

ORIGINAL ARTICLE

Rationale, design and methods of the HEALTHY study physical education intervention component

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The HEALTHY primary prevention trial was designed to reduce risk factors for type 2 diabetes in middle school students. Middle schools at seven centers across the United States participated in the 3-year study. Half of them were randomized to receive a multi-component intervention. The intervention integrated nutrition, physical education (PE) and behavior changes with a communications strategy of promotional and educational materials and activities. The PE intervention component was developed over a series of pilot studies to maximize student participation and the time (in minutes) spent in moderate-to-vigorous physical activity (MVPA), while meeting state-mandated PE guidelines. The goal of the PE intervention component was to achieve ≥ 150 min of MVPA in PE classes every 10 school days with the expectation that it would provide a direct effect on adiposity and insulin resistance, subsequently reducing the risk of type 2 diabetes in youth. The PE intervention component curriculum used standard lesson plans to provide a comprehensive approach to middle school PE. Equipment and PE teacher assistants were provided for each school. An expert in PE at each center trained the PE teachers and assistants, monitored delivery of the intervention and provided ongoing feedback and guidance.

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Introduction

HEALTHY was a middle school-based primary prevention trial with the main objective of reducing risk factors for type 2 diabetes in adolescents.¹ Of the 42 middle schools involved from seven centers across the United States, 21 were randomized to receive an intervention that integrated multiple components targeting the nutrition and physical activity environments, as well as behavior patterns and lifestyle choices of the students. The physical education (PE) intervention component intended to keep all students participating at increased levels of moderate-to-vigorous physical activity (MVPA). The intervention provided lesson plans, equipment and PE teacher training and mentoring, as well as school-wide educational and promotional activities

and events that were designed to enhance the message that physical activity was fun, easy to accomplish and a critical part of a healthy lifestyle. This paper describes (1) the rationale for the development of the HEALTHY PE intervention component, (2) the preparatory pilot work, (3) the curriculum and lesson plans, (4) the training program and (5) the implementation in schools. Other papers report on the design, methods and rationale of the nutrition intervention,² the behavior modification intervention³ and an integrated communications and promotions strategy.⁴

Background and rationale

Opportunities for youth to engage in physical activity are found both in and out of the school environment. School-provided PE classes and extracurricular sports or activity programs contribute considerably to the overall physical activity levels in children. Furthermore, there is a general belief that youth can obtain a substantial amount of activity

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in PE classes.⁵⁻⁷ The HEALTHY study investigators realized that, although school PE programs could not provide all the physical activities needed by youth, PE classes could have a considerable effect, particularly for the sedentary and overweight youth who are at the greatest risk of developing type 2 diabetes. Before or after school, programs have been used to increase physical activity in interventions targeting overweight and obesity.⁸ HEALTHY did not pursue that approach because of logistical issues and cost.

Exercise programs have the potential to reduce body fat and improve insulin sensitivity in children.^{9,10} Research in adults clearly indicates that moderately intense exercise (>40% maximal capacity) sustained for longer than 15–20 min decreases circulating insulin levels and increases insulin sensitivity.¹¹⁻¹⁶ Although there are limited data in youth on the influence of duration and intensity of exercise on insulin sensitivity, one study has suggested that 20–30 min of MVPA at least thrice a week may be necessary for improving glycemic status.¹⁷ In children with an increased risk for insulin resistance, weight loss and increased aerobic fitness improve insulin sensitivity.^{10,18}

Theoretically, MVPA should be sufficient to improve aerobic fitness and, if sustained for ~25 min, results in an increased total energy expenditure of ~12%,¹⁹ which should be sufficient to induce positive changes in body weight. The average increase in energy expenditure related to increased food intake is ~143 kcal per day.²⁰ In middle school-aged youth, there is a decrease in physical activity of 13–16% per day, or ~45 kcal compared with activity levels in elementary school children.^{21,22} Assuming that an adolescent of this age requires 1600–1800 kcal per day,²³ the increased energy intake from the 143 kcal because of increased portion sizes, combined with the lack of energy expenditure from decreased physical activity (45 kcal), represents a 190-kcal excess or 10–12% of total energy requirements. Thus, increasing the energy expenditure by 12% should influence body weight and aerobic fitness. Accordingly, a well-developed, consistently delivered program with sufficient MVPA should have a direct effect on weight status and insulin resistance, thereby reducing the risk of type 2 diabetes in youth. These assumptions provided the basis for the HEALTHY study PE intervention component.

