Identifying new associations between physical activity and cardiometabolic risk, aerobic fitness, and adiposity and exploring physical activity correlates in high-risk youth

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Abstract

In recent decades, research and policies related to nutrition and physical activity (PA) have increasingly converged, particularly amid concerns around energy imbalance and obesity. Low-income and racial/ethnic minority youth are disproportionately exposed to obesogenic environments and at risk of obesity and related disorders. This dissertation addresses questions around how youth PA relates to cardiometabolic health and what factors predict PA in a population of overweight/obese, low-income, Hispanic youth.

While research and recommendations tend to emphasize moderate-to-vigorous PA (MVPA), there are open questions on whether benefits of PA accrue specifically above the moderate-intensity threshold or through total movement at any intensity. Our first aim used NHANES data to compare the strength of associations between minutes of MVPA and total PA volume (accelerometer-derived total activity counts) and cardiometabolic risk factors, controlling for BMI z-score, dietary factors, and other covariates. Both MVPA minutes and total PA volume were associated with clustered cardiometabolic risk scores, systolic and diastolic blood pressure, insulin, and HDL ($p<0.05$), but not with waist circumference or triglycerides; associations were stronger for total PA volume than for MVPA minutes for all outcomes except insulin, where associations were similar. Future research that explores the broader relationships among PA volume, intensity, and health may have important implications for research, policy, and practice.

Our second and third aims used original data collected in partnership with Let's Get Movin' (LGM), a community-based, twice-weekly after-school PA program for low-income, overweight/obese, mostly Hispanic youth aged 8–14. For Aim 2, linear mixed models tested associations between number of program sessions attended and changes in cardiorespiratory fitness (CRF) and BMI. Attendance was associated with increases in CRF ($p=0.01$) but not with change in BMI ($p=0.97$). There were significant interactions between attendance and pedometer-measured in-program activity: attendance was associated with more favorable changes in CRF ($p<0.0001$) and BMI ($p=0.03$) as in-program activity levels increased. Prior studies in controlled settings have shown efficacy of PA programs for improving CRF and adiposity in overweight youth; our analysis provides novel evidence that such programs may also confer benefits in community settings, particularly when youth regularly attend and participate actively.

Using this same LGM dataset, Aim 3 used multivariable regression models to test potential demographic, physiologic, and psychosocial correlates of PA, including self-reported PA in general living (PA Questionnaire) and pedometer-measured PA in structured exercise and sports sessions. General-living PA was significantly associated with age (−) and perceived athletic competence (+). Pedometer steps/minute in structured exercise was significantly associated only with age (−). Steps/minute in structured sports was associated with age (−), CRF (+), and male sex (+). These results suggest that correlates of PA in overweight/obese, low-income, Hispanic youth may vary depending on the context where that PA occurs.

Together, these analyses reinforce the benefits of PA for child and adolescent health but also suggest that conceptualizing PA in narrowly-defined terms (e.g., "60 minutes of MVPA" or "PA program enrollment") may not fully account for important nuances. Future research, policies, and programs may benefit from more broadly accounting for the complexity in how youth move and how that complexity relates to children and adolescents' health and well-being.

Table of Contents

List of tables

Appendix 3:

List of figures

Chapter 1: Introduction

The problem and its significance

In recent decades, pediatric overweight/obesity has grown into a public-health crisis in the United States and other economically developed countries worldwide. In the U.S., 32% of U.S. youth ages 2−19 were overweight or obese in 2012, with even higher rates among low-income and racial/ethnic minority populations, including black and Hispanic youth.[1] This epidemic has profound health consequences; for example, obesity is the primary correlate of pediatric cardiometabolic disorders including hypertension, dyslipidemia, impaired glucose tolerance, and early atherosclerosis[2] and is also associated with psychosocial difficulties such as stigmatization, bullying, and poor self-esteem.[3]

At the population level, epidemic increases in obesity have been linked with changes on both sides of the energy-balance equation—that is, increases in energy intakes through food and beverages and concurrent decreases in energy expenditures through physical activity (PA).[4] The public-health importance of energy balance has contributed to increasing convergence of research and recommendations regarding nutrition and PA. For example, the Dietary Guidelines for Americans, which were first issued in 1980 and are refreshed every five years, initially included only tangential discussion of PA, but in more recent versions have dedicated entire chapters to energy balance and active living.[5-10]

Currently, most U.S. youth fall short of PA recommendations: according to the most recent objectively-measured, nationally-representative data, just 42% of children and 8% of adolescents achieve the recommended 60 minutes of daily moderate-to-vigorous physical activity (MVPA).[11] While increasing PA is important for all youth, those who are overweight/obese may experience particular benefits.[12] For example, PA promotes increases in cardiorespiratory fitness (CRF), which has been linked with increased likelihood of achieving normal weight [13-15] and healthier cardiometabolic risk profiles even in the absence of weight loss.[16, 17] Higher levels of PA also confer benefits for blood pressure, lipid profiles, and insulin sensitivity through pathways independent of adiposity and CRF.[12, 18-21]

While the benefits of PA for child and adolescent health are, broadly speaking, well-accepted, PA research and policy remain somewhat nascent relative to related fields like nutrition. For example, whereas the eighth edition of the U.S. Dietary Guidelines are currently in preparation, just one set of U.S. PA guidelines has been issued, in 2008, including one chapter on PA in children/adolescents. This dissertation aims to address three gaps in PA literature that have potentially important implications for future PA research, policy, and practice. First, while most research and recommendations have focused mainly on MVPA, there is growing evidence that benefits may begin to accrue at lighter intensities.[19, 22, 23] Developments in accelerometer technologies provide new opportunities to compare associations between health markers and MVPA minutes versus other dimensions of activity, like total PA volume (e.g., accelerometer-derived total activity counts, TAC).[24] Such comparisons may inform whether PA policies and programs should focus on promoting PA at certain intensity thresholds or more broadly promote increases in total movement.[24]

Second, well-controlled intervention trials have demonstrated that PA programs may increase CRF and reduce adiposity among overweight/obese children,[25, 26] but it is unclear how this evidence relates to more typical practitioner contexts, where implementation tends to be more variable.[27, 28] For example, after-school programs have been identified as promising contexts for increasing children's PA,[29] but inconsistent attendance in such programs is a challenge.[30, 31] Furthermore, children's activity levels in after-school programs and other community-based PA settings are also highly variable.[32-35] Variability in attendance and in-program activity levels may have important implications for the potential of such programs to impact adiposity or CRF.[36, 37] However, to our knowledge, just two prior studies, neither specifically targeting overweight/obese youth, have explored the impact of different levels of PA program attendance on changes in child fitness and/or adiposity,[38, 39] and no studies have addressed how in-program activity levels impact those associations.

Third, incomplete understanding of PA correlates may be a barrier to the development of more effective interventions. Prior review studies have shown that factors like age, sex, fitness, adiposity, and perceived competence may be associated with children's PA levels,[40] but emerging evidence suggests that the relative importance of these correlates varies among population subgroups. For example, correlates of PA may be different among overweight/obese compared with normal-weight youth[41, 42] and among Hispanic compared with non-Hispanic youth.[43] Correlates also appear to vary depending on the context where PA is performed—for example, whether activities are structured or unstructured.[44, 45] Therefore, to enable tailoring of PA policies and programs to priority populations and settings, research is needed within specific populations, particularly high-risk groups like low-income, overweight/obese, and racial/ethnic minority youth, and within well-defined environmental contexts.

Specific aims and hypotheses

This research explores the following aims and hypotheses to address the research gaps described above:

Aim 1a: To compare the strength of association between minutes of moderate-to-vigorous physical activity (MVPA) and total PA volume (accelerometer-measured total activity counts per day, TAC) with clustered cardiometabolic risk and individual risk factors, independent of BMI z-score, in a nationally representative sample of U.S. adolescents.

Aim 1b (exploratory): To compare associations between equivalent volumes of PA accrued at light (L-TAC) and moderate-to-vigorous intensity (MV-TAC) and cardiometabolic markers.

Hypothesis 1a: Compared with MVPA minutes, TAC will demonstrate stronger protective associations with clustered cardiometabolic risk and individual risk factors.

Hypothesis 1b: Comparable volumes of L-TAC and MV-TAC will demonstrate similar protective associations with cardiometabolic markers.

Aim 2a: To evaluate whether attendance in a nine-month, twice-weekly PA program, delivered by a community-based partner, predicts changes in CRF among overweight/obese participants ages 8−14.

Aim 2b (exploratory): To evaluate whether the relationship between program attendance and changes in CRF or body mass index (BMI) are influenced by children's in-program activity levels.

Hypothesis 2a: Higher participation in a nine-month, twice-weekly community-based PA program will be positively associated with gains in CRF among overweight/obese children ages 8−14.

Hypothesis 2b: The relationship between attendance and changes in CRF and BMI will be moderated by children's in-program activity levels, such that each session attended will have greater benefits as in-program activity levels increase.

Aim 3: To evaluate demographic (age, sex), physiologic (aerobic fitness, adiposity), and psychosocial (perceived athletic competence) correlates of PA, including both self-reported PA in general living and objectively-measured PA in structured exercise and sports sessions, among overweight/obese children participating in an after-school PA program.

Hypothesis 3: Among overweight/obese children, there will be significant associations between physical activity and age (-), female sex (-), aerobic fitness (+), adiposity (-), and perceived athletic competence (+); correlates will differ for general-living PA, PA in structured exercise, and PA in structured sports.

References

1. Ogden CL, Carroll MD, Kit BK, et al. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA 2014; 311: 806-814.

2. Steinberger J, Daniels SR, Eckel RH, et al. Progress and challenges in metabolic syndrome in children and adolescents a scientific statement from the American Heart Association atherosclerosis, hypertension, and obesity in the young committee of the council on cardiovascular disease in the young; council on cardiovascular nursing; and council on nutrition, physical activity, and metabolism. Circulation 2009; 119: 628-647.

3. Janssen I, Craig WM, Boyce WF, et al. Associations between overweight and obesity with bullying behaviors in school-aged children. Pediatrics 2004; 113: 1187-1194.

