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A reverse pathway? Actual and perceived skill proficiency and physical activity

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RUNNING TITLE: Skill proficiency and physical activity

DISCLOSURE OF FUNDING: The study was funded by NSW Health, Australia, and the University of Sydney, Department of Rural Health (Northern Rivers), Australia.
ABSTRACT

Purpose: Motor skills are considered a prerequisite to physical activity, yet the relationship may be reciprocal and perceived sports competence might mediate associations. Methods: In 2006/07, 215 adolescents completed motor skill proficiency (Get Skilled Get Active), perceived sport competence (Physical Self Perception Profile) and physical activity assessments (Adolescent Physical Activity Recall Questionnaire) as part of the Physical Activity and Skills Study. Using AMOS (Version 7.0), reciprocal relationships were examined between motor skill (object control and locomotor) and moderate-to-vigorous-physical-activity (MVPA). Both models were then run in different versions in order to understand the role of perceived sports competence as a potential mediator. Results: Mean age was 16.4 yrs, (SD .6) with 51.6% (111/215) female. A reciprocal relationship between object control and MVPA and a one-way relationship from MVPA to locomotor skill was found. When perceived sports competence was examined as a mediator, the best fitting model versions explained 16% (R² = .16) MVPA variation, and 30% object control (R² = .30) and 12% locomotor skill variation (R² = .12) (reverse relationship). Perceived sports competence partially mediates the relationship between object control proficiency and physical activity for both directions and fully mediates the relationship between physical activity and locomotor skill; but only when locomotor skill is the outcome. Conclusions: If the relationship between object control skill and physical activity is viewed as a ‘positive feedback loop’, skill development and increasing physical activity should simultaneously be targeted in physical activity interventions. Increasing perceived sport competence should also be an intervention focus. Key words: fundamental motor skill, mediation, structural equation modelling, adolescent
INTRODUCTION

Paragraph Number 1. The ability to perform fundamental motor skills (such as throwing, kicking and jumping) is considered an important prerequisite to sport and physical activity participation (21,34) and there is accumulating evidence of an association in children and adolescents (17,33,38), including that of a recent systematic review (24). There is also some evidence motor skills track through childhood (14,25) meaning childhood motor skill proficiency may be associated with subsequent physical activity. Recent longitudinal evidence from the Physical Activity and Skills Study (PASS) suggests childhood object control skill proficiency (involving manipulation of an object, e.g. a ball) is predictive of subsequent adolescent physical activity (4) and also that object control skill proficiency tracks from childhood to adolescence (5). Considering the benefits of physical activity in childhood/adolescence to both current and future health (7), developing an understanding of the role of motor skill proficiency in promoting physical activity is an important health priority.

Paragraph Number 2. There is a lack of research investigating the potential causal relationships between physical activity behavior and motor skill proficiency or the mediators of this association. It may be that participation in physical activity enhances motor skill development rather than (or in addition to) the reverse. Stodden and colleagues recently proposed a conceptual model in which a developmentally dynamic and reciprocal relationship between physical activity and motor skill competence is described (34). This was presented as a ‘positive spiral of engagement’, where those with higher levels of actual and perceived competence are more likely to be involved in physical activities and these experiences subsequently provide further opportunities to develop motor skill competence and confidence (34). Perceived sports competence is situated as a mediating variable (8) in the model between
motor skill proficiency and physical activity behavior. The incorporation of perceived sport competence in this model is also supported by a systematic review which shows there is a consistent association between perceived sports competence and motor skill proficiency (24). The model developed by Stodden and colleagues also asserts that the relationships between these variables may strengthen as children age (34).

Paragraph Number 3. This proposed theoretical model has not been thoroughly tested. One study in children found a positive association between physical activity and motor skill proficiency and also between self-perceptions of adequacy in performing and desire to participate in physical activity and motor skill proficiency (38). The PASS also investigated the role of perceived sports competence in the relationship between childhood object control proficiency and adolescent physical activity and found it acted as a mediator (2). However, no study has explored these relationships in an adolescent sample. If in fact the relationships strengthen as children age, it might be assumed that the relationships between the variables in this adolescent sample would be stronger than those found in younger children.

Paragraph Number 4. Therefore, the purpose of this paper is to: i) explore the directional relationships between motor skill proficiency and physical activity participation and ii) assess whether perceived sports competence acts as a mediator in these pathways. Given the PASS found object control, rather than locomotor proficiency, was a significant predictor of all physical activity and fitness outcome variables (3,4), and that cross-sectional motor skill research often assesses the importance of whole skill batteries to explain physical activity (33,38), a further purpose of this paper is to: iii) assess the relative contribution of object control versus locomotor proficiency to such relationships. The PASS adolescent dataset will be used to explore these relationships.

