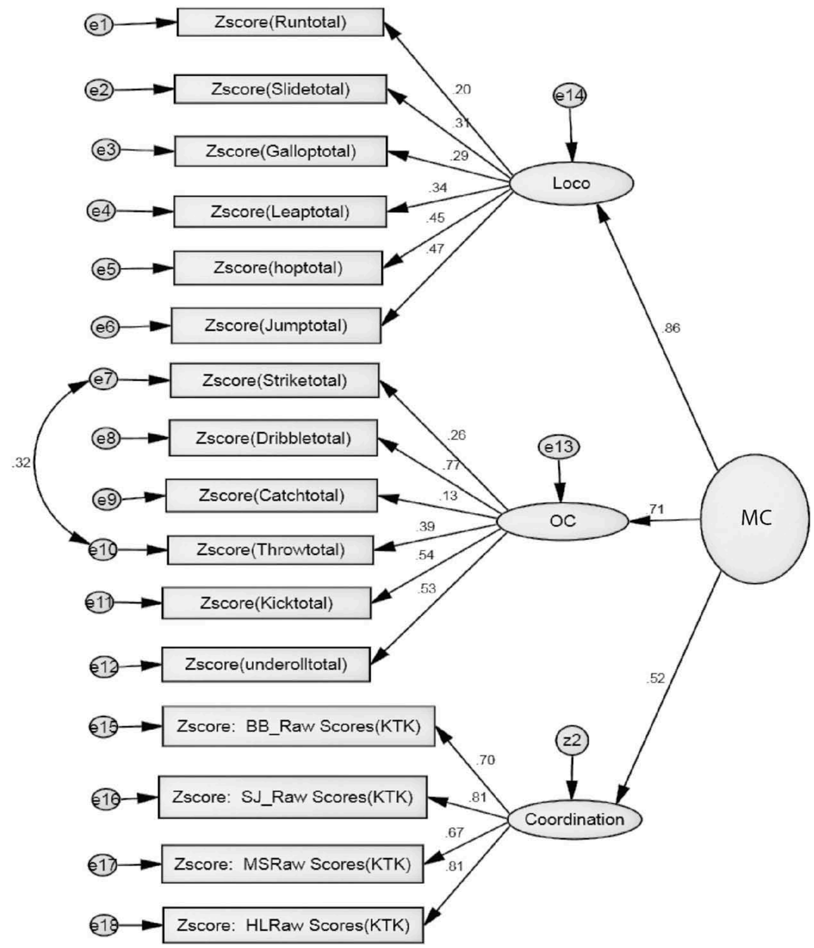

Figure 4. Final model of movement competence.

Our proposed movement competence model suggests that for children to be truly competent, they should participate in a wide range of activities. This is supported by evidence demonstrating that elite athletes do not specialise in their specific sport from an early age but participate in a wide range of activities throughout childhood and specialise when they are older (Côté & Fraser-Thomas, 2007). To this extent, children should be encouraged and given the opportunity by parents, schools and clubs to take part in task-oriented body coordination movement activities, which focus on moving and controlling the body in gravity defying ways to encourage the development of movement fluency, rhythm, timing and body strength. Suitable examples of such activities would be gymnastics, dance and martial arts. Activities such as these should be experienced alongside learning key object control and locomotive skills, learnt through deliberate play (Côté & Fraser-Thomas, 2008) and traditional sports. Together they will promote a strong foundation in overall movement competence.

Our results highlight that movement competence is a multidimensional concept and may not be recorded adequately by one test battery. As such, this model may still fail to capture all aspects of children's movement competence. In turn, this results in current interventions typically only being designed to address select aspects of movement competence. In addition, the movement competence model presented in the present study needs to be tested in larger samples of children across different countries to demonstrate its generalisability.

In conclusion, the results of the present study provide support for the factorial structure of the TGMD-2 and KTK in a sample of Australian children. In addition, movement competence consist of both FMS (process) and body coordination (product) activities. As such, this study suggests that future studies and interventions should consider using testing batteries which provide a more holistic way of assessing movement competency in children.

Disclosure statement

No potential conflict of interest was reported by the authors.

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