4. Ng SW and Popkin B. Time use and physical activity: a shift away from movement across the globe. Obesity Reviews 2012; 13: 659-680.

5. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 1st ed. Washington, DC: Washington, DC, 1980.

6. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 2nd ed. Washington, DC: Washington, DC, 1985.

7. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 3rd ed. Washington, DC: Washington, DC, 1990.

8. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 4th ed. Washington, DC: Washington, DC, 1995.

9. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 5th ed. Washington, DC: Washington, DC, 2000.

10. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans*. 6th ed. Washington, DC: Washington, DC, 2005.

11. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008; 40: 181.

12. Brambilla P, Pozzobon G and Pietrobelli A. Physical activity as the main therapeutic tool for metabolic syndrome in childhood. Int J Obes 2010; 35: 16-28.

13. Mota J, Ribeiro JC, Carvalho J, et al. Cardiorespiratory fitness status and body mass index change over time: A 2-year longitudinal study in elementary school children. Int J Ped Obes 2009; 4: 338-342.

14. McGavock JM, Torrance BD, McGuire KA, et al. Cardiorespiratory fitness and the risk of overweight in youth: the Healthy Hearts Longitudinal Study of Cardiometabolic Health. Obesity 2009; 17: 1802-1807.

15. Hruby A, Chomitz VR, Arsenault LN, et al. Predicting maintenance or achievement of healthy weight in children: The impact of changes in physical fitness. Obesity 2012; 20: 1710-1717.

16. Eisenmann JC. Aerobic fitness, fatness and the metabolic syndrome in children and adolescents. Acta Paediatr 2007; 96: 1723-1729.

17. DuBose KD, Eisenmann JC and Donnelly JE. Aerobic fitness attenuates the metabolic syndrome score in normal-weight, at-risk-for-overweight, and overweight children. Pediatrics 2007; 120: e1262-e1268.

18. McMurray RG and Ondrak KS. Cardiometabolic risk factors in children: the importance of physical activity. Am J Lifestyle Med 2013; 7: 292-303.

19. Ekelund U, Luan J, Sherar LB, et al. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA 2012; 307: 704-712.

20. Hobkirk JP, King RF, Gately P, et al. Longitudinal factor analysis reveals a distinct clustering of cardiometabolic improvements during intensive, short-term dietary and exercise intervention in obese children and adolescents. Metab Syndr Relat Disord 2012; 10: 20-25.

21. Neto AS, de Campos W, dos Santos GC, et al. Metabolic syndrome risk score and time expended in moderate to vigorous physical activity in adolescents. BMC Pediatr 2014; 14: 42.

22. Carson V and Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. BMC Public Health 2011; 11: 274.

23. Ekelund U, Anderssen S, Froberg K, et al. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. Diabetologia 2007; 50: 1832-1840.

24. Powell KE, Paluch AE and Blair SN. Physical activity for health: What kind? How much? How intense? On top of what?. Annu Rev Public Health 2011; 32: 349-365.

25. Vasconcellos F, Seabra A, Katzmarzyk PT, et al. Physical activity in overweight and obese adolescents: systematic review of the effects on physical fitness components and cardiovascular risk factors. Sports Medicine 2014: 1-14.

26. Kelley GA, Kelley KS and Pate RR. Effects of exercise on BMI z-score in overweight and obese children and adolescents: a systematic review with meta-analysis. BMC pediatrics 2014; 14: 225.

27. Ammerman A, Smith TW and Calancie L. Practice-based evidence in public health: improving reach, relevance, and results. Annu Rev Public Health 2014; 35: 47-63.

28. Brownson RC and Jones E. Bridging the gap: translating research into policy and practice. Prev Med 2009; 49: 313-315.

29. Beets MW. Enhancing the translation of physical activity interventions in afterschool programs. Am J Lifestyle Med 2012.

30. Garn AC, McCaughtry N, Kulik NL, et al. Successful after-school physical activity clubs in urban high schools: perspectives of adult leaders and student participants. J Teach Phys Educ 2014; 33: 112-133.

31. Maljak K, Garn A, McCaughtry N, et al. Challenges in offering inner-city after-school physical activity clubs. Am J Health Educ 2014; 45: 297-307.

32. Sacheck JM, Nelson T, Ficker L, et al. Physical activity during soccer and its contribution to physical activity recommendations in normal weight and overweight children. Pediatr Exerc Sci 2011; 23: 281-292.

33. Ridgers ND, Salmon J, Parrish A, et al. Physical activity during school recess: a systematic review. Am J Prev Med 2012; 43: 320-328.

34. McKenzie TL, Marshall SJ, Sallis JF, et al. Student activity levels, lesson context, and teacher behavior during middle school physical education. Res Q Exerc Sport 2000; 71: 249-259.

35. Trost SG, Rosenkranz RR and Dzewaltowski D. Physical activity levels among children attending after-school programs. Med Sci Sports Exerc 2011; 40: 622-629.

36. Janssen I and LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act 2010; 7: 1-16.

37. Carson V, Rinaldi R, Torrance B, et al. Vigorous physical activity and longitudinal associations with cardiometabolic risk factors in youth. Int J Obes 2013; 38: 16-21.

38. Yin Z, Gutin B, Johnson MH, et al. An environmental approach to obesity prevention in children: Medical College of Georgia FitKid Project year 1 results. Obes Res 2005; 13: 2153-2161.

39. Barbeau P, Johnson MH, Howe CA, et al. Ten months of exercise improves general and visceral adiposity, bone, and fitness in black girls. Obesity 2007; 15: 2077-2085.

40. Sallis JF, Prochaska JJ and Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc 2000; 32: 963-975.

41. Taylor WC, Sallis JF, Dowda M, et al. Activity patterns and correlates among youth: differences by weight status. Pediatr Exerc Sci 2002; 14: 418.

42. Biddle SJ, Atkin AJ, Cavill N, et al. Correlates of physical activity in youth: a review of quantitative systematic reviews. Int Rev Sport Exerc Psychol 2011; 4: 25-49.

43. Kelly EB, Parra-Medina D, Pfeiffer KA, et al. Correlates of physical activity in black, Hispanic, and white middle school girls. J Phys Act Health 2010; 7: 184-193.

44. Mota J and Esculcas C. Leisure-time physical activity behavior: structured and unstructured choices according to sex, age and level of physical activity. Int J Behav Med 2002; 9: 111-121.

45. Spink KS, Shields CA, Chad K, et al. Correlates of structured and unstructured activity among sufficiently active youth and adolescents: A new approach to understanding physical activity. Pediatr Exerc Sci 2006; 18: 203.

Chapter 2: Review of the Literature

Overview

In most economically developed countries worldwide, youth* fall short of the 60 minutes of daily moderate-to-vigorous physical activity (MVPA) recommended in the United States (U.S.) and other countries worldwide.[1-5] In the U.S., for example, just 42% of children and 8% of adolescents accumulate 60 minutes of daily MVPA, according to the most recent nationally-representative, objectively-measured PA data.[6] Concerns around insufficient levels of PA take on particular urgency set against the concurrent epidemic in pediatric obesity, which, among myriad other adverse outcomes, increases children and adolescents' risk of cardiometabolic disorders and of obesity and related comorbidies in later adult life.[7]

This chapter briefly reviews health impacts of pediatric obesity, with particular emphasis on cardiometabolic risk factors that are of central interest in this research. It also reviews current understanding of the relationships between PA and adiposity and cardiorespiratory fitness (CRF), which may partially mediate PA's cardioprotective benefits. Finally, current knowledge and research gaps are discussed in three areas addressed in this dissertation. First, evidence regarding the independent association between PA and cardiometabolic health is discussed, with particular emphasis on knowledge gaps regarding how PA intensity and volume relate to PA's cardiometabolic benefits. Second, the research base on the efficacy of PA-focused interventions for increasing CRF and reducing adiposity in overweight/obese youth is reviewed, along with gaps in knowledge regarding effectiveness in typical community settings. Third, the

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* Unless otherwise specified, "youth" refers to ages 2−19, "children" refers to ages 6−11, and "adolescents" refers to ages 12−19

chapter reviews current understanding of the correlates of PA in children and adolescents and the need for new research that evaluates correlates in high-risk populations and in multiple environmental contexts.

Trends in pediatric obesity and implications for cardiometabolic health

In recent decades, pediatric obesity has grown into a public-health crisis in economically developed (and, increasingly, developing) countries globally.[8] In the U.S., 32% of youth ages 2-19 were overweight or obese in 2012;[9] while these data represented flattening in pediatric obesity prevalence after decades of increases, prevalence remained approximately three times higher than it was in the 1960s.[10] Furthermore, racial/ethnic disparities in overweight/obesity persisted, with prevalence remaining substantially higher among Hispanic (39%) and non-Hispanic black (35%) youth compared with their non-Hispanic white counterparts (29%),[9] patterns that appear linked with disproportionate exposure to obesogenic environments among youth in minority communities.[11]

These trends have profound health consequences. For example, pediatric obesity is associated with increased risk of sleep apnea, asthma, and orthopedic problems, as well as psychosocial difficulties such as stigmatization, bullying, depression, low self-esteem, and reduced quality of life.[12, 13] Body fatness is also predictive of cardiometabolic risk factors including systolic and diastolic blood pressure (+), HDL cholesterol (−), triglycerides (+), and insulin (+) and is the primary correlate of diseases such as pediatric type 2 diabetes and non-alcoholic fatty liver.[7] Autopsy studies have shown that obese children may demonstrate signs of early atherosclerosis,[14] and longitudinal studies have found that pediatric obesity and related comorbidities are associated with greater risk of cardiovascular disease in adult life.[15]

In addition to its associations with cardiometabolic risk factors measured individually, obesity has been linked with the clustering of multiple risk factors in children and adolescents in patterns similar to those observed in adult metabolic syndrome.[7, 16] In pediatric populations, clustered risk is often captured with continuous risk scores, typically calculated as a summation of z-scores for cardiometabolic risk variables.[17-19] While the exact combination of z-scores included varies, clustered risk scores almost universally incorporate markers of adiposity, dyslipidemia, insulin resistance, and hypertension. Compared with cardiometabolic risk factors viewed individually, clustered risk scores in children/adolescents more strongly predict subclinical atherosclerosis and early-onset type 2 diabetes.[14, 20] Risk clustering in childhood and adolescence tends also tends to track into later life[21] and predicts incident cardiovascular disease and type 2 diabetes in adulthood.[22, 23]

Knowledge of relationships among PA, dietary intakes, and adiposity

While the etiology of obesity is multifactorial, it is fundamentally the result of chronic energy imbalance: when total energy intakes exceed total energy expenditures, excess energy is stored, mostly as fat. Conversely, when energy expenditures exceed intakes, fat is utilized to compensate for the energy gap.[24] Thus, maintenance of a healthy weight trajectory requires that energy intakes through foods and beverages remain approximately equivalent to energy expenditures over time. For those who are already overweight, achieving negative energy balance, whereby energy expenditures exceed energy intakes, is necessary to promote weight loss.