METHODS
Sample

*Paragraph Number 5.* In 2006/07, students who had participated in a childhood school-based physical activity intervention were approached for written informed consent to further assessment (both parents and students consented). The original childhood sample was drawn from interested schools, divided first into small, medium and large schools and then randomized within these categories. A total of 276 students were followed up for the PASS and compared to the original sample, they did not differ by sex ($\chi^2 = 2.40, p = .12$) but had a slightly higher mean composite childhood fundamental motor skill score (17.5 compared to 16.5, $t = 2.60, p = .01$).

*Paragraph Number 6.* Order of administration was consistent for all students (weather and school priorities permitting). Data were collected by the study coordinator and three research assistants during school hours. The assistants completed three days of training facilitated by the study coordinator and delivered by a trainer who had previously trained teachers in motor skill assessment. Training included repetitive rating by each prospective tester of children performing each skill on a video, previously rated by a panel of experts. The required observer agreement rate was >85%. Relevant ethics approvals were gained from the University of Sydney, the Department of Education, and the local Catholic Diocese.

Measures

*Paragraph Number 7.* ‘Get Skilled Get Active’ (31), was used to assess motor skills. The Australian resource includes 12 skills (catch, overhand throw, kick, forehand strike, sprint run, leap, dodge, vertical jump, hop, side gallop, skip and static balance). Test-retest reliability has been assessed for this test battery with each grade (Grades 1-3) assessed for different combinations of six skills (32). Mean agreement percentage scores ranged from 69
(95% CI; 60 - 87) for the hop with Grade 1 children, to 85 (95% CI; 70 -100) for the kick with Grade 3 children (A. Okely, personal communication, June 25th 2007).

Paragraph Number 8. Six skills were assessed in this study, including three object control (kick, catch, and overhand throw), and three locomotor (hop, side gallop, and vertical jump) skills. These skills were chosen for the original intervention as they represented a balance of skills considered important to master. An interrater reliability assessment on these six skills using the PASS adolescent sample reported $k = .70$ (6). Each skill is made up of five or six features considered integral to the proficient performance of the skill (11). The testing procedure occurred at school and allowed small groups of students to observe a motor skill demonstration before being asked to perform the skill; described more fully previously (6). For the catch, kick, overhand throw and vertical jump, the skill was performed five times (11) with a feature deemed as present if the student performed it consistently throughout the trials. For the hop and side gallop, the skill was observed as students travelled back and forth once between two points 15 meters apart. The research assistant assessed each feature of that skill as present or absent without any verbal feedback to the student.

Paragraph Number 9. The Adolescent Physical Activity Recall Questionnaire (APARQ) has been assessed for test-retest reliability and validity by looking for agreement on a three category (‘vigorous’, ‘adequate’, ‘inactive’) and also a two category (‘active’, ‘inactive’) measure. In Grade 10 students, for both the three-category and two-category measures, the values of percent agreement exceeded 70%, and all values of kappa were 0.50 or higher. In terms of validity for the two-category measure, mean laps (on the Multistage Fitness Test - MFT) were higher in the ‘active’ category than the ‘inactive’ category for both boys and girls (12). Students were asked to specify all physical activities in which they participate in a usual
week, in both summer and winter, and the frequency and duration of participation in each activity.

**Paragraph Number 10.** The Physical Self-Perception Profile (PSPP) (18,19) was designed to measure physical self-esteem. It has five, six-item scales; one for perceived sports competence. The profile uses a 4-point structured alternative format in which the student must first decide which of two statements best describes them and then must choose whether the statement is ‘sort of true’ or ‘really true’ for them. Each item can be scored from 1 (low self-perception) to 4 (high self-perception). Fox and Corbin found, through both exploratory and confirmatory factor analysis with a sample aged 19 years (mean), that all items of the PSPP contributed well to the functioning of each subscale with corrected item total correlations for the subscale of sports competence ranging from $\alpha = .60$ to $.90$ (18). The sensitivity, reliability and stability of subscales were supported for both genders (18). The protocol recommended by Fox (19) for administering the PSPP was used. The subscale for sports competence was chosen for analysis (although the PSPP was administered in its entirety). Students were asked to complete the written surveys first (i.e. physical activity and perceived sports competence) before completing the motor skill tests. This was so their perception of their own ability was not immediately influenced by undergoing physical tests.

