Does Childhood Motor Skill Proficiency Predict Adolescent Fitness?

LISA M. BARNETT[1], ERIC VAN BEURDEN[2,3], PHILIP J. MORGAN[4], LYNDON O. BROOKS[3], and JOHN R. BEARD[1,3,5]

[1]*Department of Rural Health (Northern Rivers), University of Sydney, Lismore, New South Wales, AUSTRALIA;* [2]*Health Promotion, North Coast Area Health Service, Lismore, New South Wales, AUSTRALIA;* [3]*Southern Cross University, Lismore, New South Wales, AUSTRALIA;* [4]*Faculty of Education and Arts, University of Newcastle, Newcastle, New South Wales, AUSTRALIA; and* [5]*New York Academy of Medicine, New York, NY*

ABSTRACT

BARNETT, L. M, E. VAN BEURDEN, P. J. MORGAN, L. O. BROOKS, and J. R. BEARD. Does Childhood Motor Skill Proficiency Predict Adolescent Fitness? *Med. Sci. Sports Exerc.*, Vol. 40, No. 12, pp. 2137–2144, 2008. **Purpose:** To determine whether childhood fundamental motor skill proficiency predicts subsequent adolescent cardiorespiratory fitness. **Methods:** In 2000, children's proficiency in a battery of skills was assessed as part of an elementary school-based intervention. Participants were followed up during 2006/2007 as part of the Physical Activity and Skills Study, and cardiorespiratory fitness was measured using the Multistage Fitness Test. Linear regression was used to examine the relationship between childhood fundamental motor skill proficiency and adolescent cardiorespiratory fitness controlling for gender. Composite object control (kick, catch, throw) and locomotor skill (hop, side gallop, vertical jump) were constructed for analysis. A separate linear regression examined the ability of the sprint run to predict cardiorespiratory fitness. **Results:** Of the 928 original intervention participants, 481 were in 28 schools, 276 (57%) of whom were assessed. Two hundred and forty-four students (88.4%) completed the fitness test. One hundred and twenty-seven were females (52.1%), 60.1% of whom were in grade 10 and 39.0% were in grade 11. As children, almost all 244 completed each motor assessments, except for the sprint run (n = 154, 55.8%). The mean composite skill score in 2000 was 17.7 (SD 5.1). In 2006/2007, the mean number of laps on the Multistage Fitness Test was 50.5 (SD 24.4). Object control proficiency in childhood, adjusting for gender (P = 0.000), was associated with adolescent cardiorespiratory fitness (P = 0.012), accounting for 26% of fitness variation. **Conclusion:** Children with good object control skills are more likely to become fit adolescents. Fundamental motor skill development in childhood may be an important component of interventions aiming to promote long-term fitness. **Key Words:** FUNDAMENTAL MOTOR SKILL, CARDIORESPIRATORY ENDURANCE, CHILD, LONGITUDINAL

The increasing prevalence of obesity in many developed countries has led to a growing interest in the determinants of physical activity in the general population. Because physical activity has a strong dose relationship to fitness (7), the nature and the relative importance of fitness determinants may also be critical (29). A recent review suggests that cardiorespiratory fitness or endurance is associated with both obesity and cardiovascular disease factors (29), and there is also a significant relationship between adolescent cardiorespiratory fitness and later body fatness (2,12).

In fact, cardiorespiratory fitness is emerging as a factor even more deserving of attention than physical activity. Fitness has been found to be a stronger predictor of mortality in adult men than activity patterns (23), and cardiovascular risk factors seem to relate more strongly to cardiorespiratory fitness than components of physical activity in children and adolescents (16). Yet despite the importance of physical fitness, cardiorespiratory fitness among youth is declining (11). As fitness in adolescence is closely related to fitness in adult years (33,36), improving the cardiorespiratory fitness of adolescents through increases in time spent in vigorous activity and high-intensity training should be an important public health priority (29).

