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Original article

Childhood Motor Skill Proficiency as a Predictor of Adolescent Physical Activity

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Abstract

Purpose: Cross-sectional evidence has demonstrated the importance of motor skill proficiency to physical activity participation, but it is unknown whether skill proficiency predicts subsequent physical activity.
Methods: In 2000, children's proficiency in object control (kick, catch, throw) and locomotor (hop, side gallop, vertical jump) skills were assessed in a school intervention. In 2006/07, the physical activity of former participants was assessed using the Australian Physical Activity Recall Questionnaire. Linear regressions examined relationships between the reported time adolescents spent participating in moderate-to-vigorous or organized physical activity and their childhood skill proficiency, controlling for gender and school grade. A logistic regression examined the probability of participating in vigorous activity.
Results: Of 481 original participants located, 297 (62%) consented and 276 (57%) were surveyed. All were in secondary school with females comprising 52% (144). Adolescent time in moderate-to-vigorous and organized activity was positively associated with childhood object control proficiency. Respective models accounted for 12.7% ($p = .001$), and 18.2% of the variation ($p = .003$). Object control proficient children became adolescents with a 10% to 20% higher chance of vigorous activity participation.
Conclusions: Object control proficient children were more likely to become active adolescents. Motor skill development should be a key strategy in childhood interventions aiming to promote long-term physical activity.

Keywords: Motor skill; Fundamental movement skill; Physical activity; Organized physical activity; Adolescent; Child; Longitudinal

Regular participation in physical activity is associated with important short- and long-term health benefits for children and adolescents in physical, cognitive, emotional, and social domains [1,2]. Health benefits can be seen in terms of a direct improvement to childhood health status and to adult health status (as a result of childhood health improvement). There is also some evidence physical activity behavior tracks to adulthood, with active children more likely to become active adults [3]. Current recommendations state that school-age youth should participate in 60 minutes or more of moderate-to-vigorous physical activity each day [4]. In Australia, in 2004, 40% of girls and 22% of boys in grade 10 did not meet these recommendations [5]. Identifying factors that determine adolescent physical activity may therefore be important in increasing physical activity levels at all ages.

In the last 10 years cross-sectional evidence has grown regarding the importance of fundamental motor skill proficiency to physical activity participation. Motor development models propose levels through which a child must progress to achieve motor proficiency. Motor skills associated with locomotor (often termed movement), object control (involving manipulation of an object), and postural control are usually

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perceived as occurring after a stage (or stages) involving birth reflexes, with the idea that fundamental motor skills must be mastered before development of more sport-specific skills [6]. In cross-sectional research ''motor proficiency'' has been positively associated with sport participation [7] and total [8,9], moderate-to-vigorous [9], skill-specific [10], and organized physical activity [11] in children and adolescents.

Mastery of motor skills in childhood is likely to be a key determinant of later adolescent motor skill mastery [12–14]. Competence or ''effectance'' motivation theory [15] operationalized by Harter [16], proposes that intrinsic mastery-oriented children, but not extrinsic mastery-oriented children, perceive themselves as responsible for their own success/failure, with this perception correlating with them being more skilled [17]. That is, children with high levels of perceived and actual competence may be more likely to engage in physical activity. Childhood motor skill proficiency may thus be an important factor in subsequent adolescent physical activity levels, although little longitudinal research has explored this relationship. This paper examines the relationship between motor skill proficiency in childhood and subsequent adolescent physical activity behavior in a longitudinal cohort study set in New South Wales, Australia.