PA is the most modifiable component of total energy expenditure and is therefore a key target in efforts to promote energy balance and, in turn, healthy weight.[25] However, PA's relationship to adiposity is dependent on concurrent dietary behaviors; for example, if increases in caloric expenditures through PA are accompanied by equivalent caloric intakes, the net effect on adiposity will be approximately neutral. Such compensatory caloric intakes may explain why longitudinal studies have found only mixed evidence of associations between PA and adiposity.[26, 27] However, as discussed further in the following sections, randomized controlled trials have shown that structured PA programs may help elicit weight loss among overweight/obese participants, even in the absence of dietary intervention,[28] and PA also confers health benefits independent of its relationship to adiposity.

Like PA, diet influences cardiometabolic health not only through its influence on adiposity, but also through independent protective pathways. For example, diets high in sugar, sodium, and saturated and trans fats may adversely influence children's cardiometabolic risk profiles, even among children who maintain a healthy weight.[29, 30] Conversely, diets rich in nutrients such as fiber (including fruits, vegetables, legumes, and whole grains), poly- and monounsaturated fats, and potassium provide cardiometabolic benefits.[29, 30] Therefore, in research testing associations between PA and cardiometabolic health, it is important to account for dietary factors, both protective and deleterious, that may represent potential confounding variables.

Knowledge of relationships among CRF, PA, and adiposity

Cardiorespiratory fitness refers to the ability of one's respiratory and circulatory systems to supply oxygen to working muscles during sustained PA.[31] While CRF in children/adolescents is largely determined by non-modifiable factors such as age, sex, and genetics, it can also be increased through PA,[32] particularly among youth who are inactive at baseline.[33] Increasing CRF has important health benefits for children and adolescents and has been identified as a key public-health priority in the U.S.[34] Prospective studies have shown, for example, that overweight/obese youth with high baseline CRF are less likely to experience additional excess weight gain and more likely to achieve healthy weight over time compared with overweight/obese youth with low baseline fitness.[35-37] Independent of adiposity, higher CRF is also associated with improvements in HDL cholesterol, triglycerides, insulin sensitivity, and blood pressure[38] and may substantially attenuate adiposity-related cardiometabolic risk in obese youth.[39, 40]

Although the benefits of high CRF may be particularly pronounced for overweight/obese youth, CRF tends to be inversely associated with adiposity.[41, 42] A 2012 nationally representative U.S. study found that just of 29% overweight and 17% of obese adolescents ages 12-15 (the only group for which data have been reported to date) demonstrated healthy aerobic fitness levels, compared with 54% of their normal-weight counterparts.[42] Interventions that increase CRF among overweight/obese youth may provide important benefits in terms of both promoting achievement of healthy weight and attenuating cardiometabolic risk even in the absence of weight loss.

Independent associations between PA and cardiometabolic health

Current knowledge of PA's benefits and the emphasis on MVPA in research and policy

In addition to potential cardiometabolic benefits mediated through adiposity and CRF, research suggests that aerobic PA confers benefits through independent pathways.[43] While these pathways are only partially understood, several mechanisms have been elucidated. For example, aerobic PA appears to up-regulate lipoprotein lipase activity, which improves clearance of triglycerides and raises HDL cholesterol. It also facilitates translocation of insulin-regulated glucose transport proteins to the surface of muscle cells, increasing insulin sensitivity and glucose uptake, and lowers resting sympathetic and adrenal outflow, potentially reducing vasoconstriction and blood pressure.[44, 45] Such mechanisms may underlie the inverse associations observed in several large epidemiologic studies between children/adolescents' aerobic PA and cardiometabolic risk factors, including systolic and diastolic blood pressure (–), triglycerides (–), HDL cholesterol (+), and insulin (–).[43, 46-49] An analysis of data from 9- to 16-year-olds in the European Youth Heart Study found that these protective associations persist even after adjustment for both aerobic fitness and adiposity.[43] Such benefits make increasing PA an important lifestyle strategy for improving cardiometabolic health, perhaps especially so for overweight/obese youth, who are at elevated cardiometabolic risk.[44]

To date, research on cardiometabolic benefits of PA has focused principally on MVPA minutes. Historically, this emphasis was a function of reliance on self-report instruments, which generally capture MVPA with sufficient accuracy but are less useful for detecting light PA (LPA) or PA in more finely-partitioned intensity categories (e.g., moderate, vigorous, very vigorous).[50,51] Evidence-based guidelines informed by this research, including the 2008 Physical Activity Guidelines for Americans,[3] national guidelines from Canada, Australia, and the United Kingdom, and guidelines from the World Health Organization, recommend 60 minutes of daily MVPA for children and adolescents.[1, 2, 4, 5]

Several studies have noted that these recommendations have been limited by the scope of available research.[41, 50, 52] For example, the Physical Activity Guidelines Advisory Committee, which informed the 2008 U.S. guidelines, noted in its review of evidence that, at that time, “[v]ery limited data [were] available on dose response in children and youth” and that the recommendations were based mainly on studies using self-report data.[52] Thus, the emphasis on MVPA in major policy guidelines may be less a function of evidence that benefits accrue specifically above the moderate-intensity threshold than of evidence being available mainly on MVPA and less so on PA at other intensities.

New opportunities in accelerometer research

Developments in PA evaluation technologies, particularly accelerometers, have enabled population-based studies to evaluate PA at a broader range of intensities, including not just MVPA but also sedentary time and light PA (LPA). Accelerometers record movement as activity counts over fixed time periods (epochs), and PA researchers generally use these data to calculate subjects’ average daily minutes in different intensity categories (e.g., minutes of sedentary, light, moderate, and vigorous activity). Accelerometer research can also evaluate overall PA volume, whether as total activity counts per day (TAC) or as other similar variables, such as mean counts per minute of wear time.

An emerging body of literature using accelerometer data has found that LPA and total PA volume demonstrate protective associations with cardiometabolic risk in youth.[43, 46, 53] However, researchers using accelerometer data commonly continue to combine moderate- and vigorous-intensity minutes and to use MVPA as their main study variable,[46, 48, 49] at least in part to bring their work in line with prior research and policy recommendations.[50] In this respect, ongoing emphasis on MVPA in research and policy may in large part be self-perpetuating: as researchers continue to align their work with prior studies and policy guidelines, the body of research and policies emphasizing MVPA, in turn, continues to grow.[47, 50]

Using total PA volume variables, such as TAC, in accelerometer research may offer several advantages over the more conventional MVPA minutes variable. First, unlike MVPA minutes, TAC accounts for variations in PA intensity above the moderate threshold. These variations may have important implications given that cardiometabolic benefits of PA, on a per-minute basis, appear to increase alongside increases in PA intensity.[51, 54] In addition, TAC accounts for differences in levels of LPA, which may have important health implications.[43, 46, 53] TAC also has limitations, however. For example, it treats all counts equally, regardless of factors like intensity or duration, which may influence PA's relationship to health. Few studies have tested whether MVPA minutes or total PA volume more strongly predicts cardiometabolic risk in children or adolescents, and results have been mixed.[55-57] Therefore, it remains uncertain whether

TAC's advantages outweigh disadvantages, particularly relative to the more commonly-used MVPA-minutes variable, in terms of its utility in PA research.

While the benefits of PA, on a per-minute basis, appear to increase as intensity increases, research has not clearly established whether this is a function of greater volume generated at higher intensity or, alternatively, of physiologic adaptations that occur specifically above certain intensity thresholds.[50] A small number of studies, mainly in adults, have tested associations between moderate- and vigorous-intensity activity and cardiometabolic risk factors while controlling for total volume and found that higher-intensity PA may confer greater benefits.[58] However, few studies have examined these relationships in children or adolescents, and, to our knowledge, no studies have compared the cardioprotective influence of light versus moderate-to-vigorous PA while controlling for total volume. New studies exploring the associations between PA intensity and volume and cardiometabolic health in youth will have important implications in terms of not only how PA is operationalized in research but also whether PA-related policy and practice should specifically emphasize activity above the moderate threshold or more broadly promote increases in total movement.