**Data Management**

**Paragraph Number 11.** For the motor skill scores, the number of features rated as correct for each skill (being a maximum of five for the hop and side gallop and a maximum of six for the vertical jump, kick, catch and overhand throw) were summed for each student. The three locomotor skill scores and the three object control scores were then respectively summed, with the maximum locomotor score being 16 and the maximum object control score, 18. Time in physical activity by season, type of activity and activity intensity was calculated from
the APARQ. Each physical activity was assigned a MET value (1 MET = 3.5 mL of oxygen per kilogram of body weight per minute) from a comprehensive list of physical activities (1), since expanded for another study (11). As calculated in this study (11), activities < 10 minutes in duration, with a MET value lower than 3.0, or < once per week, were excluded. Total time in MVPA was averaged between summer and winter. Three cases reported a nil value for MVPA. These cases were considered unreliable and were excluded. Time in physical activity was log transformed prior to analysis to normalize its distribution. For the subscale of sports competence from the PSPP, scores for each item were summed with a possible range of total scores from 6 - 24 (19). A student was included only if they had data for all measures.

**Data Analysis**

**Paragraph Number 12.** Means, standard deviations and bivariate correlations were calculated for all variables in SPSS (Version 15.0). AMOS (Version 7.0) was firstly used to explore directional relationships between motor skill proficiency and physical activity. The ability of motor skill proficiency to explain time in MVPA was specified. Time in MVPA was the dependent variable with object control and locomotor skill proficiency (separated using the summed sub-scores), the independent variables. Secondly, the reverse pathway was specified: i.e. the ability of time in MVPA to explain motor skill proficiency. Object control and locomotor skill proficiency were dependent variables with time in MVPA the independent variable.

**Paragraph Number 13.** Model 1 was developed to test perceived sports competence as an independent mediating variable for object control skill only (because when testing reciprocality with physical activity as the outcome, locomotor skill was not a significant predictor). Model 1 consisted of one latent or unobserved variable (perceived sports competence) and three measured (observed) variables (time in MVPA and object control and
Locomotor skill proficiency. Locomotor skill remained in the model and was allowed to covary with object control skill. Model 1 was run firstly without direct effects from object control and locomotor proficiency to time in MVPA - Version (a). Model 1 was then rerun with the addition of a direct effect from object control proficiency to time in MVPA - Version (b).

Paragraph Number 14. Model 2 was developed to test perceived sports competence as an independent mediating variable for both object control and locomotor skill. The dependent variables were object control and locomotor skill proficiency. Model 2 was run firstly without direct effects from time in MVPA to object control and locomotor proficiency - Version (a). Model 2 was then rerun with the addition of a direct effect from time in MVPA to object control proficiency - Version (b). Model 2 was rerun again with only a direct effect from time in MVPA to locomotor proficiency - Version (c). In both models, perceived sports competence was modeled as a single indicator latent variable (30) in order to account for measurement error associated with this construct.

Paragraph Number 15. The full hypothesised structural equation model and associated regression coefficients for each version of Model 1 and 2 were interpreted with reference to SEM output statistics to determine which versions best ‘fit’ the data. For this, fit indices examined included the chi-square test, Tucker-Lewis fit index (or Non-Normed Fit Index (NNFI)), Comparative Fit Index (CFI), and the Root Mean Squared Error of Approximation (RMSEA) indicate whether the model fits the data. The chi-square test should not be significant as this indicates poor fit. The Tucker-Lewis fit index and CFI values should be between 0 and 1, with values more than .95 considered a good fit for the data (22). For the RMSEA, a value of less than .05 indicates a close fit (15).
While all individual variables, bar one, were below recommended values of skewness and kurtosis (36), the multivariate kurtosis was higher (3.30) than the recommended value of <3 (26). Therefore the Bollen-Stine bootstrap method developed for non-normal data was used to test overall model fit, and was also invoked for parameter estimates (10).

RESULTS

Sample

A total of 276 completed the APARQ, 256 had the domain of sports competence calculated from the PSPP, 254 completed the skills for a composite object control score, 249 completed the skills for a composite locomotor score and 218 (79.0%) completed all assessments relevant to this paper; with 215 of these used in analysis. Slightly more than half were female (51.6%, 111/215). Mean age was 16.4 yrs, (SD .6). Descriptive statistics are reported in Table 1. All skill and physical activity variables were significantly and positively associated with one another.

