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Physical Education, Obesity, and Academic Achievement: A 2-Year Longitudinal Investigation of Australian Elementary School Children

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Objectives. We determined whether physical education (PE) taught by specialists contributed to academic development and prevention of obesity in elementary school children.

Methods. Our 2-year longitudinal study involved 620 boys and girls initially in grade 3 in Australia, all receiving 150 minutes per week of PE. One group (specialist-taught PE; n=312) included 90 minutes per week of PE from visiting specialists; the other (common-practice PE; n=308) received all PE from generalist classroom teachers. Measurements included percentage of body fat (measured by dual-emission x-ray absorptiometry) and writing, numeracy, and reading proficiency (by government tests).

Results. Compared with common-practice PE, specialist-taught PE was associated with a smaller increase in age-related percentage of body fat (*P*=.005). Specialist-taught PE was also associated with greater improvements in numeracy (*P*<.03) and writing (*P*=.13) scores. There was no evidence of a reading effect.

Conclusions. The attenuated age-related increases in percentage of body fat and enhanced numeracy development among elementary school children receiving PE from specialists provides support for the role of PE in both preventive medicine and academic development. (*Am J Public Health*. Published online ahead of print September 22, 2011: e1–e7. doi:10.2105/AJPH.2011.300220)

The education and health of children are prominent considerations in the 21st century. Schools have always had a traditional focus on increasing literacy and numeracy proficiency in children, but now they are increasingly being tasked with preventing obesity as well. Regular physical activity is directly implicated in the prevention of childhood obesity; there is evidence, however, that it may also benefit cognitive development.[1,2]

Physical education (PE) in schools is an ideal vehicle by which to promote physical activity in children because it is available to all children, and teachers have the opportunity to integrate it into the overall education process. In government elementary (primary) schools in Australia, however, PE is usually conducted by generalist classroom teachers, many of whom have little PE teacher training, thereby diminishing its potential impact. In the United States, there is evidence of a decline in the time allocated to PE,[3–5] which may be related to the recent introduction of national literacy and numeracy assessments.[6] Data indicating changes in the time allocated to PE in Australia over recent decades are not available; however, the Australian government has also recently introduced national assessments of literacy and numeracy.

Recent publications summarizing the literature provide education authorities with little incentive to pay more attention to PE, either on academic grounds or in relation to prevention of childhood obesity. First, a comprehensive review,[7] although supportive of PE in general, could only conclude that allocating time to PE did not hinder classroom-based learning, a finding supported by a subsequent study incorporating a very large sample size.[8] Second, researchers conducting a meta-analysis found little evidence to support the claim that school-based physical activity programs were effective in combating childhood obesity.[9]

We believe, however, that more positive conclusions may have emerged had all the studies involved in the review and meta-analysis met certain conditions. For example, successful PE requires trained and motivated teachers with well-designed programs,[10] a feature lacking in some studies. Moreover, cross-sectional studies were frequently employed, which are susceptible to confounding factors such as socioeconomic status.[11] On the other hand, there were 7 quasi-experimental studies considered in the review conducted by Trudeau and Shephard,[7] from which they concluded that time spent on PE did not have any negative impact on academic achievement. There might have been stronger effects on academic achievement and body composition had all of the following conditions been met within a single study study:

1. involvement of specialist PE teachers,
2. provision of sufficient intervention time and numbers of participants,
3. reliable and valid academic assessments,
4. reliable assessment of body fat, and
5. appropriate control for age-related development.

Complying with these conditions, we investigated whether PE delivered by visiting specialist PE teachers in elementary schools influenced the academic performance and body composition of mid-elementary school children.

METHODS

We used a multilevel randomized quasi-experimental design involving an intervention conducted by visiting specialist teachers (specialist-taught PE) and a control group for which classroom teachers continued teaching commonly practiced PE programs (common-practice PE). A control group without PE is neither practically nor ethically acceptable, so we calculated any effect of specialist-taught PE in reference to the effect of common-practice PE.