PA interventions for overweight/obese youth

Evidence from controlled efficacy trials

A large number of controlled studies have shown that PA or exercise interventions are efficacious for reducing adiposity and increasing CRF among overweight/obese youth. For example, a recent meta-analysis of 10 randomized controlled exercise interventions with overweight/obese youth 2–18 years old (average dose: 4 days/week, 43 minutes/session, 16 weeks duration) found average reductions in adiposity equivalent to 3% of baseline BMI z-score, with no evidence of differential effects by participants' age.[59] In another review, 7 of 10 exercise interventions with overweight/obese adolescents (dose range: 2–5 days/week, 16–60 minutes/session, 7–36 weeks) detected significant improvements in CRF.[60] Controlled exercise interventions have also been shown to be efficacious for improving CRF in younger children, but most available research has not targeted overweight/obese subjects specifically.[32]

Gaps in knowledge of the impact of PA programs in practice settings

Studies in the reviews described above mainly included randomized trials that, to maximize internal validity and potential to detect impact, delivered relatively fixed doses of PA in controlled research settings. Such studies provide important understanding of interventions' efficacy under near-optimal conditions. However, they also generally demand research expertise, funding, and levels of participant burden that are not reproducible in more resource-constrained practitioner settings, where implementation is more difficult to standardize and dose of PA delivered is more variable.[61] Because comparatively few studies have tested intervention models in typical community settings, the extent to which evidence from efficacy trials translates to potential effectiveness in community settings remains largely unclear. This gap in translational research has led to calls for more practice-based intervention studies, which are supported by researchers and informed by evidence from efficacy studies, but administered by community practitioners under usual conditions.[61-63]

In community PA programs, level of attendance is one potential source of variability in dose delivered. In after-school settings, which have been identified as an important context for increasing children's PA,[64] attendance may be especially variable compared with other environments, like schools, where participants are relatively captive; attendance may be particularly challenging when resources are unavailable for transportation, participation-based incentives, or other mechanisms for increasing child turnout.[65, 66] Given evidence of a dose-response relationship between PA and changes in adiposity and fitness,[51, 67] such variability may have important implications for health outcomes in children/adolescents. However, very little research has explored the impact of attendance rates in after-school PA programs on youth fitness and/or adiposity,[68, 69] and to our knowledge no studies have tested the relationship between after-school PA program attendance and health outcomes specifically in overweight/obese youth.

An additional source of variability in community-based PA programs is the level of activity in which children engage when they do attend. For example, one study of 7–10-year-old children participating in a 50-minute soccer match found that participants spent 33% of time in MVPA; the range extended from 12% to 60%, and overweight children engaged in less MVPA than their normal-weight peers, on average.[70] Other studies have shown similar evidence of variability in PA levels in settings such as school physical education, recess, and after-school programs.[71-73] This research has generally focused on documenting proximal PA outcomes, such as the distribution of minutes of MVPA/session, but the implications of variable activity levels for more distal outcomes, like fitness or adiposity, have not, to our knowledge, been tested in practice settings.

Correlates of PA in children and adolescents

Efforts to increase PA among children/adolescents have achieved limited success to date: in one review, just 43% of youth PA interventions (duration range: 4 weeks–140 weeks) detected significant increases in MVPA or total PA, and pooled effects were small, at only about 4 additional minutes of MVPA/day.[74] Research providing fuller understanding of PA correlates is needed to help inform more effective interventions.[75] While a growing body of research points to the importance of environmental correlates of PA in youth, individual-level factors—including demographic, physiologic, and psychosocial characteristics—may be equally or even more predictive of PA[76] and have important implications for intervention design. For example, research regarding modifiable individual-level correlates may provide insight into potential mediators of PA that can be targeted in interventions.[75] Conversely, evidence regarding non-modifiable correlates, such as sex or age, may help to identify priority populations or life stages.

The following sections discuss correlates that have been identified in previous studies as well as emerging evidence that correlates of PA appear to differ among different population subgroups and environmental contexts.

Physiologic correlates

As noted previously, research has shown that levels of PA are positively associated with CRF in children and adolescents. The causal direction of this relationship appears to be bidirectional: that is, in addition to PA eliciting increases in CRF, higher CRF may lead to higher levels of PA, since fitter children may be able to perform PA more often, at higher intensities, and/or for longer durations than their less fit counterparts.[41, 77] For example, one study in Portuguese male and female adolescents[41] and another in Swedish boys and girls[77] found that baseline CRF was associated with total PA measured over seven and four days, respectively.

While evidence of associations between adiposity and PA has been mixed overall,[78, 79] some longitudinal research has suggested that baseline adiposity is inversely associated with PA over time. For example, a three-year study in English boys and girls found that a 10% higher body fat percentage at baseline was associated with a reduction of 4 minutes of daily MVPA from age 7 to 10 years; no significant interaction was detected between baseline adiposity and sex.[80] Other research has suggested that the relationship between adiposity and PA may be moderated by child characteristics; for example, one study in U.S. adolescents found that adiposity's association with PA was influenced by complex three- and four-way interactions with age, sex, and race/ethnicity.[81]

Differences in PA levels among overweight/obese versus normal-weight youth may be a function of different barriers experienced by those groups. For example, one study with U.S. youth aged 8–16 found that overweight/obese individuals were more likely than their normal-weight peers to report body-related barriers (e.g., self-consciousness about the appearance of their body) and social barriers (e.g., teasing by peers) to PA.[82] Understanding which correlates most strongly predict PA in overweight/obese youth may require population-specific analyses, in light of evidence that correlates differ among weight-status subgroups. For example, one study in U.S. middle- and high-schoolers found that family support, peer support, number of perceived barriers, and perceived athletic coordination were associated with PA in normal-weight study participants, whereas among overweight/obese participants perceived athletic coordination was the only significant correlate.[83]

Demographic correlates

Multiple review studies evaluating demographic correlates of PA have found that girls tend to be less active than boys.[78, 84] This gender gap may be linked to factors such as fewer PA opportunities, lower levels of social support, or different concerns with physical appearance among girls compared with boys.[85, 86] Multiple review studies have also found that age is inversely associated with PA,[78, 84] perhaps due to decreases in self-efficacy and social support as children move into adolescence.[87] Some evidence suggests that age and sex interact, such that the gender-gap in activity levels increases with advancing age;[88] one underlying factor may be shifts in social norms that make participation in PA increasingly less acceptable for girls than for boys with advancing age.[89]

Some evidence, albeit mixed, suggests that low-income and racial/ethnic minority children engage in lower levels of PA compared with their higher-income and white counterparts.[90] Such differences may be a function of limited access, both physical and economic, to PA spaces and programs in many low-income and minority communities.[91] Socio-cultural factors, such as time-barriers to parents modeling PA behaviors, parental perceptions of poor neighborhood safety, or prohibitive gender norms for girls surrounding PA participation, may also represent barriers to PA for racial/ethnic minority children.[92, 93] The relative importance of PA correlates appears to vary among racial/ethnic minority groups. For example, one study of intrapersonal, interpersonal, and environmental correlates found that among Hispanic girls only perceived transportation barriers (–) was significantly associated with MVPA, whereas BMI (–) and social support (+) were the only significant correlates among black girls.[94] To our knowledge, no prior studies have examined correlates of PA specifically among overweight/obese Hispanic youth.

Psychosocial correlates. Prior studies have explored a wide range of potential psychosocial correlates of PA, including enjoyment, self-efficacy, and physical self-concept.[78, 95] There is strong evidence of associations between multiple dimensions of physical self-concept and PA; for example, a 2014 meta-analysis found that perceived general physical self-concept, perceived fitness, and perceived competence were positively associated with PA, with perceived competence demonstrating the strongest associations.[96] Age appeared to positively moderate the association, though this result should be interpreted cautiously, as only 1/59 studies focused on children (defined as < 10 years of age) and the remaining 58 included adolescents (10-19 years of age).[96] Counterintuitively, the literature does not provide strong evidence of a positive association between enjoyment and PA,[78, 97] and evidence of associations between self-efficacy and PA are likewise mixed.[78, 84]

Context-specificity of PA correlates.

Most of the correlates literature published to date has evaluated correlates of overall PA in general living, often over the course of several days. However, such analyses may not capture important differences in correlates among different environmental contexts where

PA is performed. Behavioral theorists have long recognized the importance of environmental determinants of health behaviors. Ecological systems theory, for example, stresses the influence of multiple environmental layers—including social, institutional, community, and public-policy factors—that influence human behavior,[98] and social-cognitive theory (SCT) posits that behaviors are the product of dynamic relationships among personal, behavioral, and environmental factors.[99] Given the influence of environmental variables on health behavior, it follows logically that PA correlates are likely to vary depending on the environmental contexts in which that activity occurs. For example, the relationship between a child's level of perceived athletic competence and engagement in PA may depend on the time and place where that activity occurs (e.g., active transport to school vs. PA in physical education vs. PA in recess) or different characteristic of those contexts (e.g., the extent to which activities are structured or not).

A small body of evidence supports this notion that individual-level correlates of PA vary by context. For example, one study asked children about their levels of PA in structured (e.g., activity in sports teams or exercise classes) and unstructured (e.g., pick-up sports) contexts, as well as social and interpersonal factors they believed influenced their activity levels in each. Child-reported correlates differed substantially for structured versus unstructured activities. For example, parent support was cited by 23% of children as being associated with structured activity, compared with 5% reporting parent support as being associated with unstructured activity. Conversely, 37% of participants reported that friends' participation was associated with unstructured activity, compared with 9% reporting an association with structured activity.[100] A small number of other studies have also explored PA correlates in multiple contexts. For example, one study compared correlates of PA in recess versus PA after school among 9- to 13-year old Australian youth,[101] and another compared psychosocial and environmental correlates of PA in active commuting, informal school games, and organized leisure-time sports in 9- and 13-year-old Norwegian boys.[102] Both studies found significant differences in correlates depending on context. While the authors of these studies, and others,[103] have called for further research into context-specific correlates research, the body of such literature remains limited. New research in multiple, well-defined PA contexts is needed to inform tailoring of PA policies and programs.[103] Studies investigating multi-contextual PA correlates among low-income and racial/ethnic minority children, who disproportionately experience obesity and related comorbidities, may be particularly important to inform efforts to increase PA in underserved populations and to help close related health disparities.[91]

Conclusions

Children in the U.S. and other countries worldwide fall short of recommended levels of PA. Insufficient PA is particularly concerning given the concurrent epidemic in pediatric obesity, which, along with other adverse outcomes, increases young people's risk of cardiometabolic disorders in childhood and adolescence of obesity and related comorbidies in later adult life.[7] Strategies that increase PA among children are an important public-health priority, though gaps in the PA research literature may hinder PA-promotion efforts.