One possible determinant of adolescent fitness is motor skill proficiency. Motor development models propose many levels through which a child must progress to achieve motor proficiency. Fundamental motor skills, either locomotor (involving movement, e.g., hopping) or object control

Address for correspondence: Lisa M. Barnett, MPH, Bch, Soc Sci, Department of Rural Health (Northern Rivers), University of Sydney, PO Box 3074, Lismore, NSW 2480, Australia; Email: lisa.barnett@ncahs.health.nsw.gov.au.
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(involving manipulation of an object, e.g., kicking), are usually perceived as occurring after a stage (or stages) that involves birth reflexes. Mastery of fundamental motor skills provides the foundation for the development of more sports-specific skills (15). Cross-sectional studies suggest that fundamental motor skill proficiency is related to physical activity participation in children and youth (4,15,24,37), and there is evidence that youth with poorer fundamental motor skill proficiency have lower cardiorespiratory endurance (4,15,24,32,37). Because motor skill proficiency tracks through childhood (6,21), it is plausible that children with poorer motor skills may become less active adolescents with associated poorer fitness levels. However, no longitudinal research has investigated whether fundamental motor skill proficiency in childhood predicts adolescent fitness. This article examines the relationship between childhood motor skill proficiency and subsequent adolescent cardiorespiratory fitness as part of a longitudinal cohort study known as the Physical Activity and Skills Study (PASS).

SUBJECTS AND METHODS

In 2000, 1045 children from 18 randomly selected and stratified primary (elementary) schools in a study area comprising 24555 km^2 in New South Wales (NSW), Australia, had their proficiency in a battery of motor skills assessed for a school-based physical activity intervention (34). Mean age of the sample was 10.1 yr (range = 7.9–11.9 yr).

In 2006/2007, the list of original study participants (1021 had initials on records and 929 records (91.0%) matched by gender and name to class roll) was sent to 41 consenting high schools in the original study district to identify adolescent students for follow-up as part of the PASS. One school in the study area did not consent to participation. When students' names were identified on the high school register, students were given a letter inviting them to participate in the PASS, an information sheet, and a consent form. Students who returned a consent form signed by their parents/guardian and themselves were included in the PASS sample. Ethics approval was gained from the University of Sydney (07-2006/9243), the NSW Department of Education and Training (06.296), and the local Catholic Diocese.

Slightly more than half of the 928 original (one student died before consent) participants (51.8%, n = 481/928) were in 28 schools. Each of these students was approached to participate in the study, with a consent rate of 61.7% (n = 297/481) and 57.4% (n = 276/481) ultimately assessed as part of the PASS. The overall follow-up rate was 29.7% (276/928). The followed-up sample of 276 did not differ by gender (χ^2 = 2.403, P = 0.121) but was more likely to have been originally tested in grade 4 (61.5%) than in grade 5 (38.5%; χ^2 = 22.666, P < 0.0001). This may reflect the greater difficulty of finding older participants at follow-up because they are more likely to have left the school system. Participants not lost to follow-up also had a slightly higher (17.5 compared with 16.5) mean composite childhood fundamental motor skill score (t = −2.60, P = 0.009). The childhood fundamental motor skill proficiency of the 244 students with fitness test results was also higher (17.7 compared with 16.7) than those who did not consent (t = −2.18, P = 0.030).

Data collection. Data were collected by the study coordinator and three research assistants. The assistants completed 3 d of training facilitated by the study coordinator and a trainer who had trained teachers in fundamental motor skill assessment and assessed children as part of a separate study (17). The majority of data (>94%) were collected over term 4 in 2006, with the remainder early in term 1 in 2007 (both over summer).