We recruited schools from an Australian education jurisdiction through invitations to the principals in 2005. Of 30 schools invited, 29 schools accepted. We randomly assigned 13 schools (32 classes) to the specialist-taught PE group and 16 schools (36 classes) to the common-practice PE group after ensuring that the following conditions were satisfied. First, to match schools as well as possible in terms of the socioeconomic statuses of their suburbs, facilities, general administration, and teaching methods, we chose government-funded schools in outer-city suburbs of similar average family income as indicated by data supplied by the Australian Government Bureau of Statistics. Second, we ensured that specialist-taught and common-practice schools were geographically far enough apart to minimize any chance of a specialist-taught PE influence on common-practice PE programs.

Statistical Methods

Our measurements have a multilevel structure involving variation between schools, variation between children within schools, and variation within children. We chose to analyze change in the literacy and numeracy scores from grades 3 to 5 as the response variables, thus eliminating statistical complication arising from dependencies associated with the repeated-measures nature of these data. However, we included "school" as a random factor to allow for the possibility of a school (cluster) effect on changes in the literacy and numeracy scores. We used linear mixed modeling to quantify and assess the effects of specialist-taught PE on the differences between grade 5 and grade 3 literacy and numeracy scores and percentages of body fat. These models included adjustment for any effect of variation in the initial (grade 3) measurements on these differences. Other concomitant variables such as gender, physical activity, cardiorespiratory fitness (CRF), and percentage of body fat were considered and assessed as possible confounders of group effects. The physical activity and CRF variables were scaled by square roots to better meet linearity assumptions. For statistical computation, we used the statistical package GenStat for Windows version 13 (VSN International Ltd, Oxford, UK).

As part of the characterization and comparison of the specialist-taught and common-practice programs, we compared data obtained from observations of specialist-taught and common-practice classes using a linear mixed-model analysis of the empirical logits of percentage values, adjusted for random school effects.

Participants

The 620 participants were part of the Lifestyle of Our Kids study, as previously described.[12] Initially, they were in grade 3 of elementary school. Children's ethnic descent (1 or both parents) was as follows: White, 86%; Asian, 8%; Australian Aboriginal or Torres Strait Islander, 3%; Polynesian, 1%; data missing, 2%.

Specialist-Taught and Common-Practice Groups

Responding to a questionnaire, teachers from all schools (both specialist-taught and common-practice groups) reported that children received an average of 150 minutes per week of PE, including sport, over the 2 school years of the study, thereby satisfying local curriculum requirements. In all of our schools, all PE was conducted within school hours. The specialist-taught intervention was conducted in 13 schools by 1 of 3 visiting PE teaching specialists and involved 2 classes of 45 to 50 minutes per week for 75 of the 80 weeks of school over the 2-year period. The general classroom teachers associated with the specialist-taught group conducted the remaining 50 to 60 minutes of PE in 2 or 3 extra sessions per week. All 3 visiting specialist teachers were trained physical educators and received further training through the Bluearth Foundation, a registered charitable organization with the aim of improving health through physical activity.[13] The PE in the common-practice group was conducted only by general classroom teachers.

Factors Differentiating Specialist-Taught and Common-Practice Groups

We derived pertinent differentiating characteristics from class observations involving the SOFIT method[14] (6 observers were involved, and observer agreement met the required standards), from questionnaires to teachers, and from curriculum framework manuals from both the Bluearth Foundation and the local education authority.