Physical activity from PE classes

Although PE provides a regularly scheduled time when youth can be active, evidence indicates that PE lessons often provide only limited amounts of MVPA. For example, in the United States, TAAG (Trial for Activity in Adolescent Girls) reported that sixth grade girls spent an average of 37.9% of PE classes engaged in MVPA, when assessed using the SOFIT (System for Observing Fitness Instruction Time) instrument.²⁴ This finding is consistent with an earlier review of 30 studies that used heart rate monitoring and reported that students spent an average of $37.9 \pm 14.6\%$ of a PE session engaged in MVPA.²⁵ The same article noted that a mean of

$26.6 \pm 15.2\%$ of time in PE was spent engaged in MVPA for 10 observation studies and $46.8 \pm 13.9\%$ for 4 accelerometer-based studies. Collectively, these findings suggest that most schools do not meet the US Healthy People 2010 guidelines of ensuring that all students are engaged in MVPA for at least 50% of their PE classes.²⁶

A number of interventions have attempted to increase physical activity levels during elementary (primary) school PE lessons. CATCH (Child and Adolescent Trial for Cardiovascular Health), a large multi-site trial, examined the effect of professional development training and a PE curriculum designed to minimize sedentary time on the amount of activity in PE classes.²⁷ In some schools, PE was taught by regular classroom teachers and in others it was taught by PE specialists. Using the SOFIT instrument, they found that the amount of MVPA obtained from PE classes could be increased by using their curriculum and by proper staff training, with the greatest amount of activity obtained in classes taught by PE specialists. Although the MVPA in the PE classes increased significantly, the increase amounted to only a few minutes. In the 'Move it, Groove it' study of 18 rural Australian primary schools, the intervention, which included staff training, equipment supplied to the schools, PE teacher support and a whole-school approach for increasing physical activity, resulted in significant increases in fundamental movement skills and a small, non-significant increase in MVPA.²⁸

Although less work has focused on middle schools than on elementary schools, research has begun to examine how to increase the amount of MVPA obtained during middle school PE. The MSPAN (Middle School Physical Activity and Nutrition) study was a 2-year intervention that included 15 h of PE teacher training in year 1 and 6 h in year 2, focused on improving classroom management and instructional skills.²⁹ PE teachers were also provided with sample materials that were designed to aid in the development of more active PE lessons. Analysis of the amount of MVPA obtained during PE using the SOFIT instrument indicated that the intervention schools increased to 18% above baseline at the end of the 2-year intervention, and the percentage of class time engaged in MVPA increased to 52% of the overall lesson.²⁹ These studies indicate that it is possible to increase MVPA in PE classes with interventions that focus on staff training, provision of equipment and enhanced curriculum materials.

Pilot studies

On the basis of the evidence presented above, the HEALTHY study group conducted two pilot studies to examine how much physical activity could be obtained from middle school PE classes while meeting the state-mandated instructional guidelines.³⁰ The pilot studies showed that PE teachers were most comfortable using the standard unit-based approach to teaching. Hence, a conscious effort was made to

design the intervention curriculum using units centered on specific sports or activities (for example, basketball, soccer).

A 2003 pilot study was conducted in six US middle schools to examine the amount of MVPA that could be obtained in classes using our curriculum. Each class teacher was provided with 56 instructional cards that could be combined to make lesson plans and ~\$6000 worth of equipment to facilitate the use of team games involving 2–4 students per side. A physical activity coordinator (PAC) on the study staff provided in-service training for the PE teachers on topics, including high skills progression, classroom management techniques to facilitate small group activities and instructions to encourage student participation in PE. Each school was also provided with a qualified PE teacher assistant. A random sample of five students in each class wore heart rate monitors during the 8-week study to determine the number of minutes and percentage of class time spent engaged in MVPA defined as the number of minutes with a heart rate ≥ 130 b.p.m. (beats per minute). Over the 8 weeks of pilot interventions, MVPA was fairly constant across schools at approximately 63–76% of the monitored class time, excluding time to dress out. The minutes of MVPA were considered to be as good as or better than previous studies of middle school PE.^{6,24,29,31–34}

Although the activities that were delivered in the 2003 pilot study provided high amounts of MVPA, they did not meet the state-mandated instructional requirements. Therefore, another pilot study was conducted in 2004 in seven US middle schools to examine how much MVPA could be obtained when the activities were incorporated into lesson plans that met the state-mandated guidelines. The revised program was implemented with modified PE teacher training, the same equipment and a PE teacher assistant. Random heart rate monitoring, using the same procedures used in 2003, indicated that the participants engaged in MVPA between 49–58% of the lesson time with no differences between normal weight and overweight students.

