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Associations of object control motor skill proficiency, game play competence, physical activity and cardiorespiratory fitness among primary school children

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The authors declare that there is no conflict of interest.

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This study investigated if object control relates to children's game play competence, and examined these competencies as correlates of physical activity and cardiorespiratory fitness. Game play (Game Performance Assessment Instrument), object control (The Test Gross Motor Development-3), moderate-to-vigorous physical activity (Accelerometry), and cardiorespiratory fitness (20-metre shuttle run) assessments were completed for 107 children (57% Female, 43% Male) aged 9-12 years (M 10.53, SD 0.65). Two-level regression of object control on game play competence, and object control and game play competence on physical activity and cardiorespiratory fitness assessed associations. Object control competence was positively associated with game play competence (Std. B = 0.25, t (104.77) = 2.38, p = 0.001). Game play competence (Std. B = 0.33, t (99.81) = 5.21, p < 0.000) was more strongly associated with moderate-to-vigorous physical activity than object control competence (Std. B = 0.20, t (106.93) = 2.96, p = 0.003). Likewise, game competence (Std. B = 0.39, t (104.41) = 4.36, p < 0.000) was more strongly associated with cardiorespiratory fitness than object control competence (Std. B = 0.22, t (106.69) = 2.63, p = 0.002). Object control and game competence are both important as correlates of physical activity and cardiorespiratory fitness in children.

Keywords: Manipulative skills; Physical fitness; Movement skills; Motor development; Game play; Sports performance

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Introduction

Physical inactivity is a global problem (Hallal et al., 2012). Efforts to improve health related fitness and physical activity levels in children have focused on the improvement of an individual's motor skill competence, and perception of physical competence to enhance motivation to participate (Robinson et al., 2015; Stodden et al., 2008a). This dynamic association model of motor development is supported by the positive relationship between fundamental movement skill competence and physical activity levels (Barnett, Morgan, Van Beurden, Ball, & Lubans, 2011; Barnett, Van Beurden, Morgan, Brooks, & Beard, 2009; Lubans, Morgan, Cliff, Barnett, & Okely, 2010), with object control competence appearing to be a stronger predictor of physical activity than locomotor competence among primary school aged children (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2014) and adolescents (Barnett et al., 2009).

Middle childhood (5 – 12 years) is seen as important in creating positive or negative physical activity trajectories (Robinson et al., 2015; Stodden et al., 2008b) due to the hypothetical proficiency barrier (Seefeldt, 1980). During this period, children engage in increasingly complex team based activities during physical education, with these activities also popular during non-curriculum times (Pellegrini, Blatchford, Kato, & Baines, 2004). Team sport activities are highly active, but require high levels of object control competency to participate. It is possible that the more skilled children dominate these games, increasing their activity levels, physical fitness levels, and reinforcing the proficiency divide between low and high skilled children (Cohen et al., 2014).

When considering team sports activities, the proficiency barrier in middle childhood may not be isolated to the execution of technical (motor) skills, but also the development of perceptual-cognitive skills concerned with obtaining and using information present within increasingly complex game environments. These skill sets are thought to interact continuously in a dynamic manner during sports performance (Janelle & Hillman, 2003; Williams & Ward, 2007), with competent performers better able to extract relevant information from the game environment (e.g., player movements, strategy, rules and opportunities) in order to make tactical decisions that are enacted on using motor skills (Williams & Ford, 2008).

The interaction of motor and perceptual-cognitive skills is supported by hierarchical models of motor development (Clark, 2005; Seefeldt, 1980) in which more advanced physical performers have moved from the use of motor skills in simple contexts (e.g., fundamental patterns period), to use of multiple motor skills being combined with perceptual-cognitive skills within activities of greater tactical complexity (e.g., context specific and skilful periods). Importantly, as tactical skills have been demonstrated as transferrable across game contexts (Memmert & Harvey, 2010; Memmert & Roth, 2007), students developing higher level perceptual-cognitive skills to support tactical decision making have the potential to engage successfully in many forms of game-based activity.

Given that motor control skills form only part of what is required while participating in sports, investigation of the relationship between motor control competence (in the form of object control movement skills) and competence in team based game play is of interest, as is the relationship between each of these competencies and health related physical behaviours. As object control competence displays a stronger relationship with physical activity behaviours, and appears to contribute strongly to the proficiency barrier in middle childhood, it is the focus of motor control competence this investigation.