Motor skill measurement. The initial intervention had used the Australian resource, "Get Skilled Get Active," (New South Wales Department of Education and Training 2000: DET Product Number 10614/DVD) to assess the eight (kick, catch, overhand throw, hop, side gallop, vertical jump, sprint run, and static balance) motor skills. This resource specifies a battery of fundamental motor skills tests, eight of which were validated in an original manual (catch, overhand throw, kick, forehand strike, sprint run, leap, dodge, and vertical jump) (9), returning reliability estimates (alpha coefficient method) of r = 0.70 (P < 0.01) or greater for all skills except the leap and run (r = 0.13 and r = 0.17, respectively; not significant). Four additional 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 (28).

Seven skills, three object control (kick, catch, and overhand throw) and four locomotor (hop, side gallop, vertical jump, and sprint run), assessed in 2000 were reported on in this study. This battery includes skills that both males and females have demonstrated performance mastery (22,24,35). Each skill is made up of five or six features considered integral to the proficient performance of the skill. For example, the catch consists of six features: 1) eyes focused on the object throughout; 2) feet move to place body in line with object; 3) hands move to meet the object; 4) hands and fingers relaxed and slightly cupped; 5) catch/control object with hands only, well-timed closure; and 6) elbows bend to absorb force of object.

The testing procedure allowed students to observe a fundamental 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 consistently over five occasions (9). If there was any uncertainty about whether a feature was consistently present or not, the assistant was instructed to check the feature as absent. For the hop and side gallop, the skill was observed as students traveled back and forth once between two points 15 m apart. The sprint run was observed as students ran as fast as possible between two points 20 m apart. Interrater reliability was reported previously as kappa = 0.61 (34).

Cardiorespiratory fitness measure. Cardiorespiratory "fitness" or "endurance" was estimated indirectly in 2006/2007 from the number of laps completed on the Multistage Fitness Test (also known as the 20-m Shuttle Run Test, Beep Test, or PACER) (20). This test was selected over other field measures of cardiorespiratory endurance such as timed and distance runs because it has been shown to be more motivational and appropriate for indoor testing and is less influenced by pacing among children and adolescents (10). It is also considered to be an appropriate and time-efficient test of aerobic fitness for large groups of students (10). Students are required to run between two lines 20 m apart (one "lap") starting at 8.5 $km \cdot h^{-1}$ (level 1) and increasing by 0.5 $km \cdot h^{-1}$ every 2 min, in time with a recorded beep signal, with each increase corresponding to a change in level. The number of "acceptable" laps completed is determined by the student not keeping pace with the signal from the tape for two consecutive laps (whereupon they are withdrawn from the test) or the student withdraws themselves (10).

Students were played the initial taped introduction that describes the test protocol. Students were advised they must keep in time with the "beep" sound and must place their foot on or over the line each time. The 20-m distance was marked out using a tape measure and witches' hats. Students were run in groups of no more than 15 to ensure adequate spacing. On termination, each student had their final level and shuttle scores written on their hand by the study coordinator, and scores were recorded when all students finished.

Students were also asked to specify date of birth, gender, and language spoken at home and all organized physical activities (activities involving regular classes, training, or competition that were somewhat structured or formal and had a coach, instructor, or teacher) in which they participated in a usual week, in both summer and winter. The validated Adolescent Physical Activity Recall Questionnaire was used for this assessment (3).

Data and analysis. For the fundamental motor skill measures, the number of features rated as present or correct was summed for each subject. For the descriptive reporting by skill, all features correct was considered as "mastery," all but one feature correct as "near mastery," and more than one feature incorrect as "poor." Categories of "mastery" and "near mastery" were combined and termed "advanced skill proficiency" (5). Each skill (except the sprint run) 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, and overhand throw) and three locomotor skills (hop, side gallop, and vertical jump) (27).