On the basis of pilot work, the differences in class lengths and days at each of the seven sites, and the realization that there was limited possibility of obtaining and sustaining an entire PE class of MVPA while meeting the state-mandated curricular requirements, a school eligibility criterion of at least 225 min of PE classes for each 2-week period was established to provide the opportunity for students to receive at least 150 min of MVPA over 2 weeks in PE classes.

PE intervention component curriculum

The PE intervention component curriculum contained core teaching units that were included in all 3 years, elective units chosen by the local PE teacher to complete the PE program and locally developed units. The core units were selected on the basis of pilot study data showing they met the MVPA criterion and were popular with both students and PE

teachers. The core activities consisted of basketball, soccer (speedball embedded) and team handball. Before the HEALTHY study, team handball was not a routine activity at many schools, but our pilot studies found it to be extremely popular. These units were repeated in each successive grade and modified yearly to incorporate developmentally appropriate skills and fitness levels. In addition to these core units, the PE teacher could choose from a list of elective units to complete the PE program. The list of electives included badminton, cooperative/adventure games, dance, floor hockey, football, Frisbee, lacrosse, pickleball, softball, swimming, table tennis, tennis, track and field and volleyball. Specifically, cooperative/adventure activities, dance, fitness, football, softball, swimming and volleyball were developed for the sixth, seventh and eighth grades, whereas floor hockey, Frisbee, lacrosse, racquet sports, softball and track were developed for the seventh and eighth grades. Cooperative/adventure games were part of an introductory unit taught at the start of the year for the seventh and eighth grades to improve socialization. Jump rope was taught as part of the sixth grade fitness unit and then integrated throughout the unit plans in the seventh and eighth grades.

Each unit plan included 8–15 lessons. Lessons reflected ‘best practices’ of middle school PE and the NASPE (National Association for Sport and Physical Education) 2001 Position Statement on Appropriate Practice for Middle School Physical Education.³⁵ Lessons were developmentally appropriate for the designated grade level. Lesson scope and order were arranged to build skills and abilities sequentially.

All lesson plans included four major elements. Each lesson started with an ‘instant activity’ to which students were directed immediately on entering the class. Organization was low and instructions were simple and could be displayed in writing, for example, on a dry eraser board, poster or chalk board. Instant activities typically lasted 4–7 min. If possible, the activity was related to that day’s lesson, but all were intended to initiate levels of MVPA. For example, in the soccer unit, each student took a soccer ball and immediately began dribbling the ball around the gym. As more students entered the gym, the PE teacher or assistant organized a tag game or a keep-away game while the students continued to dribble the soccer ball.

The instant activity was followed by a ‘health-related physical activity.’ The health-related physical activities were gross motor or fitness activities designed to either produce MVPA or to increase muscular strength. These activities were usually related to the unit and lasted approximately 6–8 min. An example was a circuit fitness loop that included jump rope, weights, calisthenics, stair stepping, a balance task, a reaction test and a bounce pass station for the basketball unit. At this juncture in the lesson, accumulation of 10–15 min of MVPA was possible.

Third, the main body of the lesson focused on student acquisition of skills and knowledge. To maximize activity during this portion of the lesson, all students or small groups

of 2–4 students were given equipment and practice simultaneously; thus, once directions were given, there was little inactive time. Drill and practice used individual, partner and/or group activities, once again attempting to maximize activity levels. The goal was to obtain 5–10 min of MVPA during this portion of the lesson.