Reciprocal Relationships

Motor skill proficiency explained 11% of variance in MVPA (R² = .11). However the strength of the pathway between locomotor proficiency and MVPA was small (β = .05) and not significant (p = .404), meaning object control proficiency was responsible for the variance explained in MVPA (β = 33, p <.001). For the reverse direction, time in MVPA explained 12% of variance in object control skill (R² = .12) and 2% in locomotor skill (R² = .02). The pathways from MVPA to object control and to locomotor proficiency were both significant (respectively: β = .35, p <.001 and β = .14, p = .035).
Perceived Sport Competence as a Mediator

Paragraph Number 19. For Model 1, the adjusted $p$ value (using the Bollen-Stine method) for Version (a) was significant indicating a poor fit of the model to the data. For Version (b), the adjusted value indicated a good fit (although some evidence of over fitting). The fit indices also indicated Version (b) was the better fitting model, as in Version (a), the RMSEA was $>.05$, see Table 2. The distribution of the standardized residual covariances also supported Version (b) as the preferred model with none being $<-2$ or $>.2$.

Paragraph Number 20. Model 1 Version (b), explained 16% of variance in MVPA ($R^2 = .16$). The model fit indicated object control skill was partially mediated through perceived sports competence to physical activity. Table 3 presents the standardized direct, indirect and total effects which show object control proficiency was partially mediated through perceived sports competence as the total effects were higher than direct effects (direct $\beta = .23$, indirect $\beta = .10$, total $\beta = .33$). Also, direct effects between object control skill and perceived sports competence ($\beta = .45$) and between perceived sports competence and time in MVPA ($\beta = .23$) were equal to or stronger than that between object control skill and time in MVPA ($\beta = .23$). The relationship between object control skill and perceived sport competence was stronger than the relationship between locomotor skill and perceived sport competence ($\beta = .45$ compared to $\beta = .22$), see Table 3 and Figure 1.

Paragraph Number 21. For Model 2, Version (b) also proved the best fit for the data. Examination of further fit indices also indicated a satisfactory overall fit of the hypothesised model to the data, see Table 2. The distribution of the standardized residual covariances also supported Version (b) as the preferred model with none being $<-2$ or $>.2$. Model 2 Version (b) explained 12% of variance in locomotor proficiency ($R^2 = .12$) and 29% of variance in object
control proficiency ($R^2 = .29$). The model fit indicated physical activity was fully mediated through perceived sports competence to locomotor proficiency, and partially mediated through perceived sports competence to object control proficiency. The standardized indirect, direct and total effects also show physical activity was partially mediated through perceived sports competence to object control proficiency, with the total effects higher than direct effects ($\text{direct } \beta = .19$, indirect $\beta = .16$, total $\beta = .35$). Also, direct effects between physical activity and perceived sports competence ($\beta = .35$) and between perceived sports competence and object control skill ($\beta = .44$) were stronger than between physical activity and object control skill ($\beta = .19$). The strength of the relationship between perceived sports competence and object control skill, was higher than between perceived sports competence and locomotor skill ($\beta = .44$ compared to $\beta = .34$), see Table 3 and Figure 2.

**DISCUSSION**

*Paragraph Number 22.* This is the first study to explore the reciprocal relationship between physical activity and motor skill proficiency in youth. Overall skill proficiency explained 11% of variance in physical activity and physical activity explained 12% of variance in object control skill and 2% in locomotor skill. However, the pathway between locomotor proficiency and physical activity was weak and not significant when physical activity was the outcome, and yet stronger and significant when skill was the outcome. This indicates when both skill types are examined together as correlates of physical activity, that any effect of locomotor skill is negated. Therefore the relationship between motor skill proficiency and physical activity appears to be reciprocal for object control skill, but not for locomotor skill. This finding for object control proficiency is consistent with the proposed existence of a positive feedback loop with physical activity (34). Reverse causality has not been addressed previously in studies of motor skill proficiency and physical activity. In fact, reverse causality
is not often dealt with in the physical activity field. For instance, when looking at obesity and physical activity, it is usual for studies to look at the effect of physical activity on weight loss/gain, not the reverse (35). Whilst our cross-sectional data does not prove a cause and effect relationship, it may contribute to our understanding of the potentially dynamic relationships between motor skill proficiency and physical activity.

*Paragraph Number 23.* Findings also show, regardless of the direction, that the relationship between physical activity and object control skill was stronger than the relationship between physical activity and locomotor skill. This is supported by the longitudinal PASS analysis (4) and studies which have found object control skill to correlate with physical activity in boys: \( r = .24 \) (23) and \( r = .25 \) (16,23,27). In contrast, a study in pre-school children found non-significant correlations between object control and physical activity in three year old children. However the same study found correlations for locomotor scores in four year olds, only slightly higher (MVPA, \( r = .31 \)) than those for object control scores (MVPA, \( r = .26 \)) (37). If in fact these relationships strengthen as children age (34), it might explain why the relationships between the variables in this adolescent sample appear to be stronger than those found in younger children.