Methods

Sample selection

In 2000, 1045 children from 18 randomly selected and stratified primary (elementary) schools in an area comprising 24,555 sq kilometers in New South Wales, Australia, had their proficiency in a battery of motor skills assessed for a school-based physical activity intervention [18]. The initial mean age of the sample was 10.1 (range = 7.9–11.9 years). Of these students, 1021 had first and last initials noted on their motor skill assessments. In 2006/07, the list of original study participants (of the 1021, 929 [91.0%] matched by full name and gender to class roll) was sent to all consenting high schools in the original study district (97.6%, n = 41/42) to identify adolescent students for follow-up as part of a longitudinal cohort study known as the Physical Activity and Skills Study. Half of the 928 original participants (one student passed away prior to consent) (51.8%, n = 481/928) were located in 28 schools (of the possible 41). Student consent was 61.7% (n = 297/481) with 57.4% (n = 276/481) surveyed, which represented a follow-up rate of 29.7% (n = 276/928). The followed up sample did not differ by gender ($\chi^2 = 2.40, p = .12$), but were more likely to have been originally tested in grade 4 (61.5%) than grade 5 (38.5%; $\chi^2 = 22.67, p < .0001$), and had a slightly higher (17.5 compared with 16.5) mean composite childhood fundamental motor skill score ($t = -2.60$, $p = .009$).

Data collection

Data were collected by the study coordinator and three research assistants. The assistants completed 3 days of training facilitated by the study coordinator and a trainer who had trained teachers in motor skill assessment and assessed children as part of a separate study [19]. The majority of data (>94%) were collected over term 4 in 2006, with the remainder early in term 1, 2007 (both over the summer). Ethics approval was gained from the University of Sydney (07-2006/9243), the New South Wales Department of Education and Training (06.296), and the local Catholic Diocese. Written informed consent was obtained from parents/guardians and students.

Motor skill measurement

The initial intervention had used the Australian resource, ''Get Skilled Get Active'' [20], to assess students' motor skills. This resource specifies a battery of fundamental motor skills, eight of which were validated in an original manual (catch, overhand throw, kick, forehand strike, sprint run, leap, dodge, vertical jump) [21], returning reliability estimates (alpha coefficient method) of $r = .70$ ($p < .01$) or greater for all skills except the leap and run ($r = .13$ and $r = .17$, respectively, and not significant). The four new skills (hop, static balance, skip, and side gallop) were validated as part of the subsequent test battery and were found to have good test–retest reliability for young children [22].

Using the above system, each skill is viewed as a composite of five or six features considered integral to the proficient performance of the skill [20]. For example, the overhand throw consists of six features: (1) eyes focused on target area throughout the throw, (2) stands side on to target area, (3) throwing arm moves in a downward and backward arc, (4) steps toward target area with foot opposite throwing arm, (5) hips then shoulders rotate forward, and (6) throwing arm follows through down and across the body.

Testing procedure allowed students to observe a motor skill demonstration before being asked to perform the skill. For the catch, kick, overhand throw, and vertical jump, the skill was performed five times with a feature deemed as present if the student performed it on four out of five occasions [21]. For the hop and side gallop, the skill was observed as students traveled back and forth once between two points 15 meters apart. Each feature of each skill was assessed as present or absent by the research assistant without giving verbal feedback. Interrater reliability was reported as moderate (kappa = .61) [18]. A subsequent interrater reliability assessment using this instrument in our adolescent sample found kappa =.70 (confidence interval [CI] = .61–.79) [23].

Physical activity measurement

The Adolescent Physical Activity Recall Questionnaire (APARQ) was chosen to assess physical activity participation as it measures type of activity, frequency, duration, and context of participation, and has been used in recent motor skill proficiency studies [11,24]. Students specify all organized (involving regular classes, training, or competition that were somewhat structured or formal and had a coach, instructor or teacher) and nonorganized activities (not structured or formal with no regular training/competition and no coach, instructor, or teacher) in which they participate in a usual week, in both summer and winter, and the frequency and duration of activity participation. APARQ has been assessed for test–retest reliability by looking for agreement on a three category measure (vigorous, adequate, inactive) within organized or nonorganized activity. Weighted kappa for grade 10 boys and girls was reported as ranging from .44 to .89, and percentage agreement from 67% to 97% [25]. Students also indicated date of birth, postcode of home residence, gender, language spoken at home, and Aboriginal/Torres Strait Islander status.