The practice portion of the lesson was typically followed by lead-up games using small groups and including the skill related to the unit of instruction. In the HEALTHY pilot studies, student and PE teacher interviews strongly suggested that they preferred to play games rather than participate in drills, which often involved standing in line waiting for a turn. Thus, small-group game play was used to improve MVPA. For example, instead of a typical soccer game with 11 players per side, lessons were written for multiple small areas with teams of 4 and no goalies. Smaller teams increased opportunities for individual skill practice and MVPA. PE teachers were trained on how to implement small-sided games in the lesson plans.

The small group games had the potential for accumulation of an additional 10–15 min of MVPA. To de-emphasize winning among the highly skilled individuals, games were kept short and opponents were shifted at frequent intervals. In many cases, rules were modified to insure increased activity for all students. For example, in floor hockey, the team had to complete three passes to three different individuals before a goal could be attempted.

The final part of the lesson was a closure or cool-down section in which there was no MVPA. During closure, the students were brought together for 1–3 min to collect equipment, debrief the lesson and to impart a health concept related to the HEALTHY study semester theme. These messages were developed by study group experts and included information on the importance of consuming water over sports drinks or soda, the importance of including fruits and vegetables in the diet, as well as information on trying new physical activities, reducing sedentary time, and improving energy balance.⁴ Stretching and other low-intensity exercises were part of the cool-down.

In total, the majority of the lessons had the potential to achieve 30–40 min of MVPA in a 45-min class.

Teaching strategies to increase activity in PE classes

Several teaching strategies were used to assist in accomplishing the level of MVPA. Each lesson used active roll call and strategies for quickly grouping into partnerships and small teams to reduce the transition time between class activities. Concise communication cues from the PE teacher to the students included the following: (1) the ‘80/20 rule’, meaning that, after instructions were given, 80% of the students would generally understand them, whereas the other 20% would either figure out the rules or get clarification from the teacher; (2) ‘fixing the leaks’, meaning that the PE teacher and assistant would clarify student misunderstandings inside

the activity area as the activity commences; (3) the ‘principle of three’, meaning that all game rules were presented in sets of three for ease of remembering; and (4) ‘when before what’, meaning that the teacher explained when to move before releasing the students to perform. Finally, to keep the game instructions minimal, the PE teacher stated specifically that ‘The object of the game is...’ and then briefly explained how to play. These communication cues were an integral part of the intervention training for the local PE teachers.

A second teaching strategy used in the HEALTHY PE intervention component was high skills progression.^{36,37} An example of using the high skills progression is teaching a basketball pass. Students were paired and practiced stationary passing with a basketball. Thereafter, the students increased the complexity of the pass, progressing to passing the ball to a moving partner. A third student joined the group and they engaged in a 2-on-1 keep away, transitioning to a three-catch game inside a confined space, and finally to a three-catch game moving in a direction and scoring points. This strategy was embedded in multiple lessons, primarily as a sport skill teaching strategy that sustained MVPA.

Finally, the Fitness Lab on Wheels, or FLOW, was included in all unit plans. FLOW is a circuit training program designed to provide MVPA. Originally, FLOW included six different activities using equipment, for example, two strength stations using dumbbells or elastic bands, two aerobic stations using stair steppers or jump ropes, one reaction time station using a knobbed ball and one balance station using a balance board. The activities helped build strength, endurance, balance and flexibility, while creating an individual program for each student to monitor personal progress. For the HEALTHY curriculum, a skill station was added, with the skill dependent on the unit of instruction. FLOW was intended to be used as an instant activity or as a health-related physical activity once a week for 15–20 min. Four FLOW circuits could be set up within a gym to maximize participation, and using a rotational approach, could accommodate as many as 48 students at a time. The number of stations could be increased up to 12 depending on equipment availability, which could then accommodate more than 90 students at a time. FLOW generated considerable MVPA and was well liked by both students and PE teachers, but was time consuming in both preparation and organization.

Additional elements of the PE intervention component

Equipment

In the pilot studies, the limited availability of the PE equipment resulted in a considerable waste of time as students waited for their turn to participate in an activity. In the HEALTHY study, PE equipment budgets were increased to ~\$15 000 for each intervention school over 3 years. The PE equipment included required items for core and elective curriculum units (for example, balls, standards,

mats, fitness equipment, cones, inflators), as well as special-purchase items for locally developed units.

Physical activity coordinator

The PAC was an individual with considerable experience in physical activity in children. The PAC provided the training for the local PE teachers and their assistants, and as the intervention unfolded, the PAC also observed and monitored progress and provided one-on-one feedback and guidance.