The aims of this study were to investigate associations between children's object control and game play competence, and to examine these competencies as correlates of physical activity and cardiorespiratory fitness. We hypothesized that game play competence would be associated with object control proficiency, and that game play competence would display a stronger association with health-related behaviours (physical activity and cardiorespiratory fitness) than object control competence due to closer alignment of game play competence to school and extra-curricular activities in this age group.

Methods

Participants

Elementary schools (n = 3) in the Hunter region of New South Wales, Australia were invited to take part in the study. Schools were required to have a stage 2 (9 – 10 years), and stage 3 (11 – 12 years) class, and not be currently involved in any physical activity intervention research. All three schools replied to the e-mail and were eligible for inclusion in the study. The mean index of community socio-educational advantage was 1054 (SD = 44) for these schools (National average = 1000) (Australian Curriculum Assessment and Reporting Authority, 2011). Ethics approval was granted from the university and schools authorities. A total of 148 (consent rate = 97%) parents gave written consent, with children providing written assent.

Measures

Object control competence

Four object control skills considered important for participation in invasion-style team games (overhand throw, underhand throw, two-handed catch and kick) were assessed using the Test of Gross Motor Development – 3rd Edition (TGMD-3) (Ulrich, 2017). Object control was specifically targeted as these skills are more strongly associated with physical activity levels (Barnett et al., 2009; Cohen et al., 2014). Components of each skill (3 – 4 components per skill) are rated as correctly or incorrectly executed, with correct components from two trials of each skill summed to obtain a skill raw score for analysis. Skills were filmed for evaluation, and one assessor evaluated all skills. Assessor training included rating of children performing each FMS on a video previously rated by a panel of experts (>95% agreement rate required). Ten percent of the sample was repeat rated for intra-rater reliability (98% agreement), and against ratings from a member of the research team for inter-rater quality control purposes (Kappa = 0.98; 95% CI - 0.97 to 0.99).

Game play competence

A validated Game Performance Assessment Instrument (Oslin, Mitchell, & Griffin, 1998) previously utilized in studies investigating game play performance (Harvey, Cushion, Wegis, & Massa-Gonzalez, 2010; Miller et al., 2016; Miller et al., 2017) was used to assess children's game play competence. The objective was to reliably assess student performance during an age appropriate game play activity that was accessible to a range of performance levels. A modified version of netball was chosen as it provided a combination of motor and perceptual-cognitive skills within an invasion game tactical framework. These qualities made the game specific to the physical education curriculum students were currently undertaking (age appropriate), whilst still being accessible to all students through the use of throwing and catching (rather than kicking) as the skills of involvement. Further, as tactical skills within invasion games have been demonstrated as transferrable across game contexts (Memmert & Harvey, 2010; Memmert & Roth, 2007) the assessment of game play competence in this manner demonstrates desirable ecological validity (Memmert, 2006).

Students were videoed playing a 5-minute 4 vs. 4 modified netball game against class-mates of the same sex. The aim was to move the ball across the space (10-meter x 6-meter) to a 1-meter end-zone without running with the ball, and using a minimum of five passes before making a scoring pass. An individual student was observed from start to finish of the game, with each play of the game coded as positive (1) or negative (0) within the categories of: i) defence (student's team doesn't have possession), ii) support (student's team has the ball), and iii) decision making (student has the ball) (Table 1). An indices of positive performance (0 – 100%) was used to determine the quality of each participant's involvement for defence, support and decision categories (e.g. positive defence / (positive defence + negative defence)). The average of the three game performance categories was used as the measure of game play competence, with a possible range of 0% (no positive performance recorded in any game category) to 100% (all performances in each game category were coded positive).

One research assistant performed assessment of game performance videos. Assessor training included rating of game performance using video previously rated by the first two authors (AM and NE) (>95% agreement rate required). Intra-rater reliability was assessed by re-coding a random selection of videos for approximately 20% of participants (n = 26) one week after the initial coding took place. Assessed using Hopkins reliability spreadsheets (Hopkins, 2000, 2017) the game play competence measure displayed a proportional change in the mean of -2.9% (95% CI: -7.2 – 1.5%), with an intraclass correlation coefficient (ICC, r) of 0.92 (95% CI: 0.85 – 0.96) between trials. To assess the stability of the measure among participants, a convenient sample of three groups of participants (n = 12) were re-tested within the same teams as the initial testing effort between 12 and 18 days after the initial assessment. The game play competence measure displayed a proportional change in the mean of 2.1% (95% CI: -2.7 – 7.1), with an ICC of 0.86 (95% CI: 0.65 – 0.94) between trials.