Scores for the Multistage Fitness Test were based on the last level and shuttle completed by a student. This result was converted to the number of laps achieved to create a continuous variable for analysis. We report cardiorespiratory fitness first in terms of the number of laps achieved and secondly after adjusting for age and gender. We adjusted levels using the Cooper Institute for Aerobics Research standards, constructed to ascertain the level of cardiorespiratory fitness needed to decrease risk of all-cause mortality (above 20th percentile for males and 40th for females) (8). Each physical activity was assigned a MET value (1 MET = 3.5 mL $oxygen \cdot kg^{-1}$ body $weight^{-1} \cdot min^{-1}$) from a comprehensive list of physical activities (1). As per the SPANS, activities <10 min in duration, with a MET value of <3.0, or less than once per week were excluded (3). To gain a list of highly reported voluntary out-of-school–organized sporting activities, "physical education," "sports science," and "school sport" were excluded.

A general linear model in SPSS (SPSS, Inc, Chicago, IL; http://www.spss.com/) was fitted to examine the relationship between fundamental motor skill proficiency in childhood and cardiorespiratory fitness (number of laps achieved on the Multistage Fitness Test) in adolescence. The dependent variable (cardiorespiratory fitness) was square root-transformed before analysis to normalize its distribution. The relationship between school grade, gender, childhood object control proficiency and childhood locomotor proficiency, and fitness in adolescence was initially assessed univariately for significance.

Significant variables were included as main effects in the model. Interactions between significant motor skill proficiency variables and gender were included to examine whether the relationships between motor skill proficiency and fitness differed between male and female students. Interaction terms were only retained in the final model if found significant. Predicted values of cardiorespiratory fitness, on the basis of the model parameter estimates, were back-transformed from their square root values and plotted against the observed range of object control variables by gender (Fig. 1).

Because there was only data for half the sample (n = 154), a separate linear regression examined the ability of advanced performance of the sprint run in childhood to predict cardiorespiratory fitness in adolescence. The relationship between gender, advanced performance of the sprint run, and fitness in adolescence was initially assessed univariately for significance. School grade was not included because the sprint run was primarily only assessed for one grade (grade 4, n = 140; grade 5, n = 14). Univariately, the sprint run was found not to be a significant predictor. However, the sprint run was still tested in a model with gender and the interaction term between gender and sprint run to see if the relationship between childhood performance of the sprint run and adolescent cardiorespiratory fitness differed according to gender.

RESULTS

Sample. Of 276 students followed up for the PASS, 234 (84.8%) completed the Multistage Fitness Test. Of 42 nonparticipants, 31 were unwilling to do some aspect of the

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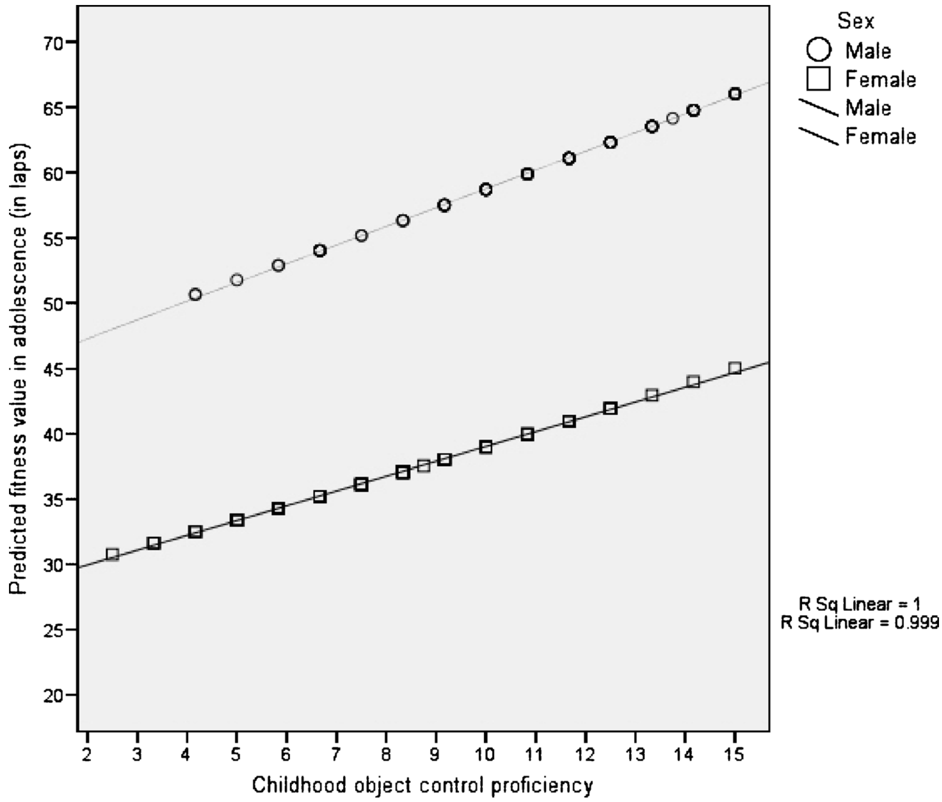