The PACs themselves underwent training to become intervention trainers. Although little is known about how teachers learn to become trainers, even less is known about the mentoring experienced by PE teachers.³⁸ In other adolescent school-based interventions, such as Pathways, MSPAN, TAAG and Bienestar,^{39–42} modest published information is devoted to the amount and kind of training that intervention trainers received before they conducted their on-site training programs. The HEALTHY investigators believed that the limited gains of MVPA in previous long-term studies could be partially attributed to inadequate investment in both personnel training programs and training time.⁴³ Thus, the HEALTHY PE expert investigators applied models used for business training that emphasized programs relevant to each specific school setting delivered by individuals with strong leadership and persuasion skills.^{44–46}

PE teacher assistant

The NASPE recommends that, for safe and effective middle school PE instruction, the size of PE classes should be consistent with that of other academic areas, that is, on the order of 30 students per 1 teacher.⁴⁷ In our pilot studies, class sizes ranged from 25 to more than 120 students, with student:teacher ratios ranging from 25:1 to 41:1. Therefore, the HEALTHY study provided at least one PE teacher assistant for each PE class to help in class management. The PE teacher assistant was required to have a background in PE or coaching sports and some teaching experience. Although the PE teacher assistant could assume complete control of the PE classes at some of the sites, their usual function was to work with the PE teacher(s) within the PE classes to implement the HEALTHY PE curriculum, including the following: (1) assisting the PE teachers with the class; (2) relieving the PE teacher of other duties so he/she could more effectively teach the class; (3) being assigned to teach specific activities or groups within the classes with PE teacher supervision; (4) managing equipment and/or facilities for class use; (5) reporting issues, problems or non-adherence with the HEALTHY PE curriculum at the school to the PAC; and (6) working collaboratively with all other HEALTHY study staff at the intervention schools so that the PE intervention component was integrated with the other components of the intervention. Specific duties and licensing varied depending on local requirements.

PE teacher and teacher assistant training

The training program was conducted in four phases. During the first phase of the training, the PACs met all PE teachers in each of the intervention schools for 1–2 h. The scope of the entire HEALTHY intervention (PE, nutrition, behavior and communications), the role of the PE teacher and the importance of MVPA for student health were covered. In phase two of the training, each participating PE teacher was observed by the PAC to obtain a baseline assessment on each teacher's teaching style, time management skills, active supervision of students, provision of student feedback, and promotion of physical activity. After the assessment, the PAC met with each PE teacher, provided both objective and subjective feedback and encouraged the teacher to improve his/her professional teaching skills through the use of the HEALTHY PE handbook of lesson plans and strategies. The third phase of training was a 6-h workshop conducted by the PAC. The majority of time was allotted for HEALTHY study lesson components, core teaching skills (time management, active supervision, student feedback, class management and fitness promotion), hands-on participation in a variety of lessons, FLOW and implementation procedures. The final phase of the training was interactive, individualized sessions with each of the participating PE teachers involving 12–15 h of observation per semester and direct one-on-one mentoring between the PAC and the PE teacher. MSPAN also found that booster trainings were especially helpful in schools with high teacher turnover.²⁹ Consequently, midway through each semester of the study, six additional hours of booster training were scheduled. Thus, over the entire intervention, PE teachers received 48 h of training plus weekly meetings with the PAC.

Central to the training program with the PE teachers was effective class time management.^{29,41} The HEALTHY study time management strategies focused on methods to maximize class time to be spent in MVPA, such as efficient roll call, quick grouping strategies, decreased transition time and reduced dressing out time.

Summary and discussion

The HEALTHY PE intervention component was a comprehensive and intensive program consisting of a grade-specific curriculum of units and lesson plans, equipment, PE teacher assistants, PE teacher and assistant training and mentoring, as well as monitoring and guidance from the PAC on the staff of each study center. The PE intervention was designed to increase levels of MVPA in students, which would lead to physical and metabolic changes conducive to decreasing risk factors for type 2 diabetes in middle school students.