Physical activity

Physical activity was assessed using hip-mounted ActiGraph GT3X accelerometers (Pensacola, FL) set to record raw triaxial acceleration at 30-Hz. Participants were asked to wear the activity monitor during all waking hours with the exception of water based activities for 7 consecutive days. Accelerometer data were downloaded in raw format using Actilife Software (version 6.13.3) and processed in R (http://cran.r-project.org/) using the software package GGIR (van Hees et al., 2013). Data extracted between the first midnight and the last midnight were retained for the analysis. Non-wear time was classified within a 60 min time window if for at least two out of the three axes, the standard deviation was less than 13 mg and the value range was less than 50 mg (Sabia et al., 2014). Data were reduced by calculating the average gravity-based acceleration units (g), per 1-s epoch, with daily time spent in moderate-to-vigorous physical activity (MVPA) determined using the sum of epochs averaging above 142 mg (Hildebrand, VT, Hansen, & Ekelund, 2014). The average minutes spent in MVPA per day and average daily wear time was computed using data from each participant's valid days. A valid day was defined as ≥8h on weekdays and ≥7h on weekend days (Barnett, Ridgers, & Salmon, 2015), with participants included in the analysis if they had data for at least 4 valid days (Trost, McIver, & Pate, 2005).

Cardiorespiratory fitness

A twenty-metre shuttle run test was used to assess cardiorespiratory fitness (Leger & Lambert, 1982). Students were required to run back and forth between two lines, 20 m apart, within a set time limit. Running speed commenced at 8.5 km/h and was increased by 0.5 km/h each minute using the 20 m Shuttle Run Test cadence CD. Participants were instructed to run in straight lines, to place one foot over the 20 m line and to pace them-selves according to the audio CD. Participants were required to run until they can no longer keep up with the speed set by the tape. The number of shuttles completed was used for analysis.

Procedure

Assessment was undertaken between February and June 2017. Physical and questionnaire measures (age, gender and cultural background) were administered in a single session during normal school hours by the research team, and accelerometers were distributed after completion of physical measures. If a student consented to involvement and was absent on the day of testing, an individual follow-up session was conducted within two weeks of the initial test date.

Analysis

For the purposes of drawing comparison to cross-section studies investigating motor competence based correlates of physical activity (Barnett et al., 2015; Barnett et al., 2009; Cohen et al., 2014; Morgan, Okely, Cliff, Jones, & Baur, 2008), statistical procedures replicated those previously undertaken. Independent t-tests were conducted to assess sex differences in object control competence, game play competence, MVPA and cardiorespiratory fitness. Three multi-level regression models were undertaken: i) object control competence as the predictor and game play competence as the outcome, ii) object control and game play competence as the predictors, and MVPA as the outcome, and iii) object control and game play competence as the predictors, and cardiorespiratory fitness as the outcome. Demographic covariates (age and sex) were entered into the model first, with object control and game play competence entered in a stepwise manner to examine the proportion of variance within the dependent variable explained by each predictor (Adjusted R^2 change). The MVPA model was also adjusted for accelerometer wear time. The class a student belonged to (seven classes; range 9 – 22 students per class) was included as a level two predictor to adjust for potential clustering at the class level. Interactions between significant predictor variables (e.g. age and sex) were performed if these variables were significantly associated with the outcome variable. Standardized coefficients (Std. B) were produced to compare the effect of predictors on the dependent variable. Analysis was undertaken using Mplus version 7.4, with significance levels set at $p < .05$. The dependent variable MVPA was log transformed prior to analysis to normalize the distribution.

Results

A total of 148 children were recruited, and 107 (75%) children completed all assessments and were included in the final analysis. The sample were aged 9 to 12 years, with a mean age of 10.53 years (SD = .65), and included both sexes (Female N = 61, 57%; Male N = 46, 43%). The majority of students identified as Australian (84%), with 10% identifying as European, and 5% Asian. Aboriginal or Torres Strait Islander students made up 5% of the sample.