The SOFIT data are shown in Table 1. There was a significant difference in the median percentage of class time devoted to vigorous physical activity, which represents an intensity of physical activity greater than that of normal walking (14.6% for specialist-taught PE vs 21.5% for common-practice PE; $P<.001$) and some indication of a difference in median percentage of lesson time devoted to moderate and vigorous physical activity (35.4% for specialist-taught PE vs 40.6% for common-practice PE; $P=.06$). The specialist-taught PE lessons devoted a significantly larger median percentage of lesson time to activities related to fitness, including strength, flexibility, and static and dynamic postural activities (17.6% for specialist-taught PE vs 2.1% for common-practice PE; $P<.001$). Common-practice fitness work mainly involved running activities, whereas specialist-taught PE emphasized strength, balance, and postural control. There was little evidence of any difference in the percentage of time spent on skill-related activities between the groups ($P=.11$). The specialist teachers spent a greater median percentage of the lesson personally demonstrating and participating in fitness-related activities than did the common-practice teachers (25.7% for specialist teachers vs 6.3% for common-practice teachers; $P<.001$). SOFIT observers also reported less variation in content and structure of the specialist-taught program, suggesting a more consistent approach to lesson planning and delivery by the specialist teachers.

We obtained further understanding of the differences between the specialist-taught and common-practice programs over the 2 years through our regular observations of lessons, discussions with the teachers, and reference to the respective teaching manuals. Differences included the following:

1. In providing moderate and vigorous physical activity, common-practice PE classes predominantly used walks, runs, and traditional games, whereas specialist teachers employed minor games and group activities.

TABLE 1—Median Percentages of Class Time Spent in Various Activities in Specialist-Taught and Common-Practice PE, as Determined by SOFIT Observations: Canberra, Australia, 2006 and 2008

SOFIT Characteristic[a]	Specialist-Taught PE, %	Common-Practice PE, %	P^b
Moderate or vigorous physical activity[c]	35.4	40.6	.06
Vigorous physical activity[d]	14.6	21.5	<.001
Fitness activity[e]	17.6	2.1	<.001
Skills practices[f]	12.1	10.6	.11
Activity demonstration[g]	25.7	6.3	<.001

Note. PE = physical education.
[a]SOFIT[14] is a system by which the activities of 4 randomly selected children and the teacher are observed on a rotational basis. The duration of each unit of observation is 10 seconds, followed by 10 seconds of recording, and this is continued for the entirety of the class. There were 97 SOFIT observations of specialist-taught PE classes and 97 observations of common-practice PE classes.
[b]*P* values apply to differences between mean logit percentage values following a formal linear mixed-model analysis adjusting for random school effects.
[c]Moderate or vigorous physical activity denotes activity in which the energy required for normal walking (or more) is expended.
[d]Vigorous physical activity denotes activity in which more energy than that required for walking is expended.
[e]Comprised cardiovascular endurance, strength, or flexibility activity.
[f]Comprised ball or movement skill activities.
[g]Teacher demonstrated or participated in class activities.

2. In teaching skills, the common-practice method was to introduce the skills (e.g., catching, throwing, hitting, and kicking) through structured practices in groups typical of traditional practices for sports such as football or basketball, whereas the specialist teachers developed skills through a less structured exploratory approach involving individual, partner, and small-group practices with balls, beanbags, hoops, and Frisbees.
3. The specialist teachers (but not the common-practice teachers) emphasized development of posture, balance, and breathing control through a variety of yogalike static and dynamic activities, which often required muscular strength.
4. The specialist teachers always participated in activities, whereas common-practice teachers usually did not.
5. The specialist teachers (but not the common-practice teachers) consistently encouraged individual and group discussions of game and skill development strategies and introduced quiet periods of reflection at the end of the lesson.

Finally—in a finding of interest to educational authorities—the sustainability and economic viability of the specialist-taught PE program was enhanced by an ongoing course of professional development for the classroom teachers provided by the visiting specialists.[13]

Measurements

We measured children's height to the nearest 0.001 meter using a portable stadiometer and body weight to the nearest 0.05 kilogram with portable electronic scales. We used dual-energy x-ray absorptiometry (DXA) to measure body composition and QDR version 12.4:7 (Hologic Discovery QDR Series, Hologic Inc, Bedford, MA) to calculate the percentage of body fat. We used the 20-meter multistage run, a well-established field test for children, to estimate CRF.[15] For measurement of physical activity, children wore pedometers on their hips for 7 consecutive days, and we calculated a physical activity index as previously described.[16] The same technician was involved for every DXA measurement in both grades 3 and 5, and the same scientist was involved in every physical activity and fitness measurement, supervising a small team of technicians.