The strengths of the HEALTHY PE intervention compared with previously published studies included the following: (1) a PE curriculum and class structure focused on enhancing student MVPA levels; (2) a curriculum based on pilot studies

showing effectiveness and feasibility; (3) lesson plans developed by PE professionals specifically for middle school PE teachers; (4) extensive PE teacher instruction, observation and booster training; (5) sufficient amounts of equipment; (6) specific behavioral messaging during daily lessons to promote healthy lifestyle choices both in and out of school; and (7) the opportunity to devote three consecutive years to promote the adoption of practices and assimilation of learned behavior patterns.

The long-term effect of programs like the HEALTHY PE intervention component on reduction of risk factors for type 2 diabetes is unknown. As PE was integrated into the overall intervention, extricating its individual influence will not be possible. Another interesting question is whether practices and behavior patterns learned during HEALTHY PE will be sustained on an individual student or teacher level. Furthermore, although the HEALTHY PE intervention incorporated a variety of school and state requirements, translation of the program beyond the research setting could be problematic. Costs related to equipment, training and staffing may prove to be barriers to widespread implementation.

By showing that PE in middle schools can be modified to meet Healthy People 2010 guidelines (>50% of PE time in MVPA), the HEALTHY PE intervention component could be used to affect public policy and educational practice. The training strategies and methods used for the PE teacher could provide a framework for universities and colleges to train future PE teachers and for school districts to train current teachers to meet the 2008 Physical Activity Guidelines for Americans regarding adolescents.^{48,49}

Conflict of interest

R McMurray works as a consultant for two grants on measuring physical activity in children, one with the University of Utah (R-21) and another with Michigan State University (R-21). Neither of these projects conflicts with the HEALTHY study. SL Volpe has received consulting fees from Gatorade Sports Science Institute. The remaining authors declare no conflict of interest.

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An online Appendix shows an example PE teacher handbook lesson.

References

- 1 The HEALTHY Study Group. HEALTHY study rationale, design and methods: moderating risk of type 2 diabetes in multi-ethnic middle school students. *Int J Obes* 2009; 33(Suppl 4): S4–S20.
- 2 Gillis B, Mobley C, Stadler DD, Hartstein J, Virus A, Volpe SL *et al.*, for the HEALTHY Study Group. Rationale, design and methods of the HEALTHY study nutrition intervention component. *Int J Obes* 2009; 33(Suppl 4): S29–S36.
- 3 Venditti EM, Elliot DL, Faith MS, Firrell LS, Giles CM, Goldberg L *et al.*, for the HEALTHY Study Group. Rationale, design and methods of the HEALTHY study behavior intervention component. *Int J Obes* 2009; 33(Suppl 4): S44–S51.
- 4 DeBar LL, Schneider M, Ford EG, Hernandez AE, Showell B, Drews KL *et al.*, for the HEALTHY Study Group. Social marketing-based communications to integrate and support the HEALTHY study intervention. *Int J Obes* 2009; 33(Suppl 4): S52–S59.
- 5 Baquet G, Bertoin S, VanPraagh E. Are intensified physical education sessions able to elicit heart rate at sufficient level to promote aerobic fitness in adolescents? *Res Quart Exerc Sport* 2002; 73: 282–288.
- 6 Morris HH. The roles of school physical education in public health. *Res Quart Exerc Sport* 1991; 62: 143–147.
- 7 Trudeau F, Shephard RJ. Contribution of school programmes to physical activity levels and attitudes in children and adults. *Sports Med* 2005; 35: 89–105.
- 8 Gutin B, Yin Z, Johnson M, Barbeau P. Preliminary findings of the effect of a 3-year after-school physical activity intervention on fitness and body fat: the Medical College of Georgia Fitkid Project. *Int J Pediatr Obes* 2008; 3: 3–9.
- 9 Gutin B, Cucuzzo N, Islam S, Smith C, Stachura ME. Physical training, lifestyle education, and coronary risk factors in obese girls. *Med Sci Sports Exerc* 1996; 28: 19–23.
- 10 McMurray RG, Bauman MJ, Harrell JS, Brown S, Bangdiwala SI. Effects of improvement in aerobic power on resting insulin and glucose concentrations in children. *Eur J Appl Physiol* 2000; 81: 132–139.
- 11 McMurray RG, Hackney AC. Endocrine responses to exercise and training. In: Garrett WE, Kirkendall DT (eds). *Exercise and Sport Science*. Lippencott, Williams & Wilkins: Philadelphia, PA, 2000, pp 135–162.
- 12 Brown MD, Moore GE, Korytkowski MT, McCole SD, Hagberg JM. Improvement of insulin sensitivity by short-term exercise training in hypertensive African American women. *Hypertension* 1997; 30: 1549–1553.
- 13 Larsen JJS, Dela F, Madsbad S, Galbo H. The effect of intense exercise on postprandial glucose homeostasis in type II diabetic patients. *Diabetologica* 1999; 42: 1282–1292.
- 14 Mikines KJ, Sonne B, Farrell PA, Tronier B, Galbo H. Effect of physical exercise on sensitivity and responsiveness to insulin in humans. *Am J Physiol* 1988; 254: E248–E259.
- 15 Viru A. Plasma hormones and physical exercise. *Intl J Sports Med* 1992; 13: 201–209.