Consistent evidence indicates that PA demonstrates beneficial associations with cardiometabolic risk factors in youth. While historically PA research and recommendations for children have focused principally on MVPA, the extent to which benefits occur specifically above the moderate-intensity threshold is in fact unclear.[50,51] New research is needed comparing the benefits of MVPA with those of total activity volume, including volume accrued at lower intensity. Developments in accelerometer technologies, which can detect movement at a wider range of intensities compared with historically relied-upon self-report instruments, open opportunities for such investigation.[50]

Research has also shown that PA programs delivered in controlled settings are efficacious for improving CRF and reducing adiposity, particularly in overweight/obese youth. However, these findings may not generalize to real-world practitioner settings.[59, 60] Practice-based studies are needed to advance understanding of the effects of PA programs delivered in contexts where findings from controlled trials are to be applied, such as community-based PA programs.[61, 63] Prior studies have shown that children's levels of participation in after-school PA programs and other practice settings varies considerably in terms of both attendance and in-program activity levels,[65, 66, 70, 72, 73, 104] but the impact of that variability on outcomes like CRF and adiposity is not well understood and needs further investigation.

Finally, prior research has identified correlates of PA in children and adolescents, but the importance of correlates appears to vary based on individual and contextual factors. To our knowledge, no prior studies have examined correlates of PA in multiple contexts among overweight/obese, low-income, Hispanic youth. Studies that examine PA correlates in such high-risk population subgroups, including analyses spanning multiple environmental contexts, are needed to support tailoring of PA policies and programs to priority populations and environments.

References

1. Bull F. *Physical activity guidelines in the UK: Review and recommendations*. Leicestershire, UK, 2010.

2. Australian Government Department of Health. Australia's Physical Activity and Sedentary Behaviour Guidelines, www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines#apa1317 (2014, accessed 12/4 2014).

3. U.S. Department of Health and Human Services. *Physical Activity Guidelines for Americans*. Washington, DC, 2008.

4. Tremblay MS, Warburton DE, Janssen I, et al. New Canadian physical activity guidelines. Appl Physiol Nutr Metab 2011; 36: 36-46.

5. World Health Organization. *Global recommendations on physical activity for health*. Geneva, Switzerland: Geneva, Switzerland, 2010.

6. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008; 40: 181.

7. Steinberger J, Daniels SR, Eckel RH, et al. Progress and challenges in metabolic syndrome in children and adolescents a scientific statement from the American Heart Association atherosclerosis, hypertension, and obesity in the young committee of the council on cardiovascular disease in the young; council on cardiovascular nursing; and council on nutrition, physical activity, and metabolism. Circulation 2009; 119: 628-647.

8. Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet 2014; 384: 766-781.

9. Ogden CL, Carroll MD, Kit BK, et al. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA 2014; 311: 806-814.

10. Troiano RP and Flegal KM. Overweight children and adolescents: description, epidemiology, and demographics. Pediatrics 1998; 101: 497-504.

11. Lovasi GS, Hutson MA, Guerra M, et al. Built environments and obesity in disadvantaged populations. Epidemiol Rev 2009; 31: 7-20.

12. Lobstein T, Baur L and Uauy R. Obesity in children and young people: a crisis in public health. Obes Rev 2004; 5: 4-104.

13. Daniels S. Complications of obesity in children and adolescents. Int J Obes 2009; 33: S60-S65.

14. Berenson GS, Wattigney WA, Tracy RE, et al. Atherosclerosis of the aorta and coronary arteries and cardiovascular risk factors in persons aged 6 to 30 years and studied at necropsy (The Bogalusa Heart Study). Am J Cardiol 1992; 70: 851-858.

15. Baker JL, Olsen LW and Sørensen TI. Childhood body-mass index and the risk of coronary heart disease in adulthood. N Engl J Med 2007; 357: 2329-2337.

16. Goodman E, Dolan LM, Morrison JA, et al. Factor analysis of clustered cardiovascular risks in adolescence: obesity is the predominant correlate of risk among youth. Circulation 2005; 111: 1970-1977.

17. Cook S, Auinger P, Li C, et al. Metabolic syndrome rates in United States adolescents, from the national health and nutrition examination survey, 1999–2002. J Pediatr 2008; 152: 165-170. e2.

18. Eisenmann JC. On the use of a continuous metabolic syndrome score in pediatric research. Cardiovasc Diabetol 2008; 7: 17.

19. Thivel D, Malina RM, Isacco L, et al. Metabolic syndrome in obese children and adolescents: dichotomous or continuous?Metab Syndr Relat Disord 2009; 7: 549-556.

20. Franks PW, Hanson RL, Knowler WC, et al. Childhood predictors of young-onset type 2 diabetes. Diabetes 2007; 56: 2964-2972.

21. Camhi SM and Katzmarzyk PT. Tracking of cardiometabolic risk factor clustering from childhood to adulthood. Int J Pediatr Obes 2010; 5: 122-129.

22. Morrison JA, Friedman LA, Wang P, et al. Metabolic syndrome in childhood predicts adult metabolic syndrome and type 2 diabetes mellitus 25 to 30 years later. J Pediatr 2008; 152: 201-206.

23. Morrison JA, Friedman LA and Gray-McGuire C. Metabolic syndrome in childhood predicts adult cardiovascular disease 25 years later: the Princeton Lipid Research Clinics Follow-up Study. Pediatrics 2007; 120: 340-345.

24. Ravussin E and Swinburn BA. Pathophysiology of obesity. The Lancet 1992; 340: 404-408.

25. Institute of Medicine (US). Committee on Accelerating Progress in Obesity Prevention and Glickman D. *Accelerating progress in obesity prevention: solving the weight of the nation*, 2012.

26. Wilks DC, Sharp SJ, Ekelund U, et al. Objectively measured physical activity and fat mass in children: a bias-adjusted meta-analysis of prospective studies. PLOS ONE 2011; 6: e17205.

27. Trinh A, Campbell M, Ukoumunne OC, et al. Physical activity and 3-year BMI change in overweight and obese children. Pediatrics 2013; 131: e470-7.

28. Fisher G, Hunter GR and Allison DB. Commentary: Physical activity does influence obesity risk when it actually occurs in sufficient amount. Int J Epidemiol 2013; 42: 1845-1848.

29. American Heart Association Nutrition Committee, Lichtenstein AH, Appel LJ, et al. Diet and lifestyle recommendations revision 2006: a scientific statement from the American Heart Association Nutrition Committee. Circulation 2006; 114: 82-96.

30. Gidding SS, Dennison BA, Birch LL, et al. Dietary recommendations for children and adolescents: a guide for practitioners. Pediatrics 2006; 117: 544-559.

31. Corbin C and Lindsey R. *Concepts in Physical Education with Laboratories*. 8th ed. Dubuque, IA: Dubuque, IA, 1994.

32. Baquet G, Van Praagh E and Berthoin S. Endurance training and aerobic fitness in young people. Sports Med 2003; 33: 1127-1143.

33. Kristensen PL, Moeller NC, Korsholm L, et al. The association between aerobic fitness and physical activity in children and adolescents: the European youth heart study. Eur J Appl Physiol 2010; 110: 267-275.

34. Institute of Medicine. *Fitness Measures and Health Outcomes in Youth*. Washington, DC: Washington, DC, 2012.

35. Mota J, Ribeiro JC, Carvalho J, et al. Cardiorespiratory fitness status and body mass index change over time: A 2-year longitudinal study in elementary school children. Int J Ped Obes 2009; 4: 338-342.

36. McGavock JM, Torrance BD, McGuire KA, et al. Cardiorespiratory fitness and the risk of overweight in youth: the Healthy Hearts Longitudinal Study of Cardiometabolic Health. Obesity 2009; 17: 1802-1807.

37. Hruby A, Chomitz VR, Arsenault LN, et al. Predicting maintenance or achievement of healthy weight in children: The impact of changes in physical fitness. Obesity 2012; 20: 1710-1717.

38. Ortega F, Ruiz J, Castillo M, et al. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes 2007; 32: 1-11.

39. Eisenmann JC. Aerobic fitness, fatness and the metabolic syndrome in children and adolescents. Acta Paediatr 2007; 96: 1723-1729.

40. DuBose KD, Eisenmann JC and Donnelly JE. Aerobic fitness attenuates the metabolic syndrome score in normal-weight, at-risk-for-overweight, and overweight children. Pediatrics 2007; 120: e1262-e1268.

41. Aires L, Silva P, Silva G, et al. Intensity of physical activity, cardiorespiratory fitness, and body mass index in youth. J Phys Act Health 2010; 7: 54.

42. Gahche J, Fakhouri T, Fulton J, et al. Cardiorespiratory fitness levels among US adolescents (1028.4). The FASEB Journal 2014; 28: 1028.4.

43. Ekelund U, Anderssen S, Froberg K, et al. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. Diabetologia 2007; 50: 1832-1840.

44. Brambilla P, Pozzobon G and Pietrobelli A. Physical activity as the main therapeutic tool for metabolic syndrome in childhood. Int J Obes 2010; 35: 16-28.

45. McMurray RG and Ondrak KS. Cardiometabolic risk factors in children: the importance of physical activity. Am J Lifestyle Med 2013; 7: 292-303.

46. Ekelund U, Luan J, Sherar LB, et al. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA 2012; 307: 704-712.

47. Carson V, Ridgers ND, Howard BJ, et al. Light-intensity physical activity and cardiometabolic biomarkers in US adolescents. PLOS ONE 2013; 8: e71417.

48. Chaput J, Saunders TJ, Mathieu M, et al. Combined associations between moderate to vigorous physical activity and sedentary behaviour with cardiometabolic risk factors in children. Appl Physiol Nutr Metab 2013; 38: 477-483.

49. Neto AS, de Campos W, dos Santos GC, et al. Metabolic syndrome risk score and time expended in moderate to vigorous physical activity in adolescents. BMC Pediatr 2014; 14: 42.

50. Powell KE, Paluch AE and Blair SN. Physical activity for health: What kind? How much? How intense? On top of what?. Annu Rev Public Health 2011; 32: 349-365.

51. Janssen I and LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act 2010; 7: 1-16.

52. Physical Activity Guidelines Advisory Committee. Physical activity guidelines advisory committee report, 2008.

53. Carson V and Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. BMC Public Health 2011; 11: 274.

54. Hay J, Maximova K, Durksen A, et al. Physical activity intensity and cardiometabolic risk in youth. Arch Pediatr Adolesc Med 2012; 166: 1022-1029.