FIGURE 1—Predicted values for cardiorespiratory endurance in adolescence (in laps) on the basis of childhood object control proficiency by gender.

testing/surveying. Of 42 nonparticipants, 10 provided a Multistage Fitness Test result undertaken during physical education at school in the previous 3-month period. These results were included bringing the total number of students with fitness results to 244 (88.4%). Slightly more than half of this sample were females (52.1%, n = 127), with 60.1% (n = 146) in grade 10 and 39.0% (n = 97) in grade 11. All but one spoke English at home.

Childhood motor skill proficiency. Nearly all of the 244 students followed up were assessed in the catch, kick, overhand throw, vertical jump, side gallop, and hop. The sprint run was only assessed for students in one of the two school grades (Table 1). Mean composite childhood motor skill score was 17.7 (SD 5.1). Overall, males were more proficient with a mean of 19.3 (CI 18.4–20.2) compared with females with a mean of 16.4 (CI 15.5–17.3). There were no differences between those originally tested in grade 4 and those tested in grade 5 in terms of childhood locomotor skill proficiency (t = −0.42, P = 0.677) or object control skill proficiency (t = −1.36, P = 0.174).

Males were more proficient at performing object control skills, 11.5 (CI 11.0–12.0), compared with females, 7.9 (CI 7.5–8.4). More males possessed advanced skills in the catch, overhand throw, and kick. More males also possessed advanced skills in the sprint run, which is a locomotor skill. For the other locomotor skills, although females scored slightly higher in skill proficiency, this did not reach significance (8.5 compared with 7.8; t = −1.86, P = 0.064). This pattern was repeated for the vertical jump, side gallop, and hop (Table 1).

Cardiorespiratory fitness and sporting participation in adolescence. The mean number of laps completed was 50.5 (SD 24.39). Males achieved higher cardiorespiratory fitness scores, with a mean of 63.4 laps

TABLE 1. Percentage of students who possessed advanced skills in childhood, by skill and gender, and the mean number of laps achieved on the Multistage Fitness Test in adolescence by gender.

	Childhood				Adolescence					
	Advanced Skills %				Mean No. of Laps (n = 244)					
Skills	Male	Female	x^2	P	Male	CI	Female	CI	T	P
Catch (n = 243)	62.4	47.6	5.345	0.021	63.4	59.0–67.9	38.6	35.4–41.7	9.21	0.0001
Kick (n = 243)	61.5	13.5	60.336	0.0001						
Overhand throw (n = 240)	50.4	14.4	35.942	0.0001						
Side gallop (n = 244)	43.5	54.0	2.648	0.104						
Vertical jump (n = 236)	25.4	34.4	2.263	0.133						
Hop (n = 244)	13.7	16.7	1.254	0.517						
Sprint run (n = 154)	46.3	29.6	6.064	0.014						

TABLE 2. The five most reported organized sporting activities for each season, for males and females, as a percentage of the total organized activities reported for that season and gender.