Literacy and Numeracy Measures

The classroom teachers administered the literacy and numeracy tests in grades 3 and 5 (2006 and 2008). In grade 3, the tests were designed and assessed by the local government education authority; in grade 5, the tests were the responsibility of the Australian Curriculum, Assessment and Reporting Authority in conjunction with the local jurisdiction.[17] The latter body was responsible for the scaling of the data. All children undertook the same pairs of tests in grades 3 and 5.

Timing of Measurements

The children undertook the physical activity, fitness, and body composition assessments in the same order and in the same months in grades 3 and 5 (in 2006 and 2008, respectively). The grade 3 assessments were finished 3 weeks before the start of the specialist-taught PE intervention, which began in April 2006. Because this study was part of a multidisciplinary study involving several areas of investigation, it was necessary to introduce the intervention 2 months before the first literacy and numeracy assessment in grade 3. The intervention continued through all of the second assessments in grade 5.

RESULTS

Table 2 summarizes raw data describing the participants' characteristics, together with summaries of the raw values of physical activity, CRF, percentage of body fat, and literacy and numeracy scores measured in grades 3 and 5, cross-classified by gender, year, and group.

Effects of Specialist-Taught Physical Education

Percentage of body fat. As shown in Figure 1, the mean increase in percentage of body fat in the specialist-taught group was 0.66 percentage points less than that in the common-practice group ($P = .02$), with little evidence of any gender-by-intervention interaction ($P = .1$). Adjustment for potential confounders, in this case for physical activity and CRF, did not account for the intervention effect. For purposes outlined in the Discussion section, we also analyzed the effect of the specialist-taught program on the surrogate of adiposity, body mass index (BMI, defined as weight in kilograms divided by the square of height in meters), but there was little evidence of any effect ($P > .2$).

TABLE 2—Physical and Performance Characteristics of Participants, With Raw Data Cross-Classified by Gender, School Grade, and PE Group: Canberra, Australia, 2006 and 2008

	Grade 3		Grade 5	
Variable	Specialist-Taught PE, Mean	Common-Practice PE, Mean	Specialist-Taught PE, Mean	Common-Practice PE, Mean
Height, cm				
Boys	132.0	131.2	141.9	141.5
Girls	130.1	130.5	140.6	141.0
Weight, kg				
Boys	29.8	29.6	36.5	36.7
Girls	29.4	29.9	36.7	36.9
Body fat, %				
Boys	23.0	22.6	24.1	24.8
Girls	28.0	28.0	28.8	28.8
BMI, kg/m^2				
Boys	17.0	17.1	18.0	18.2
Girls	17.2	17.4	18.4	18.4
PA, square root of steps/d				
Boys	108.6	107.7	102.7	103.1
Girls	97.4	98.4	93.1	94.7
CRF, square root of stages reached				
Boys	2.01	2.01	2.35	2.33
Girls	1.81	1.86	2.06	2.07
Numeracy score				
Boys	418.6	425.3	499.7	489.9
Girls	414.5	419.6	482.6	473.8
Writing score				
Boys	408.0	402.1	482.3	466.2
Girls	439.6	427.0	505.5	492.9
Reading score				
Boys	415.2	406.9	498.0	486.3
Girls	439.6	429.4	521.1	505.2

Note. BMI = body mass index; CRF = cardiorespiratory fitness; PA = physical activity; PE = physical education. For boys, n = 158 for specialist-taught PE and 159 for common-practice PE; for girls, n = 154 for specialist-taught PE and 149 for common-practice PE. This number of repeated measures varied slightly in each measure. There were no significant differences between the specialist-taught and common-practice groups in any of the baseline measures ($P > .05$). Information on the methods of scaling of the literacy and numeracy scores is available from the Australian National Assessment Program Web site.[17]

Physical activity and fitness. There was little evidence of any differences between specialist-taught and common-practice PE in changes in physical activity or CRF during the period of investigation ($P > .1$ in both cases).