55. Ness AR, Leary SD, Mattocks C, et al. Objectively measured physical activity and fat mass in a large cohort of children. PLOS Med 2007; 4: e97.

56. Riddoch CJ, Leary SD, Ness AR, et al. Prospective associations between objective measures of physical activity and fat mass in 12-14 year old children: the Avon Longitudinal Study of Parents and Children (ALSPAC). BMJ 2009; 339: b4544.

57. Leary SD, Ness AR, Smith GD, et al. Physical activity and blood pressure in childhood: findings from a population-based study. Hypertension 2008; 51: 92-98.

58. Swain DP and Franklin BA. Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. Am J Cardiol 2006; 97: 141-147.

59. Kelley GA, Kelley KS and Pate RR. Effects of exercise on BMI z-score in overweight and obese children and adolescents: a systematic review with meta-analysis. BMC Pediatrics 2014; 14: 225.

60. Vasconcellos F, Seabra A, Katzmarzyk PT, et al. Physical activity in overweight and obese adolescents: systematic review of the effects on physical fitness components and cardiovascular risk factors. Sports Med 2014: 1-14.

61. Brownson RC and Jones E. Bridging the gap: translating research into policy and practice. Prev Med 2009; 49: 313-315.

62. Glasgow RE, Green LW, Taylor MV, et al. An evidence integration triangle for aligning science with policy and practice. Am J Prev Med 2012; 42: 646-654.

63. Ammerman A, Smith TW and Calancie L. Practice-based evidence in public health: improving reach, relevance, and results. Annu Rev Public Health 2014; 35: 47-63.

64. Beets MW. Enhancing the translation of physical activity interventions in afterschool programs. Am J Lifestyle Med 2012; 6: 328-341.

65. Garn AC, McCaughtry N, Kulik NL, et al. Successful after-school physical activity clubs in urban high schools: perspectives of adult leaders and student participants. J Teach Phys Educ 2014; 33: 112-133.

66. Maljak K, Garn A, McCaughtry N, et al. Challenges in offering inner-city after-school physical activity clubs. Am J Health Educ 2014; 45: 297-307.

67. Carson V, Rinaldi R, Torrance B, et al. Vigorous physical activity and longitudinal associations with cardiometabolic risk factors in youth. Int J Obes 2013; 38: 16-21.

68. Yin Z, Gutin B, Johnson MH, et al. An environmental approach to obesity prevention in children: Medical College of Georgia FitKid Project year 1 results. Obes Res 2005; 13: 2153-2161.

69. Barbeau P, Johnson MH, Howe CA, et al. Ten months of exercise improves general and visceral adiposity, bone, and fitness in black girls. Obesity 2007; 15: 2077-2085.

70. Sacheck JM, Nelson T, Ficker L, et al. Physical activity during soccer and its contribution to physical activity recommendations in normal weight and overweight children. Pediatr Exerc Sci 2011; 23: 281-292.

71. Ridgers ND, Stratton G and Fairclough SJ. Physical activity levels of children during school playtime. Sports medicine 2006; 36: 359-371.

72. McKenzie TL, Marshall SJ, Sallis JF, et al. Student activity levels, lesson context, and teacher behavior during middle school physical education. Res Q Exerc Sport 2000; 71: 249-259.

73. Trost SG, Rosenkranz RR and Dzewaltowski D. Physical activity levels among children attending after-school programs. Med Sci Sports Exerc 2011; 40: 622-629.

74. Metcalf B, Henley W and Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes. BMJ 2012; 345: e5888.

75. Sallis JF and Owen NG. *Physical Activity and Behavioral Medicine*, 1998.

76. Graham D, Wall M, Larson N, et al. Multicontextual correlates of adolescent leisure-time physical activity. Am J Prev Med 2014; 46: 605-616.

77. Dencker M, Thorsson O, Karlsson MK, et al. Daily physical activity and its relation to aerobic fitness in children aged 8–11 years. Eur J Appl Physiol 2006; 96: 587-592.

78. Sallis JF, Prochaska JJ and Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc 2000; 32: 963-975.

79. Ortlieb S, Schneider G, Koletzko S, et al. Physical activity and its correlates in children: a cross-sectional study (the GINIplus & LISAplus studies). BMC Public Health 2013; 13: 349-2458-13-349.

80. Metcalf BS, Hosking J, Jeffery A, et al. Fatness leads to inactivity, but inactivity does not lead to fatness: a longitudinal study in children (EarlyBird 45). Arch Dis Child 2011; 96: 942-947.

81. Belcher BR, Berrigan D, Dodd KW, et al. Physical activity in US youth: Impact of race/ethnicity, age, gender, and weight status. Med Sci Sports Exerc 2010; 42: 2211-2221.

82. Zabinski MF, Saelens BE, Stein RI, et al. Overweight children's barriers to and support for physical activity. Obes Res 2003; 11: 238-246.

83. Taylor WC, Sallis JF, Dowda M, et al. Activity patterns and correlates among youth: differences by weight status. Pediatr Exerc Sci 2002; 14: 418.

84. Biddle SJ, Atkin AJ, Cavill N, et al. Correlates of physical activity in youth: a review of quantitative systematic reviews. Int Rev Sport Exerc Psychol 2011; 4: 25-49.

85. Taylor WC, Yancey AK, Leslie J, et al. Physical activity among African American and Latino middle school girls: consistent beliefs, expectations, and experiences across two sites. Women Health 2000; 30: 67-82.

86. Gordon-Larsen P, Griffiths P, Bentley ME, et al. Barriers to physical activity: qualitative data on caregiver–daughter perceptions and practices. Am J Prev Med 2004; 27: 218-223.

87. Garcia AW, Antonakos CL, and Ronis DL. Changes in physical activity beliefs and behaviors of boys and girls across the transition to junior high school. J Adol Health 1998; 22: 394-402.

88. Voss C, Ogunleye AA and Sandercock GR. Physical Activity Questionnaire for children and adolescents: English norms and cut-off points. Pediatr Int 2013; 55: 498-507.

89. Slater A and Tiggemann M. “Uncool to do sport”: A focus group study of adolescent girls’ reasons for withdrawing from physical activity. Psychol Sport Exerc 2010; 11: 619-626.

90. Molnar BE, Gortmaker SL, Bull FC, et al. Unsafe to play? Neighborhood disorder and lack of safety predict reduced physical activity among urban children and adolescents. Am J Health Promot 2004; 18: 378-386.

91. Whitt-Glover MC, Taylor WC, Floyd MF, et al. Disparities in physical activity and sedentary behaviors among US children and adolescents: prevalence, correlates, and intervention implications. J Public Health Policy 2009: S309-S334.

92. Lindsay AC, Greaney ML, Sussner KM, et al. Socio-cultural, organizational, and community level influences on physical activity levels of latino preschool-age children: a qualitative study. Int J Child Health Nutr 2014; 3: 41-47.

93. Teresia M, Cerin E, Lee RE, et al. Environmental and cultural correlates of physical activity parenting practices among Latino parents with preschool-aged children: Ninos Activos. BMC Public Health 2014; 14: 707.

94. Kelly EB, Parra-Medina D, Pfeiffer KA, et al. Correlates of physical activity in black, Hispanic, and white middle school girls. J Phys Act Health 2010; 7: 184-193.

95. Biddle SJ, Whitehead SH, O Donovan TM, et al. Correlates of participation in physical activity for adolescent girls: A systematic review of recent literature. J Phys Act Health 2005; 2: 423.

96. Babic MJ, Morgan PJ, Plotnikoff RC, et al. Physical activity and physical self-concept in youth: systematic review and meta-analysis. Sports Med 2014: 1-13.

97. Van der Horst K, Paw M, Twisk JW, et al. A brief review on correlates of physical activity and sedentariness in youth. Med Sci Sports Exerc 2007; 39: 1241.

98. McLeroy KR, Bibeau D, Steckler A, et al. An ecological perspective on health promotion programs. Health Educ Behav 1988; 15: 351-377.

99. Bandura A. Health promotion from the perspective of social cognitive theory. Psychol Health 1998; 13: 623-649.

100. Spink KS, Shields CA, Chad K, et al. Correlates of structured and unstructured activity among sufficiently active youth and adolescents: A new approach to understanding physical activity. Pediatr Exerc Sci 2006; 18: 203.

101. Stanley RM, Ridley K, Olds TS, et al. Increasing specificity of correlate research: exploring correlates of children's lunchtime and after-school physical activity. PLOS ONE 2014; 9: e96460.

102. Ommundsen Y, Klasson-Heggebø L and Anderssen SA. Psycho-social and environmental correlates of location-specific physical activity among 9-and 15-year-old Norwegian boys and girls: the European Youth Heart Study. Int J Behav Nutr Phys Act 2006; 3: 32.

103. Giles-Corti B, Timperio A, Bull F, et al. Understanding physical activity environmental correlates: increased specificity for ecological models. Exerc Sport Sci Rev 2005; 33: 175-181.

104. Ridgers ND, Salmon J, Parrish A, et al. Physical activity during school recess: a systematic review. Am J Prev Med 2012; 43: 320-328.