	Organized Physical Activity							
	Summer				Winter			
	Males		Females		Males		Females	
	Activity	%	Activity	%	Activity	%	Activity	%
1	Cricket	24	Touch football	11	Football	39	Netball	22
2	Touch football	18	Swimming	11	Soccer	23	Soccer	13
3	Football	18	Dance	11	Hockey	12	Hockey	11
4	Basketball	4	Netball	10	Basketball	3	Dance	8
5	Squash	3	Football	5	Baseball	2	Aerobics	5
Cumulative total		80		70		86		78

compared with 38.6 laps for females, see Table 1. However, after adjusting according to the Cooper Institute for Aerobics Research standards for males and females and different ages (8), there was no significant difference between males and females, with 59.8% of males and 63.0% of females reaching the specified standard (χ^2 = 0.260, P = 0.610). There was no relationship between cardiorespiratory fitness and school grade. Students from grade 10 recorded a mean of 49.9 laps (CI 45.1–53.7) compared with 51.0 (CI 45.9–56.1) for students from grade 11.

The five most reported organized physical activities in summer and winter for males and females are reported in Table 2. Touch football and football were popular physical activities in summer for both males and females. Cricket was the most reported activity for boys in summer but does not feature in girls five most reported activities. Swimming, dance, and netball are highly reported among girls but not among boys. In winter, among boys, football was the most reported activity, whereas for girls, netball participation rates were the highest. Soccer and hockey were popular activities between both sexes in winter.

Childhood motor skill proficiency and adolescent cardiorespiratory fitness. Table 3 shows the unadjusted univariate relationships and the final model of adjusted parameter estimates for the relationship between object control proficiency and cardiorespiratory fitness in adolescence. The final model, adjusting for gender (P = 0.000), revealed that object control proficiency in childhood was associated with adolescent cardiorespiratory fitness (P = 0.012), accounting for 25.9% (R^2 = 0.259) of the variation in fitness (Table 3). The interaction between gender and object control proficiency was not significant (P = 0.390) and was excluded from the final model.

Predicted values from the final model showed that boys in adolescence achieve approximately 20 more laps than girls with the same level of childhood object control proficiency. Children of either gender with good object control skills (score > 10/15) achieved, on average, more than six additional laps on the Multistage Fitness Test than those with poor (score < 5) childhood object control skills.

Table 4 illustrates the unadjusted univariate relationships and the final model of adjusted parameter estimates for the relationship between advanced performance of the sprint run and cardiorespiratory fitness in adolescence. The final model, adjusted for gender (P = 0.000), revealed that advanced performance of the sprint run in childhood was not associated with adolescent cardiorespiratory fitness (P = 0.102). The interaction between gender and advanced skill run performance was also not significant (P = 0.173) and was excluded.

DISCUSSION

This is the first study to examine the relationship between childhood motor skill proficiency and adolescent cardiorespiratory fitness. We found that object control proficiency observed in elementary school predicted subsequent fitness levels in adolescence. In fact, predicted values from the final model showed that children of either gender with good object control skills achieved on average more than six additional laps on the Multistage Fitness Test than those with poor childhood object control skills. Childhood locomotor skill proficiency did not predict subsequent fitness levels.

These findings are consistent with previous cross-sectional studies. The 1997 NSW Schools Fitness and Activity Survey found that kick and strike for boys, and throw for girls, were correlated with fitness among grade 10 students (26), and in another cross-sectional study, kicking and throwing were also associated with a combination of physical fitness measures (32).

One plausible explanation for why object control skills predicted subsequent fitness is that these types of skills

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TABLE 3. Unadjusted estimates of covariates and final adjusted parameters for the relationship between object control proficiency and cardiorespiratory fitness in adolescence.