Data analysis

For the fundamental motor skill measures, the number of features rated as present or correct for six skills were summed for each subject. Each participant was rated for each skill at one of three levels. If all features were correctly performed this was considered ''mastery,'' all but one feature correct, ''near mastery,'' and more than one feature incorrect ''poor.'' Achievement of either ''mastery'' or ''near mastery'' was termed ''advanced skill proficiency'' [26]. Each skill was then standardized to a score of 5, and scores for the six skills were summed to create scores out of 15 for the three object control (kick, catch, throw) and three locomotor skills (side gallop, hop, vertical jump) [11].

Time in physical activity by season, type of activity, and activity intensity were calculated from the APARQ. Each physical activity was assigned a metabolic equivalent total (MET) value (1 MET = 3.5 mL of oxygen per kilogram of body weight per minute) from a comprehensive list of physical activities [26], expanded from a previous measure [27]. Activities less than 10 minutes in duration, with a MET value of less than 3.0, or less than once per week were excluded, as per the Schools Physical Activity and Nutrition Study [24]. Total time in moderate-to-vigorous (including both organized and nonorganized activity), and organized activity, was averaged between summer and winter.

Chi squares and *t*-tests were used for basic cross-sectional differences. Two general linear models were fitted to examine the relationship between fundamental motor skill proficiency in childhood to (1) time in moderate-to-vigorous activity and (2) time in organized activity per week in adolescence. The dependent variables (time in moderate-to-vigorous and in organized physical activity) were both log transformed prior to analysis to normalize the distribution. The relationship between school grade, gender, childhood object control proficiency, and childhood locomotor proficiency and (1) time in moderate-to-vigorous activity and (2) time in organized activity per week in adolescence were initially assessed univariately for significance.

Significant variables were included as main effects in the model. Interactions between significant motor skill proficiency variables and both gender and school grade were included to examine whether the relationships between motor skill proficiency and physical activity differed between male and female students and between students of different year groupings. Interaction terms were only retained in the final model if found significant. Predicted values of (1) time in moderate-to-vigorous activity, based on the model parameter estimates, were back transformed from their log transformed values and plotted against the observed range of object control variables by gender and grade (Figure 1).

A logistic regression was fitted to examine the probability of participating in some vigorous activity, as a function of skill proficiency in childhood. As nearly all students participated in at least moderate activity, vigorous activity was chosen as a reference point to assess intensity as a function of skill proficiency. The initial model included school grade, gender, object control, and locomotor proficiency as main effects, and the corresponding two-way interactions involving the motor skill variables. Manual backward elimination was used to eliminate nonsignificant interactions first, followed by nonsignificant main effects. The predicted chance of participating in some vigorous activity in adolescence based on a given childhood motor skill score was then calculated.

A logistic regression was fitted to examine the probability of participating in some organized activity (as opposed to no organized activity), as a function of skill proficiency in childhood. Organized activity was chosen as the reference point to assess type of activity as a function of skill proficiency, as it has been previously linked to motor skill proficiency [11]. This regression was completed only for grade 11 students, as all grade 10 students participated in organized activity (compulsory in this school grade). The initial model included gender, object control proficiency, and locomotor proficiency as main effects, and the corresponding two-way interactions involving the motor skill variables. All analysis used SPSS [28], and the consistent a priori level used to determine significance was $p < .05$ throughout the paper, although the exact p-value is reported.

Results

Sample

Slightly more than half the sample were female (52.2%, n = 144/276). Most were in grade 10 in 2006/07 (57.8%, n = 159/275). The mean age at follow-up was 16.4 (range = 14.2 to 18.3 years). All but one spoke English at home and 7.0% of the sample identified as Aboriginal or Torres Strait Islander (n = 19/271). Using home postcode of residence as a proxy for socioeconomic advantage/disadvantage as defined in the Australian Bureau of Statistics Index of Disadvantage, nearly the entire sample was classified as below the New South Wales state average (98.9%, n = 273/276) [29].