Chapter 3: Methods

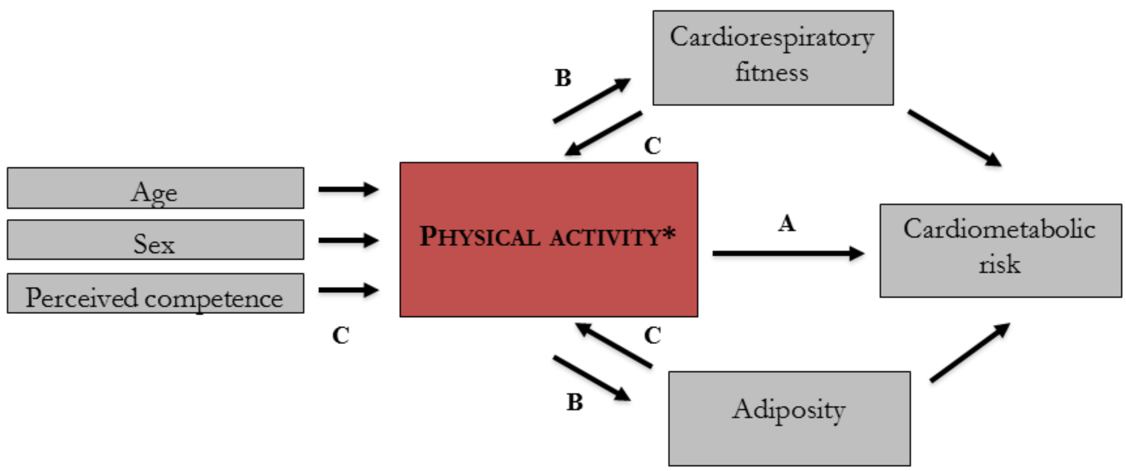
This section introduces the conceptual framework that guided this overall research and describes the datasets and analytical methods that were used to test hypotheses pertaining to relationships between different constructs within the framework. Subsequent chapters also describe these datasets and analytical methods, along with corresponding results and conclusions.

Conceptual framework

In recent decades, research and policies concerning physical activity (PA) and nutrition have become increasingly intertwined, particularly amid growing public-health concerns around energy imbalance and obesity.[1, 2] The conceptual framework for this research (Figure 1) centers principally on PA, which represents either the main predictor variable or main outcome variable for all questions investigated. PA itself is a multidimensional construct, and each aim examines a distinct dimension. Using accelerometer data from a nationally-representative dataset, Aim 1 examines the interplay between PA volume and intensity, taking as its main predictor variables total volume, moderate-to-vigorous PA (MVPA) minutes, and PA volume accrued at light and moderate-to-vigorous intensity. The cross-sectional relationships between these different PA variables and cardiometabolic risk markers in adolescents are examined and compared (Path A). In Aim 2, which uses longitudinal data from a community-based PA program serving overweight/obese children, PA-based predictor variables include program attendance as well as pedometer-measured PA level in program. This aim examines the relationship between attendance and changes in cardiorespiratory fitness (CRF) and body mass index

(BMI) (Paths B), as well as whether in-program activity levels influence those associations. Aim 3 uses data from participants in the same program, but different dimensions of PA are the main outcome variables: these include self-reported PA level in general living, as well as pedometer-measured PA level in a structured program, including both structured exercise and structured sports sessions. This aim explores correlates of these different dimensions of PA, including children's demographic (age, sex), physiologic (aerobic fitness, BMI z-score), and psychosocial (perceived athletic competence) characteristics (Paths C).

Figure 1. Conceptual framework



*This dissertation examines multiple dimensions of physical activity (PA), including total PA volume and intensity, attendance at a PA program, self-reported general-living PA, and PA in a structured program, including structured exercise and sports.

National Health and Nutrition Examination Survey (NHANES) dataset

Overview of NHANES methods

NHANES is a nationally representative, cross-sectional survey of the U.S. population and the primary source of objectively collected health data in the U.S. It uses a complex, multistage probability design to generate a representative sample of the non-institutionalized civilian population.[3] The survey includes two main components. First, trained interviewers visit participants' homes to administer an in-home survey. Second, participants complete a health examination, including a basic physical exam and blood draws for laboratory assessment, in a mobile examination center (MEC).[4] In 2003-2004 and 2005-2006 NHANES, black, Mexican-American, and adolescent populations were oversampled.[3] These two NHANES cycles are also the most recent in which accelerometers were administered and the data are publicly available. This dissertation uses 2003–2006 data for subjects ages 12–19; two of our main outcome variables, insulin and triglycerides, were not measured in younger children participating in NHANES.

NHANES study protocols were approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board. Written informed consent was obtained from all subjects. Consent was also received from parents/guardians of those <18 years old. Because NHANES data are fully de-identified and publicly available, analysis of these data was exempted from review by the Tufts University Institutional Review Board (IRB). The following sections describe the variables used for analyses in this dissertation.

Physical activity predictor variables

Non-wheelchair-bound subjects were given uniaxial accelerometers (ActiGraph AM-7164) and asked to wear them on the right hip for seven consecutive days during waking hours, except when swimming or bathing. The devices recorded activity counts in 60-second epochs. Activity count files were processed using syntax adapted from the

National Cancer Institute,[5] which facilitates identification and editing of unreliable or invalid values. Non-wear time was classified as 60+ consecutive minutes with zero counts, allowing for up to two consecutive minutes with 1–100 counts. Only subjects with ≥ 10 hours of wear time per day for ≥ 3 days were included in the analyses.[6] The intensity of each epoch was designated using cut-points validated by Evenson and colleagues: <100 counts per minute (CPM) was sedentary; 100–2291 CPM was light; 2292–4007 CPM was moderate; and ≥4008 counts was vigorous.[7] While we originally proposed using the cut-points developed by Freedson and colleagues, we changed our plans in light of a validation study that found the Evenson thresholds yielded the best overall classification accuracy for multiple categories of PA and, unlike the Freedson cut-points, did not demonstrate age-related misclassification of LPA as MPA.[8] Differential misclassification of PA by age might lead to confounding in analyses of associations between PA and cardiometabolic risk factors, which are likewise associated with adolescent age and pubertal development.[9-11]

For each subject, the number of sedentary, light, moderate, vigorous, and moderate-to-vigorous minutes were calculated for each valid day (i.e., days with ≥10 hours of wear time) and averaged across all valid days. Our total volume variable, total activity counts (TAC), was calculated as the total number of accelerometer counts in valid days divided by the number of valid days. Total activity counts at light intensity (L-TAC) was calculated as the sum total of accelerometer counts in light epochs across all valid days, divided by the number of valid days. Total activity counts at moderate-to-vigorous intensity (MV-TAC) was calculated as the sum total of accelerometer counts in moderate or vigorous epochs across all valid days, divided by the number of valid days.

Our decision to examine PA as total counts as well as counts by intensity category was informed in part by exploratory analyses investigating inter-subject variability in the average number of activity counts per minute of PA in each category (Appendix 1.A). For example, the sample median for mean counts per minute of MVPA was 3476, but the interquartile range spanned nearly 700 counts (IQR: 3170–3855). We also conducted multivariable regression analyses exploring whether child factors (age, sex, household poverty-to-income ratio, race/ethnicity, and BMI z-score) predicted mean counts/minute of each LPA and MVPA (Appendix 1.B–C). We found significant associations between mean counts/minute of both LPA and MVPA and male sex (+) and age (–), and of mean counts/minute of MVPA with BMI z-score (–). The non-random variability in mean counts/minute of PA in different intensity categories may be a potential source of bias in analyses using variables like LPA or MVPA minutes. One advantage of using TAC, L-TAC, and MV-TAC are that these variables account for variability in counts above the intensity cut-points.

Individual cardiometabolic risk factor variables

In the MEC exam, trained NHANES staff measured height and weight with a single measurement. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared, and BMI z-scores were determined based on CDC growth charts.[12] Waist circumference (WC) was measured at the uppermost lateral border of the ilium on the midaxillary line with a single measurement. Three consecutive blood pressure (BP) measurements were taken after subjects rested quietly for five minutes while seated; systolic BP and diastolic BP were determined by averaging values for all non-zero readings. Detailed laboratory protocols for blood measures, including quality-control mechanisms, are described elsewhere.[3] HDL was evaluated for all participants, and triglycerides, insulin, and glucose were measured only for participants in the morning examinations who had fasted for at least eight hours, as determined by interview. Because there were equipment and laboratory changes in 2005–2006 compared with 2003–2004 for insulin analyses, the 2005–2006 values were adjusted using a regression equation provided by CDC.[3] For one subject the regression equation generated a negative value, which was set to missing;[13] no other values appeared biologically implausible.

Homeostasis model assessments

As an indicator of insulin sensitivity, homeostasis model assessments were calculated using the HOMA calculator available from the Diabetes Trial Unit at the University of Oxford (www.dtu.ox.ac.uk/homacalculator/). The calculator uses fasting insulin and glucose values to generate estimates of steady-state beta-cell function (HOMA%B) and insulin sensitivity (HOMA%S) as a percentage of a normal reference population.[14] Validation studies have found HOMA%S to be strongly correlated with insulin sensitivity measured via euglycemic clamp in children and adolescents.[15] However, in the present sample, we found that variability in HOMA%S was explained almost entirely by insulin values; for example, when log-HOMA%S was regressed on log-insulin, the R^2 value was 0.999. This suggests limited utility in analyses using HOMA%S above and beyond analyses using insulin. As a result, we chose to include only insulin, and not HOMA%S, in our NHANES paper submitted for publication.

Clustered risk

Several prior studies have suggested that continuous risk scores, typically calculated as a summation of z-scores for cardiometabolic risk variables,[16] are appropriate measures of risk-clustering in youth. [16-18] To summarize clustered cardiometabolic risk, we used the continuous metabolic risk index (CMRI) developed and validated in youth by Martinez-Vizcaino and colleagues.[19] Mean arterial pressure ([systolic BP + 2*diastolic BP]/3),[20] WC, fasting insulin, and triglycerides-to-HDL ratio were each regressed on age and sex and the residuals divided by the standard deviations of the residuals to generate z-scores; fasting insulin, WC, and triglyceride-to-HDL ratios were first log-transformed to normalize skewed distributions. The four z-scores scores were summed to yield CMRI.

Given NHANES's complex design, determining the standard deviations of the residuals required complex manual calculations since these statistics could not be obtained directly from SAS. We contacted NCHS for guidance and used the following process to generate the standard deviation of each residual, accounting for the complex survey design: 1. regress the variable on age and sex using PROC REG and output the residual; 2. use PROC MEANS to calculate the standard deviation (SD) of the residual's mean; 3. calculate the standard error (SE) of the residual's mean: (SD of the mean from step 2)/(√ n); 4. calculate the SE of the residual's mean accounting for complex design using PROC SURVEYMEANS; 5. calculate the design effect: (SE from step 4)/(SE from step 3); 6. calculate the simple random sample (SRS) SE of the residual's mean: (SE from step 4)/(√[Design Effect]); 7. Calculate the SRS SD of the residual's mean: ([SE from step 6] × [√ n]); 9. Calculate the SD of the residual accounting for the complex design: √([SD Mean from step 7]^2) + [SE Mean from step 6]^2).