Males had significantly better object control skills compared to girls (Table 2). One student scored 30/30 for object control competence. No adjustment was made to scores as a ceiling effect was not displayed for multiple subjects. There were no significant differences between sexes for game play competence, physical activity, or cardiorespiratory fitness.

Object control competence was positively associated with game play competence (Std. B = 0.25, t (104.77) = 2.38, p = 0.001) (Table 3). The variance explained by the model (adjusted R^2) was 7.2%, with object control competence accounting for 3.5% of variance in game play competence.

For the MVPA model, significant positive associations were displayed for object control competence (Std. B = 0.20, t (106.93) = 2.96, p = 0.003), and game play competence (Std. B = 0.33, t (99.81) = 5.21, $p < 0.000$), with game play competence more strongly associated with MVPA than object control competence. The model explained 20.8% of the variance in MVPA, with object control and game play competence accounting for 5.0% and 10.9%, respectively.

For the cardiorespiratory fitness model, significant positive associations were found for object control competence (Std. B = 0.22, t (106.69) = 2.63, $p = 0.002$), and game play competence (Std. B = 0.39, t (104.41) = 4.36, $p < 0.000$), with game play competence more strongly associated with cardiorespiratory fitness than object control competence. The model explained 26.1% of the variance in cardiorespiratory fitness, with object control and game play competence accounting for 6.4% and 13.2%, respectively.

Discussion

To our knowledge this is the first study to demonstrate an association between object control and game play competence, and that game play competence is positively associated with MVPA and cardiorespiratory fitness, displaying a stronger association than object control competence in this cohort.

These findings indicate that movement skills (object control competence) and the ability to engage positively in game play (game play competence) are both important as correlates of physical activity and cardiorespiratory fitness in children. These findings support the importance of motor skill development within dynamic association models of motor learning (Robinson et al., 2015), whilst supporting extension beyond motor skill competence to include cognitive capabilities promoted within hierarchical motor development models (Clark, 2005; Seefeldt, 1980).

We hypothesized that object control and game-play competence would demonstrate a significant relationship based on the inherent connection between the use of motor and perceptual cognitive skills within game play activity (Williams & Ford, 2008), with a significant association evident in these data. The low strength of the relationship (adjusted $R^2 = 3.5\%$) (Cohen, 1988) signifies that object control competence measured using the TGMD-3 had little bearing on the ability to positively engage in game play in this cohort. The selection of object control skills likely had limited use within a netball style assessment of game engagement that evaluated the quality of positioning in defence and support, and decisions made in attack.

To date, game-play competence has not been investigated as a correlate of physical activity or cardiorespiratory fitness. We hypothesized that game play competence would be a stronger predictor of physical activity and cardiorespiratory fitness than object control competence, and whilst both predictors displayed significant positive association with physical activity and cardiorespiratory fitness, game play competence was more strongly associated with the dependent variables.

It is hypothesised that a higher level of motor competence enables a student to engage more readily during physical education lessons (Fairclough & Stratton, 2005), and during school break times and outside school activities (Cohen et al., 2014). Higher engagement leads to greater physical activity accumulation, and in-turn higher cardiorespiratory fitness levels. The same rationale is suggested for the positive association between game play competence and health related outcomes (physical activity and cardiorespiratory fitness) observed in this study. As children in the upper years of primary school progress from chase style activities to team-based games that require greater social and cognitive skill levels for competent participation (Pellegrini et al., 2004), having greater levels of competence to interact with the rules and game structures (e.g., attack and defence) within team based games is likely to enable greater participation during physical education, break time and extra-curricular activities popular in this age group. As many of these games are highly active, and have common structures and strategies (Memmert & Harvey, 2010), it is likely that those with higher game play competence are engaging more actively within games and/or with a wider variety of games, leading to a positive association with cardiorespiratory fitness levels.

The stronger association with physical activity and cardiorespiratory fitness observed for the game play competence measure is potentially a consequence of the product related game play assessment more closely resembling the activities undertaken by participants in the 9 – 12 years age group than the process related object control measure. The positive association between a process measure of object control and a product measure of game play competence supports the assumption that object control competence enables engagement in game play (Cohen et al., 2014; Fairclough & Stratton, 2005), however the ability to contribute effectively during defence, support and attack within a team game displayed a stronger relationship with health related outcomes. Indeed, having high level object control skills more likely means a player can adapt these movement patterns to the changing environment of team games, however this player still needs the cognitive elements to know where to be and how a game works to be effective (and gain access) within the game. In any case, when combined, object control and game play competence explained 15.9% and 19.6% of the variance in the physical activity and cardiorespiratory models respectively, and both are considered as important correlates of health related outcomes in the present sample.