	Univariate Relationships				Final Model			
Effect	*B*	*P*	Lower CI	Upper CI	*B*	*P*	Lower CI	Upper CI
Intercept (females at 0 object control proficiency)					5.313	0.000	4.681	5.945
Gender (males–females)	1.750	0.000	1.362	2.137	1.418	0.000	0.954	1.881
Grade	−0.064	0.781	−0.518	0.390			Excluded	
Object control proficiency	0.217	0.000	0.152	0.281	0.093	0.012	0.021	0.165
Locomotor proficiency	0.022	0.557	−0.051	0.094			Excluded	

Final model R^2 = 0.265 (adjusted R^2 = 0.259).

TABLE 4. Unadjusted estimates of covariates and final adjusted parameters for the relationship between advanced performance of the sprint run and cardiorespiratory fitness in adolescence.

	Univariate Relationships				Final Model			
Effect	*B*	*P*	Lower CI	Upper CI	*B*	*P*	Lower CI	Upper CI
Intercept (females at 0 proficiency)					6.569	0.000	5.926	7.212
Gender (males–females)	1.750	0.000	1.362	2.137	1.568	0.000	1.073	2.063
Advanced performance of sprint run	0.639	0.084	−0.088	1.365	0.542	0.102	−0.108	1.191

Final model R^2 = 0.221 (adjusted R^2 = 0.211).

(kicking, throwing, and catching) are often associated with physical activity experiences of a moderate and/or vigorous intensity (such as recreational or organized sports training and competition) (30). Thus, students who are proficient at performing these skills may participate more in the type of activities likely to increase fitness levels. This is supported by the type of organized sporting activities most reported in the current study. Of the sports reported by males in both summer and winter, all centered on object control skill ability (cricket, football, basketball, squash, soccer, hockey, and baseball). For girls, highly reported activities also benefit from object control skill proficiency (football, netball, soccer, and hockey). Dance and aerobics, which primarily use locomotor skills, were also reported by girls but only constituted 13% of the organized activities in winter. Physical activity opportunities of adolescents may thus be increased if they are competent at performing many prerequisite sports skills that may be associated with training and competition that develop cardiorespiratory fitness.

Our findings did not support previous cross-sectional research that has found an association between locomotor skill proficiency and fitness. The 1997 NSW Schools Fitness and Physical Activity Survey found that the sprint run and the jump were associated with fitness (26), and a study tracking a small group of children over time found that children with low locomotor competence (in the run, broad jump, and balance) performed less well each year than children with high motor competence on both fitness and motor skill competency measures (14). The same skills were measured with the same instrument in the PASS study as in the NSW Schools Fitness and Physical Activity Survey, so it is surprising that the sprint run was not predictive of fitness in our study. Because the Multistage Fitness Test is a cardiorespiratory test involving running, it might be expected that this skill would relate to fitness measured in this way (26). However, process-oriented motor skill assessments which assess technique (as opposed to speed or endurance) may not relate as expected to fitness as measured by the Multistage Fitness Test. It is also possible that because we had a reduced sample for this analysis, a larger sample would have provided different results. Lastly, the run is reported to have a low reliability estimate (alpha coefficient method, r = 0.17) (9), possibly indicating that assessment for the sprint run is not as accurate with this instrument.

An important finding of our study was that 26% of variance in adolescent cardiorespiratory fitness was explained by childhood object control proficiency. By comparison, the 1997 NSW Schools Fitness and Physical Activity Survey found that the battery of six skills (four being object control) assessed in grade 10 girls explained 28% of variance in fitness, whereas for boys, this measure only accounted for 18% (26). Even by adolescence, very few girls have reached proficiency in object control skills (only 20% of girls in grade 10 have advanced skills in the kick and overhand throw (4)). These findings suggest that if a girl possesses these skills in adolescence, the influence may be stronger on physical activity and subsequent fitness than for a boy. However, this study was cross-sectional, and our findings provide additional insight into the potential long-term influence of fundamental motor skill development in childhood on health-related behaviors later in life.