*Paragraph Number 24.* Perhaps for adolescents, actually being able to perform object control skills leads to more opportunity to participate in sports and activity, whereas proficiency in locomotor skills may not contribute to opportunity to the same degree. For example, the ability to catch or throw in basketball may have more obvious significance to the participant and the team, compared to the ability to hop and vertical jump, even though the ability to hop and vertical jump (by transferring weight in readiness to jump for a hoop) are also useful skills.
Paragraph Number 25. The importance of object control skills is also supported once perceived sports competence was added to the models. Perceived sports competence partially mediated the relationship between object control proficiency and physical activity for both directions. This illustrates perception of skill proficiency may also be important for the relationship between physical activity and actual object control skill. In Model 1, the direct path between object control proficiency and perceived sports competence was stronger than that between locomotor skill proficiency and perceived sports competence ($\beta = .45$ vs. $\beta = .22$). One possible explanation is that an individual’s perception of their ability to perform locomotor skills may be less accurate than an individual’s perception of their ability to perform object control skills, because the ability to catch, throw and kick is more noticeable to the self and others in a game context than the ability to hop or jump; therefore reinforcing a more accurate self-perception.

Paragraph Number 26. There was a slightly stronger relationship in the reverse direction for the complete model (i.e. being physically active and having higher perceived sports competence was associated with more proficiency in object control skills), further reinforcing the idea that many sports and games help to develop these types of skills. Although, evidence for reciprocality was also evident, as the direct pathway between object control and physical activity in Model 1 was stronger than in Model 2 ($\beta = .23$ vs $\beta = .19$), indicating that possessing better object control skills may provide greater opportunities to participate in activities involving these skills.

Paragraph Number 27.

Strengths and Limitations
**Paragraph Number 27.** Using SEM in order to explore directions and mediation is a novel approach in this field. Other study strengths include an adequate sample size and the use of a comprehensive battery of motor skills, divided between locomotor and object control. In terms of limitations, the sample used for the current paper was complete data drawn from 276 students followed up as part of a prior intervention, which means it is a selected sample possibly limiting generalizability. Another limitation is the use of a self-report measure for physical activity. Also, physical activity expenditure in terms of moderate to vigorous activity was categorised using a compendium of physical activities derived from adult samples; in the absence of an adolescent compendium. An issue with the motor skill assessment was a potential ceiling effect operating as many students reached proficiency in their motor skills at follow-up, which may have impacted on relationships between variables. It may also be considered a limitation that test-retest reliability for the motor skill instrument has only been previously assessed with younger children, although the interrater reliability was assessed with this adolescent sample which reinforces the appropriateness of this measure with adolescents.

**Conclusions and Implications**

**Paragraph Number 28.** The implication of actual and perceived skill proficiency and physical activity being potentially inextricably linked in this sample is that motor skill development may not only be important for children but also for adolescents. Motor skill development is generally seen as a core component of elementary school physical education (20) but recent Australian research has shown motor skills are not being taught adequately (28,29). Many students may therefore leave elementary school without adequate motor skill competence (13), yet in high school, motor skills are no longer a core focus of physical education with a greater emphasis on game-based play and tactics (9). If poor perceived sports competence developed during childhood tracks into adolescence this has the potential to negatively impact on
physical activity. If we can increase actual and perceived skill competence in adolescence we may be able to increase physical activity levels.

Paragraph Number 29. Although causality cannot be determined, our data provide some evidence that to encourage physical activity across the lifespan it might be useful to support continued motor skill development. If we view this relationship as a ‘positive feedback loop’ (34), it would seem appropriate to target motor skill development and activity simultaneously. Furthermore, since perceived sports competence is an integral part of this reciprocal relationship, interventions to encourage adolescents to be active should also focus on increasing perceived sports competence.
ACKNOWLEDGEMENTS: Thanks to the research assistants and importantly, the students, teachers, and schools for participating. The study was funded by NSW Health, Australia, and the University of Sydney, Department of Rural Health (Northern Rivers), Australia. The results of the present study do not constitute endorsement by ACSM.
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FIGURE CAPTIONS:

Figure 1: Model 1 - Motor Skill to Physical Activity - Version (b)

Figure 2: Model 2 - Physical Activity to Motor Skill - Version (b)