Consistent with existing literature object control motor skill proficiency was associated with objectively measured physical activity (Logan, Kipling Webster, Getchell, Pfeiffer, & Robinson, 2015; Robinson et al., 2015), and cardiorespiratory fitness (Cattuzzo et al., 2016). In studies using objectively measured physical activity in a similarly aged cohort (Hume et al., 2008; Morgan et al., 2008), the relationship between motor control competency and physical activity only demonstrated an effect among males, and was slightly higher (R^2 = 5.8 – 6.3%)

than the present study (adjusted R^2 = 5.0%). The mixed sex analysis, differences in object control skills assessed (Morgan et al., = 6 skills; Hume et al., = 3 skills), or the sample size between studies may explain this difference. Whilst the present study is the first to examine the effect of object control competence on cardiorespiratory fitness using a cross-section design in a mixed sex cohort aged 9 – 12 years using the TGMD-3, and employing multivariate analysis, the findings support the existing consensus of a positive association (Cattuzzo et al., 2016).

There are several implications associated with the findings of this study. First, game play competence displaying an effect in addition to the significant association of object control competence supports a dual focus on the development of cognitive elements of game play, and object control competence among children aged 9 to 12 years for the promotion of physical activity and cardiorespiratory fitness. Previous interventions focused on development of motor and game play competence through exposure to game based activity have demonstrated a simultaneous effect on both of these outcomes (Miller et al., 2016; Miller et al., 2015), and a multi-component intervention involving engagement in game play has demonstrated increases in physical activity among children (Cohen, Morgan, Plotnikoff, Callister, & Lubans, 2015). Further study is required to establish if improvements in game play and object control competence translate to increases in physical activity and cardiorespiratory outcomes in experimental studies. Second, the results of this study provide support for a physical literacy model focusing on the development of multiple and integrated capabilities of physical development (Keegan, Barnett, & Dudley, 2017) for promotion of health related outcomes. Whilst hierarchical models of motor development (Clark, 2005; Seefeldt, 1980) support the combination of motor and cognitive elements within higher levels of development, dynamic models of motor development that are based on research evidence (Robinson et al., 2015;

Stodden et al., 2008a) are yet to incorporate measures of greater complexity (like game play competence). This is in part due to the measurement of activities that involve a combination of capabilities. The development of measures and research that evaluates how children perform in activities involving integration of capabilities, and how this effects health related outcomes are required to further inform dynamic models.

Limitations

Object control skills deemed most appropriate for participation in a wide range of invasion games were assessed during this investigation, which excluded the skills of dribble and strike typically included in the TGMD-3. Whilst unlikely to affect the strength of the associations, the exclusion of these two skills should be recognized. The exclusion of locomotor competence must also be noted as a limitation. This exclusion most likely effects the relationship between motor control competence and game play competence as locomotor skills are also required within the game play assessment. Additionally, whilst regression models were adjusted for age, sex, accelerometer wear time and clustering, weight and maturation status were not included, and may have a confounding effect on these results. Finally, this study establishes a cross-sectional association between game-play competence and physical activity. Whether this association holds within an experimental domain requires testing.

Conclusion

The ability for children to combine motor and perceptual-cognitive skills within complex game-based activities is considered more advanced physical development within hierarchical motor development models. Evidence from this investigation displays an association between higher levels of hierarchical physical development and health related outcomes of physical activity and cardiorespiratory fitness. A dual focus on the development of object control and game play competence is recommended given the combined strength of these correlates within physical activity and cardiorespiratory fitness models, with a focus of motor control development within game related activities desirable for greater alignment of learning experiences with their potential use among the 9 – 12 years age group. Experimental testing of this association is required, as is further development of measures designed to assess how children perform physically when combining physical capabilities within more complex physical domains.