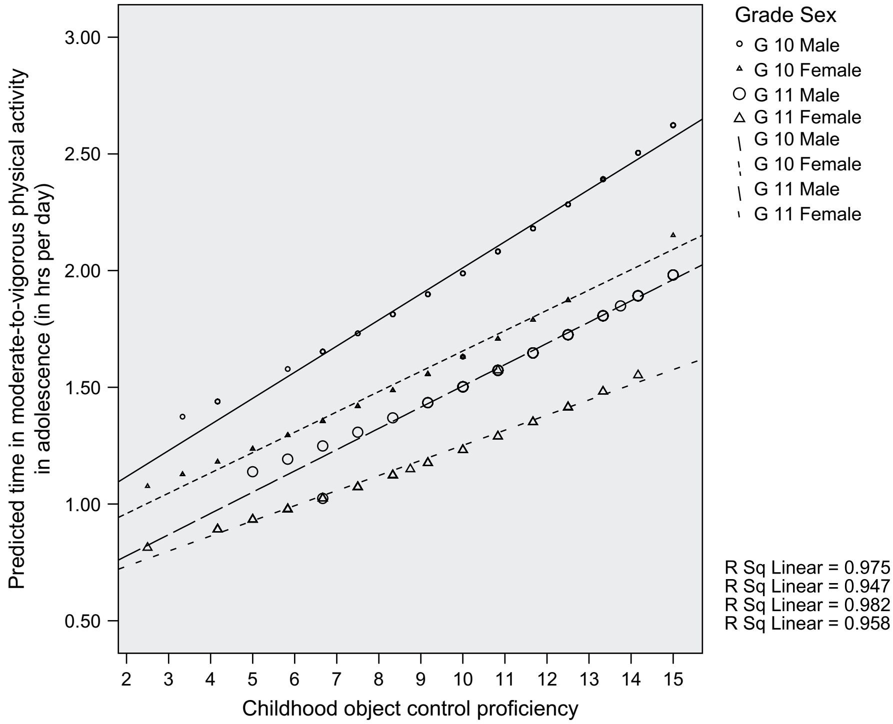

Figure 1. The predicted value for time in moderate-to-vigorous activity (in hours per day), in adolescence, based on childhood object control proficiency, by gender and school grade.

Motor skill proficiency in childhood

Mean composite childhood skill score for 2000 was 17.6 (SD = 5.0). Overall, males were more proficient at performing motor skills with a mean of 19.0 (CI = 18.2–19.8), compared with females with a mean of 16.2 (CI = 15.4–17.0; t = 4.79, $p < .0001$). Males were more proficient at object control skills, 11.3 (CI = 10.9–11.8), compared with females, 7.8 (CI = 7.3–8.2; t = 10.91, $p < .0001$). Females were more proficient at locomotor skills, with a mean of 8.5 (CI = 8.0–9.0), compared with males, 7.7 (CI = 7.1–8.2; $t = -2.23$, $p = .03$).

Physical activity levels in adolescence

Nearly all students (98.9%, n = 273/276) participated in at least some moderate-to-vigorous activity, with three reporting no activity. Most (97.8%, n = 267) participated in some moderate intensity activity and 84.4% (n = 233) in some vigorous activity. Students spent an average of 118 minutes per day in moderate-to-vigorous activity physical activity. Males reported significantly more moderate-to-vigorous, moderate, and vigorous activity than females (Table 1).

Most students participated in at least some organized activity (93.8%, n = 259), with 17 students in grade 11 who did not. Most students also participated in some nonorganized activity (92.8%, n = 256). Students spent an average of 55.8 minutes per day in organized and 69.3 minutes per day in nonorganized physical activity. Males reported significantly more time in nonorganized and organized activity than females (Table 1).

Childhood motor skill proficiency and adolescent time in moderate-to-vigorous activity

All interactions were removed as nonsignificant, followed by locomotor proficiency ($p = .362$). The final model, adjusting for school grade and gender, revealed that object control proficiency in childhood was associated with time in moderate-to-vigorous activity in adolescence accounting for 12.7% ($r^2 = .127$) of the variation (Table 2). When looking at the unique contributions (in terms of variance explained) of individual variables (adjusted r^2) to the final physical activity model (in order—type 1 sums of squares); grade accounted for 2.7% of variation ($r^2 = .027$), grade and the addition of gender accounted for 9.1% of variation ($r^2 = .091$), and grade, gender, and the addition of object control proficiency accounted for 12.7% of variation ($r^2 = .127$). That is, the individual contribution of object control skill proficiency to this equation was 3.6% ($r^2 = .036$).