- 16 Winder WW, Hickson RC, Hagberg JM, Ehsani AA, McLane JA. Training-induced changes in hormonal and metabolic responses to submaximal exercise. *J Appl Physiol* 1979; **46**: 766–771.
- 17 Kahle EB, Zipf WB, Lamb DR, Horswill CA, Ward KM. Association between mild, routine exercise and improved insulin dynamics and glucose control in obese adolescents. *Int J Sports Med* 1996; **17**: 1–6.
- 18 Gutin B, Islam S, Treiber F, Smith C, Smith C, Manos T. Fasting insulin concentration is related to cardiovascular reactivity to exercise in children. *Pediatrics* 1995; **96**: 1123–1125.
- 19 Eliakim A, Scheett T, Allmendinger N, Brasel J-A, Cooper DM. Training, muscle volume, and energy expenditure in nonobese American girls. *J Appl Physiol* 2001; **90**: 35–44.
- 20 Rolls BJ, Roe LS, Kral TVE, Mengs JS, Wall DE. Increasing the portion size of a packaged snack increases energy intake in men and women. *Appetite* 2004; **42**: 63–69.
- 21 Kimm SY, Glynn NW, Kriska AM, Fitzgerald SL, Aaron DJ, Similo SL *et al*. Longitudinal changes in physical activity in a biracial cohort during adolescence. *Med Sci Sports Exerc* 2000; **32**: 1445–1454.
- 22 McMurray RG, Harrell JS, Bangdiwala SI, Hu J. Tracking of physical activity and aerobic power from childhood through adolescence. *Med Sci Sports Exerc* 2003; **35**: 1914–1922.
- 23 Johnson MS, Figueroa-Colon R, Herd SL, Fields DA, Sun M, Hunter GR *et al*. Aerobic fitness, not energy expenditure, influences subsequent increase in adiposity in black and white children. *Pediatrics* 2000; **106**: E50.
- 24 McKenzie TL, Catellier DJ, Conway T, Lytle LA, Grieser M, Webber LA *et al*. Girls' activity levels and lesson contexts in middle school PE: TAAG baseline. *Med Sci Sports Exerc* 2006; **38**: 1229–1235.
- 25 Fairclough S, Stratton G. Physical activity levels in middle and high school physical education: a review. *Ped Exerc Sci* 2005; **17**: 217–236.
- 26 US Department of Health and Human Services. *Healthy people 2010: Understanding and Improving Health*. US Department of Health and Human Services: Washington, DC, 2000.
- 27 McKenzie TL, Stone EJ, Feldman HA, Epping JN, Yang M, Strikmiller PK *et al*. Effects of the CATCH physical education intervention teacher types and lesson location. *Am J Prev Med* 2001; **21**: 101–109.
- 28 Van Beurden E, Barnett LM, Zask A, Dietrich UC, Brooks LO, Beard J. Can we skill and activate children through primary school physical education lessons? 'Move it, Groove it'—a collaborative health promotion intervention. *Prev Med* 2003; **36**: 493–501.
- 29 McKenzie TL, Sallis JF, Prochaska JJ, Conway TL, Marshall SJ, Rosengard P. Evaluation of a two-year middle school physical education intervention: MSPAN. *Med Sci Sports Exerc* 2004; **36**: 1382–1388.
- 30 Jago R, McMurray RG, Bassin S, Pyle L, Bruecker S, Jakicic JM *et al*. Modifying middle school physical education: piloting strategies to increase physical activity. *Pediatr Exerc Sci* 2009; **21**: 171–185.
- 31 Simons-Morton BG, Taylor WC, Snider SA, Huang IW, Fulton JE. Observed levels of elementary and middle school children's physical activity during physical education classes. *Prev Med* 1994; **23**: 437–441.
- 32 Keating XD, Kulinna PH, Silverman S. Measuring teaching behaviors, lesson context, and physical activity in school physical education programs: comparing the SOFIT and the C-SOFIT instruments. *Measur Physical Educ Exerc Sci* 1999; **3**: 207–220.