Writing. As shown in Figure 2, the average improvement in numeracy score over the 2 years was 10.9 points greater in the specialist-taught group than it was in the common-practice group ($P < .03$), with no significant interaction between gender and intervention ($P = .73$). This difference represented 2.2% of the overall average final numeracy score.

Writing. The average improvement in writing score was 10.1 points greater in the specialist-taught group than it was in the common-practice group, but it was not statistically significant ($P = .13$). There was no interaction between gender and intervention ($P = .52$).

Reading. The average improvement in reading score was 5.8 points greater in the specialist-taught group than it was in the common-practice group, but it was not statistically significant ($P = .41$), and there was no interaction between gender and intervention ($P = .88$).

Relationships Among Combined Data

When we combined all data or analyzed data by group or gender, we detected no significant relationships between writing, reading, or numeracy scores and physical activity, CRF, or percentage of body fat (all $P > .1$).

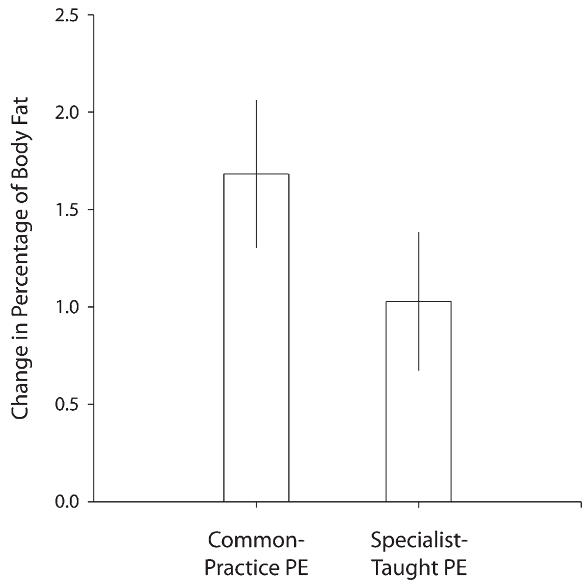
DISCUSSION

Our data indicate that an appropriately designed and administered PE program can produce benefits for elementary school children, not only by attenuating increases in percentage of body fat typical of children in this age group but also by enhancing numeracy development.

It is possible for an analysis of an intervention to demonstrate statistically significant effects, even though the small magnitudes of the changes raise doubt as to their practical effect in the community. The practical significance of the 10.9-point greater improvement in numeracy score in the specialist-taught group was illustrated by an announcement from the local jurisdiction's minister for education that specialist literacy and numeracy teachers were to be employed with the aim of improving overall scores by 9 points.

Body fat increased 0.66% less in the specialist-taught group than it did in the common-practice group. The practical significance of this finding is illustrated when we convert the percentage to actual grams of fat: approximately 0.24 kilogram in both genders. With the average increases in fat mass over the 2 years being close to 2.2 kilograms for both boys and girls, the specialist-taught effect of 0.24 kilogram was a reduction in fat mass increase (relative to common-practice group) of about 11% in both genders.

Our data do not support the conclusion of the meta-analysis of Harris et al.[9] that school-based physical activity interventions are ineffective at improving body composition. However, our findings relating to body composition are consistent with a more recent study conducted over 1 year with Swiss children[18] that was not considered in the Harris et al. meta-analysis. The Swiss researchers, who also used a PE



Note. PE = physical education. Data for boys and girls were combined. The effect is the value by which the specialist-taught group improved more than the common-practice group (effect = −0.66; SE = 0.260; $P = .02$). Bars represent means; lines represent SEs.