Predicted values from this model show that grade 10 males were the most active, followed by grade 10 females, grade 11 males, and grade 11 females. Regardless of level of object control skill proficiency in childhood, grade 10 males were likely to be involved in at least half an hour more moderate-to-vigorous activity per day than grade 11 females with matching childhood skill proficiency (Figure 1). This finding equates to 2 hours compared with 1.5 hours for

Table 1
The proportion of the sample (n = 276) in adolescence that participated in some activity of the type or intensity specified, mean time in the specified activity (in weekly and daily minutes), and associated gender differences

Type/Intensity of activity		N	% Who participated in any	MW (mean weekly minutes)	MD (mean daily minutes)	SD	T	p
Moderate and/or vigorous	Total	273	98.9	825.9	118.0	551.1		
	Males	142	52.0	974.4	139.2	599.0	4.4	.000
	Females	131	48.0	688.8	98.4	464.3		
Moderate	Total	267	97.8	524.7	75.0	403.3		
	Males	130	48.7	610.2	87.2	462.7	3.4	.001
	Females	137	51.3	443.6	63.4	318.6		
Vigorous	Total	233	84.4	366.4	52.3	304.3		
	Males	114	48.9	424.0	60.6	310.4	2.9	.004
	Females	119	51.1	311.3	44.5	289.1		
Organized	Total	259	93.8	390.9	55.8	260.5		
	Males	124	47.9	436.7	62.4	272.5	2.7	.006
	Females	135	52.1	348.8	49.8	242.5		
Nonorganized	Total	256	92.8	485.3	69.3	440.6		
	Males	127	49.6	578.7	82.7	478.2	3.4	.001
	Females	129	50.4	393.2	56.2	379.9		

those with good skills and 1.5 hours compared with 1 hour per day for those with poor skills.

Childhood motor skill proficiency and probability of participating in any vigorous activity in adolescence

All interactions were removed as nonsignificant, followed by locomotor proficiency ($p = .997$), grade ($p = .296$), and finally gender ($p = .168$). The final model included object control proficiency as the sole significant predictor (Wald statistic = 12.90, df = 1, $p = .000$; β_i [$\pm$SE]: $\beta_0 = -0.066$ [$\pm$0.50], $\beta_1 = 0.210$ [$\pm$0.58]).

Predicted values from this model show that children with good (>10) object control skills have at least a 20% greater chance of participating in at least some vigorous activity in adolescence, compared with those with poor (<5) object control skills (Figure 2).

Childhood motor skill proficiency and adolescent organized physical activity

Object control proficiency in childhood was associated with time in organized activity in adolescence. The final model, adjusting for school grade and the interaction between grade and object control proficiency, revealed that childhood object control proficiency accounted for 18.2% ($r^2 = .182$) of the variation in time spent in organized activities (Table 3).

Object control proficiency in childhood did not increase the probability of participating in any organized activity in adolescence. All interactions were removed from the model as nonsignificant followed by locomotor proficiency ($p = .455$) and gender ($p = .238$). The final model was significant ($p = .047$) but object control proficiency fell short of significance ($p = .053$).

Table 2
Significant main effects for the relationships between childhood object control proficiency and time in moderate-to-vigorous activity in adolescence, controlling for gender and grade

Source	F	df	p
Intercept	23118.79	1	.000
Grade	10.49	1	.001
Gender	19.69	1	.000
Childhood Object Control Proficiency	12.09	1	.001
Error		267	
Total		271	

Type 1 sums of squares
$R^2 = .137$ (adjusted $R^2 = .127$).