Table 1. *Coding for game play assessment*

Game skill	1 = good	0 = poor
Defence	- Player blocks an attacking option (cover of space or player) - Provides immediate pressure on a ball player - Causes an indirect pass to be thrown (over the head pass)	- Not moving to engage in play (standing or walking towards play) - Involved in play, but not covering a clear attacking option - Covering a player, but not stopping the player from receiving a FLAT pass - Moving to be involved, but not covering a player or option (e.g. ball following)
Support	- Moving to engage in play (this includes any movement to space if a team mate gets stuck with the ball) - Being in a SPACE to receive a pass (note. using space behind a defender if covered, rather than staying covered and requiring a 50/50 ball from the passer)	- No attempt to provide an open passing option for the passer (e.g. stuck on spot behind defender)
Decision	- Pass to an open player (note. If the pass required is an uncatchable long bomb, player should have waited for another option) - Wait to pass when a good pass option is not available - Pass to score (note. if 5 passes have been thrown)	- Pass to opposition - When player should wait for a better option (e.g. use of low percentage long bomb pass) - Interrupted pass (note. Regardless of catch or knock-down) - Breaks rules with pass (e.g. pass to in-goal player before 5 passes)

Table 2. Children's object control competence, game play competence, moderate-to-vigorous physical activity (MVPA) [a], and cardiorespiratory fitness (Fitness) by sex differences [b].

Variable	Range	Mean (SD)
Object control competence (0 – 30)		
Total	8 - 30	18.9 (4.4)
Male	14 - 30	20.9 (3.7)*
Female	8 - 28	17.4 (4.4)
Game play competence (0 – 100)		
Total	36.59 - 91.24	67.1 (11.9)
Male	42.82 - 91.24	67.1 (10.7)
Female	36.59 - 90.61	67.0 (12.9)
MVPA (mins/day)		
Total	13.84 - 62.67	34.63 (11.9)
Male	17.28 - 61.35	36.19 (10.9)
Female	13.84 - 62.67	33.45 (12.5)
Fitness (20m shuttle laps)		
Total	9 - 75	26.63 (14.2)
Male	9 - 75	29.20 (17.3)
Female	9 - 60	24.71 (11.54)

[a] Assessed via accelerometry.

[b] Independent t-tests examined sex differences.

* $p < 0.05$

Table 3. Summary of mixed model regression analyses for moderate-to-vigorous physical activity (MVPA), and cardiorespiratory fitness (Fitness) outcome variables [a].

Outcome	Model parameters	*B*	Std. *B*	SE *B*	LCI	UCI	*p*	Adjusted R^2 change	Model total adjusted R^2	Interaction	*p*
Game play competence	Age	3.27	0.19	1.67	0.52	6.01	0.050				
	Sex	1.23	0.06	2.26	-2.48	4.95	0.585				
	Object control competence	0.64	0.25	0.19	0.33	0.95	0.001	0.035	0.072	Age*OC	0.362
MVPA (mins/day)[b]	Age	-0.02	-0.03	0.06	-0.12	0.09	0.810				
	Sex	0.05	0.08	0.06	-0.04	0.14	0.339				
	Object control competence	0.02	0.20	0.01	0.01	0.03	0.003	0.050			
	Game play competence	0.96	0.33	0.18	0.65	1.26	0.000	0.109	0.208	OC*Game	0.624
Fitness (20m shuttle laps)	Age	2.63	0.13	1.34	0.42	4.84	0.050				
	Sex	-2.32	-0.09	2.66	-6.69	2.05	0.382				
	Object control competence	0.67	0.22	0.22	0.31	1.02	0.002	0.064			
	Game play competence	0.44	0.39	0.12	0.25	0.64	0.000	0.132	0.261	OC*Game	0.341

Note. B, beta coefficient; Std. B, Standardised beta coefficient; SE B, standard error beta; LCI, lower 95% confidence interval; UCI, upper 85% confidence interval.

[a] All models adjusted for clustering at the class level.

[b] Model adjusted for average daily accelerometer wear time.

References

Australian Curriculum Assessment and Reporting Authority. (2011). *Guide to understanding ICSEA*. Sydney, NSW.