FIGURE 1—Changes in percentage of body fat over 2 years (grades 3–5) for the specialist-taught and the common-practice physical education groups, with adjustment for initial values: Canberra, Australia, 2006 and 2008.

intervention conducted by PE specialists compared with control groups in which PE was taught only by classroom teachers, reported lower age-related increases in skinfold sum and BMI in the intervention group.

Notwithstanding the BMI attenuation observed in the Swiss study, a factor that may have confounded the conclusions of the previously cited meta-analysis[9] was the common use of BMI to represent change in body composition in the studies considered. BMI measures do not distinguish between changes in fat mass and lean body mass. Consequently, when BMI is used, a physical activity intervention–induced reduction in fat mass may be masked by a simultaneous increase in lean mass. Moreover, BMI may pose further problems when used as a surrogate of adiposity in children,[19] as illustrated by its failure to detect any specialist-taught PE effect in our current work, despite a clear specialist-taught PE effect on percentage of body fat as shown by DXA.

Irrespective of the quasi-experimental design of our study, we acknowledge the need to exercise caution regarding any assertions of causality. Nevertheless, our data do promote certain insights that may encourage collegial debate, and we offer the following comments.

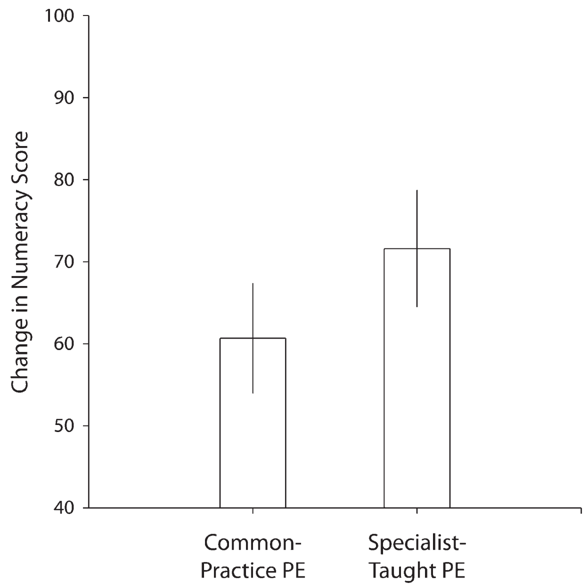
Evidence derived from cross-sectional relationships has stimulated interest in physical activity,[20] CRF,[6] and adiposity[21] as potential influences on literacy and numeracy, and evidence from animal and human neuroimaging[1] has linked physical activity and CRF with cognitive function. Indeed, prominent researchers in the field of neurobiology and exercise science have stated a consensus view that voluntary physical activity and exercise training can favorably influence brain plasticity by facilitating neurogenerative, neuroadaptive, and neuroprotective processes.[22]

In the current study, however, we found little evidence of any relationships between changes in literacy and numeracy scores and changes in physical activity, CRF, or percentage of body fat. Our longitudinal data therefore cannot be used to support any argument that physical activity, CRF, or percentage of body fat have a direct causal effect on literacy and numeracy development. We therefore suggest another possibility.

In recent decades, there has been considerable neuropsychological and imaging evidence of cerebro-cerebellar interaction, implicating cerebellar function with cognitive function such as executive control, memory, and learning.[23,24] Balance and postural challenges were prominent features of specialist-taught PE but not of common-practice PE, and the role of the cerebellum in balance and postural control is well established. This finding in turn provides support for the suggestion that the influence of specialist-taught PE on academic achievement may be mediated through cerebellar function. This suggestion is supported by a study of adolescents that found that just 10 minutes of specific coordination activity, compared with 10 minutes of general physical activity, improved attention and concentration.[25] If improved concentration was a mediator of the effect of specialist-taught PE on academic development, then improved concentration may have resulted from the demands made on concentration powers associated with attempting to master complex balance challenges. Interestingly, several classroom teachers did make unsolicited comments that the specialist-taught PE program seemed to be improving students' concentration in class.