Discussion

This is one of few studies to longitudinally examine the relationship between childhood motor skill proficiency and

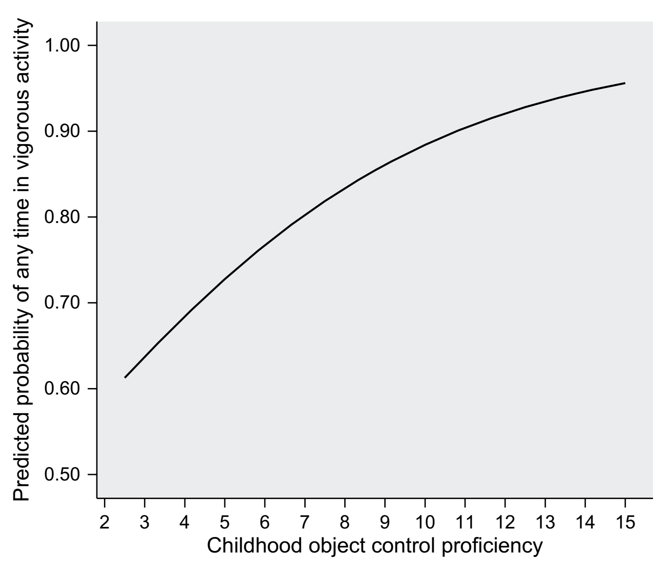

Figure 2. The predicted probability of participating in any vigorous activity as an adolescent based on childhood object control proficiency (both grades combined).

Table 3
Significant main effects and interactions for the relationships between childhood object control proficiency and time in organized activity, controlling for grade

Source	F	df	p
Intercept	1740.950	1	.000
Grade	50.153	1	.000
Childhood object control proficiency	8.772	1	.003
Grade by childhood object control proficiency	5.212	1	.023
Error		272	
Total		276	

Type 1 sums of squares
$R^2 = .191$ (adjusted $R^2 = .182$).

adolescent physical activity. We found that fundamental motor skill proficiency in elementary school, particularly object control proficiency, predicted adolescent physical activity behavior. In particular, childhood object control proficiency predicted subsequent time spent in both moderate-to-vigorous activity and organized activity. Also, childhood object control proficiency increased the probability of whether an adolescent would participate in *any* vigorous activity but not the probability of participation in *any* organized activity.

Our results suggest that being able to perform object control skills (such as catching, throwing, and kicking) competently in childhood may be a significant factor in subsequent engagement in adolescent physical activity. This may be because these types of skills are often associated with physical activity experiences of a moderate and/or vigorous intensity (such as recreational or organized sports training and competition) [10]. Having greater motor skill competence as a child may result in greater self-esteem related to these types of activities and increased enjoyment of them. This, in turn, may result in greater spontaneous and regular participation. Those with motor difficulties may choose not to participate in physical activity as a coping strategy [30]. These are important findings, as it is well established that physical levels generally decline during adolescence, with the most marked decrease taking place between the ages of 13 and 18 [31]. A promising strategy to increase adolescent physical activity may be to design and implement interventions that target motor skill development in childhood in both school and community settings. This may be an effective means of increasing physical activity participation and intensity in later life.

The full model explained 13% of the variation in levels of moderate-to-vigorous physical activity 6 years later in adolescence. This is a reasonable proportion of the variation in activity levels, considering the long follow-up period and the many other factors likely to influence adolescent physical activity. Our findings are consistent with cross-sectional studies, although these have generally explained less variance than in our study. Wrotinak and colleagues [9] found that motor skill proficiency accounted for 8.7% of variance in children's activity after controlling for a number of factors, and Okely et al. [11] found that movement skills accounted for 4.3% of organized vigorous activity variance in adolescents after controlling for gender, grade, and rurality. In terms of the unique contribution of motor skills to physical activity, our findings are comparable to cross-sectional studies. In our model, object control proficiency explained 3.6% of the variation in adolescent time in moderate-to-vigorous physical activity. Okely et al. [11] also found that the actual variance in activity explained by movement skill was 3%. This is surprising, as it might be expected that skill proficiency and physical activity measured at the same point in childhood or adolescence would have a stronger association than childhood skill proficiency and adolescent physical activity.