Barnett, L. M., Morgan, P. J., Van Beurden, E., Ball, K., & Lubans, D. R. (2011). A reverse pathway? Actual and perceived skill proficiency and physical activity. *Med Sci Sport Exer, 43*(5), 898-904. doi: 10.1249/MSS.0b013e3181fdfadd

Barnett, L. M., Ridgers, N. D., & Salmon, J. (2015). Associations between young children's perceived and actual ball skill competence and physical activity. *J Sci Med Sport, 18*(2), 167-171. doi: http://dx.doi.org/10.1016/j.jsams.2014.03.001

Barnett, L. M., Van Beurden, E., Morgan, P., Brooks, L. O., & Beard, J. R. (2009). Childhood Motor Skill Proficiency as a Predictor of Adolescent Physical Activity. *J Adolescent Health, 44*(3), 252-259

Cattuzzo, M. T., dos Santos Henrique, R., Ré, A. H. N., de Oliveira, I. S., Melo, B. M., de Sousa Moura, M., . . . Stodden, D. (2016). Motor competence and health related physical fitness in youth: A systematic review. *J Sci Med Sport, 19*(2), 123-129. doi: https://doi.org/10.1016/j.jsams.2014.12.004

Clark, J. E. (2005). From the beginning: A developmental perspective on movement and mobility. *Quest, 57*(1), 37-45

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Earlbaum Associates.

Cohen, K., Morgan, P. J., Plotnikoff, R. C., Callister, R., & Lubans, D. R. (2015). Physical activity and skills intervention: SCORES cluster randomized controlled trial. *Med Sci Sport Exer, 47*(4), 765-774. doi: 10.1249/mss.0000000000000452

Cohen, K. E., Morgan, P. J., Plotnikoff, R. C., Callister, R., & Lubans, D. R. (2014). Fundamental movement skills and physical activity among children living in low-income communities: a cross-sectional study. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 49. doi: 10.1186/1479-5868-11-49

Fairclough, S., & Stratton, G. (2005). Physical activity levels in middle and high school physical education: a review. *Pediatr Exerc Sci, 17*, 217-236

Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., & Ekelund, U. (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *The Lancet, 380*(9838), 247-257. doi: http://dx.doi.org/10.1016/S0140-6736(12)60646-1

Harvey, S., Cushion, C. J., Wegis, H. M., & Massa-Gonzalez, A. N. (2010). Teaching games for understanding in American high-school soccer: a quantitative data analysis using the game performance assessment instrument. *Physical Education and Sport Pedagogy, 15*(1), 29-54

Hildebrand, M., VT, V. A. N. H., Hansen, B. H., & Ekelund, U. (2014). Age group comparability of raw accelerometer output from wrist- and hip-worn monitors. *Med Sci Sport Exer, 46*(9), 1816-1824. doi: 10.1249/mss.0000000000000289

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Med, 30*(1), 1-15

Hopkins, W. G. (2017). *A New View of Statistics*. Retrieved from http://www.sportsci.org/resource/stats/precision.html

Hume, C., Okely, A., Bagley, S., Telford, A., Booth, M., Crawford, D., & Salmon, J. (2008). Does weight status influence associations between children's fundamental movement skills and physical activity? *Res Q Exercise Sport, 79*(2), 158-165. doi: 10.1080/02701367.2008.10599479

Janelle, C. M., & Hillman, C. H. (2003). Expert performance in sport: current perspectives and critical issues. In J. L. Starkes & K. A. Ericson (Eds.), Expert performance in sports (pp. 19-49). Chaampaign, IL: Human Kinetics.

Keegan, R., Barnett, L. M., & Dudley, D. (2017). *Physical literacy: Informing a definition and standard for australia*. https://www.ausport.gov.au/participating/physical_literacy.

Leger, L., & Lambert, J. (1982). A maximal multistage 20 m shuttle run test to predict VO2max. *Eur J Appl Physiol, 49*, 1–12

Logan, S. W., Kipling Webster, E., Getchell, N., Pfeiffer, K. A., & Robinson, L. E. (2015). Relationship between fundamental motor skill competence and physical activity during childhood and adolescence: A systematic review. *Kinesiology Rev, 4*(4), 416-426

Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents: review of associated health benefits. *Sports Med, 40*(12), 1019 - 1035

Memmert, D. (2006). Developing creative thinking in a gifted sport enrichment program and the crucial role of attention processes. *High Ability Studies, 17*(1), 101-115. doi: 10.1080/13598130600947176

Memmert, D., & Harvey, S. (2010). Identification of non-specific tactical tasks in invasion games. *Phys Educ Sport Peda, 15*(3), 287-305