Consistent with other studies (19), we also found that boys completed more laps than girls on the Multistage Fitness Test. We also found that boys in adolescence achieved approximately 20 more laps on the Multistage Fitness Test than girls with the same level of childhood object control proficiency. However, the relationship between childhood object control proficiency and adolescent cardiorespiratory fitness did not differ by gender. In other words, higher skill in childhood predicted higher fitness in adolescent for both males and females. Also, after adjusting according to standards proposed by the Cooper Institute for Aerobics Research, there were no differences between the proportion of males and females that reached the required standard of fitness (girls according to this standard are not expected to reach the same level of fitness of boys). The proportion of boys (60%) and girls (63%) in the PASS who reached criterion standards of cardiorespiratory fitness associated with health benefits was comparable to that found in representative studies in the Australian population (67% for boys and 63% for girls in the Schools Physical Activity and Nutrition Study (4)).

Our study has indicated that a skill-oriented focus in childhood may help to address health-related concerns in later life through the promotion of cardiorespiratory fitness in adolescence. Assisting children to become competent and confident performers of object control or sports-related skills may lead to a greater willingness to participate in competitive and noncompetitive sporting activities that provide opportunities to improve fitness levels. In particular, our findings suggest that object control skills should be targeted through school and community interventions as a key strategy in promoting subsequent cardiorespiratory fitness. It is important that such skills are taught during the primary or elementary school years as children are at an optimal age in terms of motor skill learning (13). In addition, improving the object control skills of girls should be a priority because many girls lack proficiency in these skills (4), even by late adolescence. Existing school physical education and sport programs may not be sufficiently catering for girls who are not proficient at performing sports-related skills.

In the current climate of childhood obesity concerns, it has been suggested that school physical education classes are an effective forum to increase physical activity and fitness levels (18). Our findings suggest that a balanced approach for teaching (and developing) both skill and health-related fitness components is important. The Move It Groove It intervention managed to increase fundamental skill proficiency in physical education lessons without sacrificing physical activity (34), and the SPARK intervention reported substantial improvements in physical activity levels with a physical education curriculum that targeted both the development of motor skills and the improvements in health-related fitness (31). A continued challenge for physical educators is not only to increase object skill proficiency levels, particularly for girls, but also to increase health-related fitness components among students in physical education lessons.

LIMITATIONS

Although there was little evidence of bias, our findings should be considered in the light of a follow-up rate of one third. This was unavoidable due to the length of the follow-up period and the difficulties locating students who had moved between regions or schools. However, the consent rate in PASS was higher than for similar studies (4). Although there were some differences in grade between consenters and nonconsenters, the reason for lower consent in grade 11 was due to less students of this age being located (students of this age in Australia can legally leave school). There was also no differential loss to follow-up by gender; however, there was a difference in mean composite childhood skill score, suggesting that followed-up students may have been potentially more skilled. However, because the difference was only 1 point on a 30-point scale, loss to follow-up is unlikely to have biased our findings in any substantial way. In addition, maturation (13) and weight status (25) were not controlled for, both factors that can effect motor skill performance. Moreover, it would have been preferable to have had a complete data set for the sprint run to further explore whether locomotor skills can be predictive of fitness.

CONCLUSION

This study has shown that object control skill proficiency developed in primary school years has a strong influence on subsequent fitness in adolescence. Its strengths include a longitudinal cohort design, a valid and reliable measure of cardiorespiratory fitness, a good sample size, and the use of a comprehensive battery of motor skills, divided between locomotor and object control. Our findings suggest that community and school-based interventions should consider motor skill development as a key strategy in promoting cardiorespiratory fitness. Promoting the achievement of cardiorespiratory fitness among youth, not simply physical activity participation, has tangible health benefits for later adult life. Programs that balance skill acquisition with health-related physical activity are important. Object control skills should be a key skill focus, particularly for girls, because these skills are predictive of cardiorespiratory fitness.

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