Only one other longitudinal study, by McKenzie and colleagues [32], also a 6-year follow-up, has examined the relationship between childhood movement skills and subsequent activity. However, this study examined early childhood (ages 4–6 years) movement skills and early adolescent (12 years) physical activity participation and did not identify a significant relationship between the two. It may be that measuring motor skill proficiency in early childhood is too early to detect relationships with subsequent physical activity. Furthermore, only one object control skill (catching) was measured, which may have limited the likelihood of detecting a significant relationship [32].

Object control skills, as opposed to locomotor skills, were the predictor of physical activity in our study. Perhaps object control proficiency was associated with physical activity because these skills are fundamental to involvement in various games and sports that involve object control skill-related performance. Okely and colleagues [11] found a battery of movement skills (including four object control skills and two locomotor skills) was associated with organized activity; however, the individual contribution of object control versus locomotor proficiency on physical activity was not assessed. Further research is needed to explore the relative contributions of object control proficiency and locomotor proficiency to physical activity.

It is interesting that even though males were significantly more active than females on every measure of activity, that gender was only a significant predictor for time in moderate-to-vigorous activity. It seems that girls and boys have an equal chance of participating in activity of a higher intensity if their childhood proficiency is similar. However, we know that girls tend to perform object control skills with less proficiency [9,32–34], so there is particular reason to target improving the object control skills of girls.

School grade was a significant predictor for participation in any vigorous activity and time spent in organized activity. This is likely because of the fact that in Australia, physical education and sport at school is not compulsory after grade 10. That childhood object control proficiency did not increase the probability of participation in organized activity (but approached significance), may be because of the smaller sample. Only grade 11 students were used, as all grade 10 students participated in compulsory activity at school.

Limitations

One limitation is using a self-report measure for physical activity measurement. However, because of the large sample tested in many different schools over a large geographical area, more objective physical activity measures would have been problematic to monitor. The APARQ has had reasonable validation [25]; however, further validation against more objective physical activity measures would be beneficial. Nevertheless, the APARQ was chosen as it identifies and quantifies most aspects of physical activity participation (including organized and nonorganized contexts) and is acceptable to the target group, having been used in Australia previously for key school based population studies [24].

Another limitation is the proportion of the original matched sample followed up (one third). This can be explained by the length of the follow-up period, which extended into adolescence, and in some cases beyond schooling and limiting the study to schools in the original intervention area. Perhaps the greatest influence on follow-up rates was the large number of children likely to have left the study area over the study period. This is partially offset by a higher consent rate in this age group than for similar studies [24]. There was also no differential loss to follow-up by gender; however, there was a difference in mean composite childhood skill score, suggesting followed up students may have been potentially more skilled. However, as the difference was only one point on a 30-point scale, loss to follow-up is unlikely to have biased our findings in any substantial way. Although there were grade differences in those followed up, the reason for lower follow-up in grade 11 was because less students of this age were located (students of this age in Australia can legally leave school). Also, we did not adjust for school-level variation. As there were 18 elementary and 28 high schools, with only 11 of the 50 school combinations (excluding those with zero) having more than six students, a cross-classified model was not seen as viable. Lastly, fundamental motor skills were not video-assessed, which would have permitted greater measurement scrutiny.

Conclusions

This study found that skill proficiency developed in primary school years significantly impacts on later physical activity. Object control skills, rather than locomotor, appear to be more crucial to total activity time, activity of a higher intensity and also to type of activity undertaken in adolescence. Further research would be beneficial to help determine the relative importance of object control and locomotor proficiency to physical activity. Study strengths include a good sample size and the use of a comprehensive battery of motor skills, equally divided between locomotor and object control [32–34]. Community-based and school interventions should therefore consider targeting fundamental motor skills as a strategy to promoting long-term activity. Motor skill programs in primary schools may be particularly important with particular attention paid to improving object control skills.

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