- 33 McKenzie TL, Marshall SJ, Sallis JF, Conway TL. Student activity levels, lesson context, and teacher behavior during middle school physical education. *Res Quart Exerc Sport* 2000; **71**: 249–259.
- 34 Schuldheisz JM, van der Mars H. Active supervision and students' physical activity in middle school physical education. *J Teach Phys Educ* 2001; **21**: 75–90.
- 35 National Association for Sport and Physical Education. *Appropriate Practice for Middle School Physical Education: A Position Statement of the National Association for Sport & Physical Education Developed by the Middle and Secondary School Physical Education Council (MASSPEC)*. AAHPERD Publications: Oxon Hill, MD, 2001, <http://iweb.aahperd.org/naspe/> (accessed 1 March 2009).
- 36 McNamee J, Bruecker S, Murray T, Speich C. High-activity skills progression: a method for increasing MVPA. *J Phys Educ Rec Dance* 2007; **78**: 17–21.
- 37 Rosengard P, McKenzie TL. *SPARK Physical Education Program Grades 6–8*. San Diego State University Foundation: San Diego, CA, 2001.
- 38 McCaughtry N, Martin JJ, Hodges-Kulinna PH, Cothran D. What makes teacher professional development work? The influence of instructional resources on change in physical education. *J In-Service Educ* 2006; **32**: 221–235.
- 39 Stone EJ, Norman JE, Davis SM, Stewart D, Clay TE, Caballero B *et al*. Design, implementation, and quality control in the Pathways American-Indian multicenter trial. *Am J Prev Med* 2003; **37**: S13–S23.
- 40 Sallis JF, McKenzie TL, Alcaraz JE, Kolody B, Faucette N, Hovell MF. The effects of a 2-year physical education program (SPARK) on physical activity and fitness in elementary school students. Sports, play and active recreation for kids. *Am J Public Health* 1997; **87**: 1328–1334.
- 41 Webber LS, Catellier DJ, Lytle LA, Murray DM, Pratt CA, Young DR, *et al*, the TAAG Collaborative Research Group. Promoting physical activity in middle school girls: Trial of Activity for Adolescent Girls. *Am J Prev Med* 2008; **34**: 173–184.
- 42 Treviño RP, Pugh JA, Hernandez AE, Menchaca VD, Ramirez RR, Mendoza M. Bienestar: a diabetes risk-factor prevention program. *J Sch Health* 1998; **68**: 62–67.
- 43 Hodges-Kulinna P, McCaughtry N, Cothran D, Martin JJ, Faust R. Teachers mentoring teachers: a view over time. *J Teach Phys Educ* 2005; **24**: 326–343.
- 44 Blanchard S, Homan M. *Leverage Your Best, Ditch the Rest: the Coaching Secrets Top Executives Depend on*. Harper Collins Publishers: New York, 2004.
- 45 Garvin DA, Roberto MA. Change through persuasion. *Harvard Business Rev* 2005; **83**: 104–112.
- 46 Grant AM. Life coaching 2002. *Int J Evidence-Based Coach Mento* 2002; **1**: 25–40.
- 47 National Association for Sport and Physical Education. Teaching large class sizes in physical education: guidelines and strategies. Reston VA, 2006, <http://iweb.aahperd.org/naspe/> (accessed 1 March 2009).
- 48 Physical Activity Guidelines Advisory Committee Report 2008. Washington, DC, US Department of Health and Human Services, 2008, <http://www.health.gov/paguidelines> (accessed 3 September 2009).
- 49 Physical Activity Guidelines for Americans. US Department of Health and Human Services, 2008, <http://www.health.gov/paguidelines> (accessed 3 September 2009).

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