Another distinct program variation with potential influence was the specialist teachers' regular interaction with the children in analyzing and discussing movement challenges and game strategies. Observations have been made that successful PE requires motivated, well-trained teachers,[10] and that learning is likely to be enhanced when school settings emphasize mastery and understanding of skills.[26] Given the plasticity of children's developing brains, nerves, and muscles, together with the interaction of these organs, the specialist-taught PE program, in linking analytical thought with movement tasks, provides another possible avenue by which specialist-taught PE may have influenced numeracy scores.

In any case, our study provides further supporting evidence for the statement that "exercise may prove to be a simple, yet important, method of enhancing those aspects of children's mental functioning central to cognitive development."[27(p111)]



Note. PE = physical education. Data for boys and girls were combined. The effect is the value by which the specialist-taught group improved more than the common-practice group (effect = 10.9; SE = 4.9; P = .03). Bars represent means; lines represent SEs.

FIGURE 2—Changes in numeracy scores over 2 years (grades 3–5) for the specialist-taught and the common-practice PE groups, with adjustment for initial values: Canberra, Australia, 2006 and 2008.

Regarding the mechanisms behind the attenuation in percentage of body fat, we did not detect any change in physical activity between the groups. However, the 7-day pedometer records measure only walking and running activity and may not have been sufficiently specific or sensitive to detect any small average increase in weekly energy output of the specialist-taught group relative to the common-practice group that could have influenced percentage of body fat over 2 years. On the other hand, any specialist-taught PE attenuation effect on percentage of body fat implies a corresponding augmentation of percentage of lean mass. We therefore suggest that the specialist-taught PE program may have influenced percentage of body fat through its effect on lean mass, induced via its emphasis on strength-related activities.

Strengths of our study include the relative homogeneity of the schools and the statistical model, which included adjustments for potentially confounding issues such as socioeconomic status; the objectivity of physical activity, CRF, and percentage of body fat measurement and the continuity of measurement personnel; the administration of identical teacher-independent literacy and numeracy tests; and the objective measures applied in differentiating the specialist-taught and common-practice PE programs.

The main limitations included our inability to incorporate a true control group that had no PE, the reliance on classroom teachers' reports of allocated time, and the possible inability of the 7-day pedometer measures to detect small variations in energy output. Moreover, the intervention effects may have been more significant had the specialist teachers taught all lessons each week; however, the collaboration between the specialist and classroom teachers was considered a more economically realistic and sustainable proposition in terms of government funding in elementary schools. Finally, in any longitudinal work a note on loss of data or attrition is relevant. Apart from the 620 children measured in both grades 3 and 5, we obtained some measures on 130 more children in grade 3. Because of absences from school on testing days, however, insufficient sets of data on those children, either initially or in grade 5, precluded the use of their data in our analyses. However, there is no reason to suspect that the reduction in our data set influenced the nature of any of our findings.

In summary, our data provide evidence that PE administered over 2 years by specialist teachers (assisted by classroom teachers) can contribute to body composition control and academic achievement in 21st-century elementary schools. ■

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Contributors

R.D. Telford was responsible for conceptualizing the project and for writing the initial and final manuscripts. R.B. Cunningham developed and carried out all statistical analyses, wrote the section on statistics, and played a leading role with R.D. Telford in the interpretation of the results, with assistance from R. Fitzgerald. L.S. Olive was responsible for characterizing the intervention. L. Prosser and X. Jiang provided advice throughout the study. R.M. Telford was responsible for the physical activity and fitness tests and database management. All authors read, modified, and approved the final manuscript.

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Human Participation Protection

This study was approved by the ACT Health and Community Care Human Research Ethics Committee and the Ethics Committee at the Australian Institute of Sport. Parental and child consent was obtained for all measures in this study.

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