Memmert, D., & Roth, K. (2007). The effects of non-specific and specific concepts on tactical creativity in team ball sports. *Journal of Sports Sciences, 25*(12), 1423-1432. doi: 10.1080/02640410601129755

Miller, A., Christensen, E. M., Eather, N., Gray, S., Sproule, J., Keay, J., & Lubans, D. (2016). Can physical education and physical activity outcomes be developed simultaneously using a game-centered approach? *Eur Phys Educ Rev, 22*(1), 113-133. doi: 10.1177/1356336x15594548

Miller, A., Christensen, E. M., Eather, N., Sproule, J., Annis-Brown, L., & Lubans, D. R. (2015). The PLUNGE randomized controlled trial: Evaluation of a games-based physical activity professional learning program in primary school physical education. *Prev Med, 74*(0), 1-8. doi: http://dx.doi.org/10.1016/j.ypmed.2015.02.002

Miller, A., Harvey, S., Morley, D., Nemes, R., Janes, M., & Eather, N. (2017). Exposing athletes to playing form activity: outcomes of a randomised control trial among community netball teams using a game-centred approach. *Journal of Sports Sciences, 35*(18), 1846-1857. doi: 10.1080/02640414.2016.1240371

Morgan, P. J., Okely, A. D., Cliff, D. P., Jones, R. A., & Baur, L. A. (2008). Correlates of objectively measured physical activity in obese children. *Obesity, 16*(12), 2634-2641. doi: 10.1038/oby.2008.463

Oslin, J., Mitchell, S., & Griffin, L. (1998). The game performance assessment instrument (GPAI): Development and preliminary validation. *Journal of Teaching in Physical Education, 17*(2), 231-243

Pellegrini, A. D., Blatchford, P., Kato, K., & Baines, E. (2004). A Short-term Longitudinal Study of Children's Playground Games in Primary School: Implications for Adjustment to School and Social Adjustment in the USA and the UK. *Social Development, 13*(1), 107-123. doi: 10.1111/j.1467-9507.2004.00259.x

Robinson, L. E., Stodden, D., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Med, 45*(9), 1273-1284. doi: 10.1007/s40279-015-0351-6

Sabia, S., van Hees, V. T., Shipley, M. J., Trenell, M. I., Hagger-Johnson, G., Elbaz, A., . . . Singh-Manoux, A. (2014). Association between questionnaire- and accelerometer-assessed physical activity: the role of sociodemographic factors. *Am J Epidemiol, 179*(6), 781-790. doi: 10.1093/aje/kwt330

Seefeldt, V. (1980). Developmental motor patterns: Implications for elementary school physical education. In C. H. Nadeau, W. R. Halliwell, K. M. Newell & G. C. Roberts (Eds.), *Psychology of motor behavior and sport* (pp. 314–323). Champaign, IL: Human Kinetics.

Stodden, D., Goodway, J., Langendorfer, S., Roberton, M., Rudisill, M., Garcia, C., & Garcia, L. (2008a). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008b). A Developmental Perspective on the Role of Motor Skill Competence in Physical Activity: An Emergent Relationship. *Quest (00336297), 60*(2), 290-306

Trost, S. G., McIver, K. L., & Pate, R. R. (2005). Conducting accelerometer-based activity assessments in field-based research. *Med Sci Sport Exer, 37*(11 Suppl), S531-543. doi: 10.1249/01.mss.0000185657.86065.98

Ulrich, D. A. (2017). Introduction to the special section: Evaluation of the psychometric properties of the TGMD-3. *J Motor Learn Dev, 5*(1), 1-4. doi: 10.1123/jmld.2017-0020

van Hees, V. T., Gorzelniak, L., Dean León, E. C., Eder, M., Pias, M., Taherian, S., . . . Brage, S. (2013). Separating movement and gravity components in an acceleration signal and implications for the assessment of human daily physical activity. *Plos One, 8*(4), e61691. doi: 10.1371/journal.pone.0061691

Williams, A. M., & Ford, P. R. (2008). Expertise and expert performance in sport. *Int Rev Sport Exer P, 1*(1), 4-18. doi: 10.1080/17509840701836867

Williams, A. M., & Ward, P. (2007). Perceptual-cognitive expertise in sport: Exploring new horizons. . In G. Tenenbaum & R. Eklund (Eds.), *Handbook of sport psychology* (pp. 203-223). New York: Wiley.