Other variables

Data on age, sex, household income, household composition, pregnant/lactating status, prior diagnosis of diabetes or asthma, and physical limitations were collected through computer-assisted personal interviews conducted by NHANES household interviewers. Subjects ages 16 and older were interviewed directly; parents/caregivers served as proxy respondents for subjects ages 12–15 and for subjects unable to answer questions. Poverty-to-income ratios were calculated as the ratio between household income and federal poverty thresholds.

Serum cotinine levels were included in NHANES laboratory analyses, and subjects were categorized as smokers (cotinine ≥3 ng/mL) or nonsmokers (cotinine < 3 ng/mL) based on previously published cut-points.[21] We also ran exploratory analyses using data on self-reported tobacco use in the prior five days. There was good agreement between self-reported tobacco use and elevated cotinine (Cohen's kappa = 0.62), but a small number of subjects who self-reported smoking had cotinine levels < 3 ng/mL. Classifying these individuals as smokers did not change the results of our analyses; for the sake of simplicity, we decided to use the cotinine biomarker only to categorize smoking status in our final analyses.

Dietary data were generated from a single 24-hour dietary recall administered by trained interviewers using the United States Department of Agriculture's Automated Multiple-Pass Method. Dietary variables (total energy; fiber; sugar; monounsaturated, polyunsaturated, and saturated fat, each as a percentage of total energy; dietary cholesterol; sodium; and potassium) were included as covariates due to their potential association with cardiometabolic risk factors, as noted in the American Academy of Pediatrics and American Heart Association (AHA) joint dietary recommendations for children and adolescents[22] and/or the AHA diet and lifestyle guidelines for all Americans.[23]

While sedentary behavior may increase cardiometabolic risk independent of PA,[24] accelerometer-derived sedentary time could not be included as a covariate due to multi-collinearity with other PA variables; in our regression analyses using L-TAC and MV-TAC in particular, the variance inflation factor exceeded the commonly accepted threshold of 10 (VIF = 13.1).[25] Therefore, self-reported television and computer time, which represent a substantial proportion of sedentary time in U.S. adolescents,[26] were included in all models as an alternative indicator of sedentary behavior. During the household interview, subjects were asked, in two separate questions, the average daily time spent in the prior 30 days a) watching television/videos and b) using a computer, with seven response options ranging from none to ≥5 hours. For each variable, responses were collapsed into three categories: ≤1 hour, 2–3 hours, or ≥4 hours.

Other potential confounding variables include pubertal stage, sleep, stress, and family history of cardiometabolic disorders, but these variables were unavailable in NHANES 2003–2006. Cardiorespiratory fitness data (VO_2 max) were available in NHANES 2003–2004 but not 2005–2006; we considered the possibility of running analyses using only the 2003–2004 NHANES dataset but determined that the sample size (n=907 and n=430 for non-fasting and fasting sub-samples, respectively) would provide insufficient statistical power to test our research questions.

Analytic sample

The study sample was limited to participants aged 12–19, since two of our main outcome variables (fasting insulin and triglycerides) were available only from participants beginning at age 12. Subjects were excluded from the study sample if they had returned accelerometers out of calibration or had fewer than 3 days with ≥10 accelerometer wear hours; were underweight or pregnant/lactating; had previously been diagnosed as diabetic; or had missing HDL data, examination measures (missing height, weight, WC, or <1 valid BP reading), or other covariate data. Because fasting insulin and triglycerides were measured only in NHANES subjects participating in morning examinations, a fasting subsample was created, with subjects with missing insulin or triglycerides data excluded.

Aim 1 analyses

All analyses were conducted in SAS 9.3 and accounted for NHANES's complex design and sample weights.[3] Given non-random loss of substantial numbers of subjects (>50%) from the study samples, mainly due to incomplete accelerometer data, weights were adjusted to restore national representativeness across age, sex, and racial-ethnic groups. To ensure reweighting restored representativeness, we compared demographic characteristics in the full NHANES sample of subjects ages 12–19 (n=4591) using the CDC-provided interview weights with characteristics in our main study sample (n=2105) and fasting sub-sample (n=953) using the reweighted MEC and fasting sample weights, respectively. As hoped, the reweighted study samples were similar to the NHANES interview sample in terms of sex, race/ethnicity, and age (Appendix 1.D).

Participant demographic, anthropometric, and cardiometabolic characteristics were calculated for the study sample and fasting subsample. For PA and sedentary-time variables, means were calculated for the study sample as well as for sex subgroups, and independent-samples t-tests (continuous variables) or chi-square tests (categorical variables) were used to test for differences between males and females.

Multivariable regression models were used to test for associations between PA predictor variables and cardiometabolic outcome variables. Residuals were examined to test assumptions of normality, and WC, insulin, and triglycerides were log-transformed. Three main models were employed: model 1 analyses included TAC as the main predictor, model 2 analyses included MVPA minutes as the main predictor, and model 3 analyses included both L-TAC and MV-TAC as the main predictors. As secondary analyses, we also modeled TAC and MVPA together to determine whether either variable was significantly associated with cardiometabolic outcomes independent of the other. Each model was run with seven cardiometabolic outcome variables: CMRI, waist circumference, systolic BP, diastolic BP, HDL, insulin, triglycerides. All analyses adjusted for BMI z-score; accelerometer wear time; age; sex; race-ethnicity; self-reported television time (≤ 1hr, 2–3 hours, ≥ 4 hrs); self-reported computer time (≤ 1 hr, 2–3 hours, ≥ 4 hrs); smoking status (y/n); poverty-to-income ratio; energy intake; dietary fiber; dietary sugar; dietary cholesterol; dietary saturated, monounsaturated, and polyunsaturated fat, each as % of total kilocalories; dietary sodium; dietary potassium; and self-reported asthma (y/n) and physical limitations (y/n). Moderation analyses were conducted to determine whether age or sex influenced associations between PA predictors and cardiometabolic outcomes. A threshold of $p < 0.05$ was used to determine statistical significance in our main analyses. To minimize potential for type-1 error, the threshold was lowered to $p < 0.001$ for moderation analyses, which were secondary to our main study objectives.[27] Results of these analyses are reported in Chapter 4.

Additional analyses

In the original dissertation proposal defended in July 2013, Aim 1 focused on relationships between minutes of PA at different intensities and cardiometabolic risk factors, as well as moderation of those relationships by BMI z-score. However, NHANES data are publicly available, and a paper published by Carson and colleagues in August 2013 used this same dataset to test similar questions regarding associations between light PA (LPA) and MVPA and cardiometabolic risk factors.[27] Appendix 1.E shows results of our multivariable regression analyses testing associations between light PA and MVPA and moderation of those associations by BMI z-score. After the Carson and colleagues paper was published, we also decided to test whether associations between MVPA and insulin and HOMA%S were moderated by race/ethnicity; we found no evidence of moderation (Appendix 1.F). Ultimately it was determined that a more fundamental change in our analytical models would be necessary to differentiate our work from Carson and colleagues, and our aim was refocused to center on the relationships between TAC, MVPA minutes, L-TAC, and MV-TAC and cardiometabolic risk factors.

Let’s Get Movin’ program and dataset

Program overview

Data for Aims 2 and 3 were collected from October 2012–June 2013 in partnership with Let’s Get Movin’ (LGM), a community-based after-school PA program in a low-income, mostly Hispanic community in East Boston, Massachusetts. Founded in 2005 by the East Boston Neighborhood Health Center (EBNHC), the program serves children ages 8–14 referred by pediatricians based on a diagnosis of overweight or obesity. Importantly, the foundation for this research partnership was laid over the course of several years prior to the research period. The principal investigator for this research worked with LGM on a volunteer basis during the 2010–2011 program year and as a part-time employee during the 2011–2012 program year, developing lesson plans, leading program sessions for children, and contributing to broader program objectives (e.g., assisting with grant applications). These experiences provided important opportunities to earn the trust of LGM’s staff and leadership team, to understand LGM participants and their unique needs, to assess local assets, and to build relationships more broadly within the community (e.g., with staff at local facilities where program sessions were held). The 2012–2013 partnership was designed to both support research hypothesis testing and provide the program with high-quality program-evaluation protocols that could be replicated in future program years; thus, methodological rigor was balanced against cost-containment and ease of implementation for program staff. All study protocols were approved by the Tufts University Institutional Review Board. Since the initial research period, the program curriculum and evaluation plans developed through this partnership have been refined and reproduced in the 2013–2014 and current (2014–2015) program years.

During the 2012–2013 program year, children participating in LGM were assigned to one of five program sites, all in YMCA- or city-owned gymnasiums. Each site was led by two coaches hired through the federal government's AmeriCorps program; the child-to-coach ratio was capped at 13:1. Program sessions were held twice/week after school for two hours, except during school holidays; 59 total sessions were offered.

Each program session, children engaged in semi-structured free play (e.g., tag games) for the first 10 minutes. The remaining time included two main sessions: exercise and sports. Lessons aimed to achieve > 50% of time in MVPA. The exercise session included a dynamic warmup (10 minutes), walking/running activities (20-30 minutes), and strength-building activities (10-20 minutes). Exercises were designed to be feasible for low-fit children. Participants were provided choices as possible (e.g., choosing to walk or run), and popular music was played throughout. Participants reported walking/running distances completed in program and, based on mileage accrued, could earn medals and other small awards, like t-shirts; these rewards were provided through Mighty Milers (www. mightymilers.org), a not-for-profit organization that provides these resources at no charge to programs serving low-income children. After the exercise session was a 10-minute break with a healthy snack (e.g., a piece of fruit). The sport session included sports drills and game play (40-50 minutes), which emphasized fun/skill-building over competition and included soccer, basketball, ultimate Frisbee, and football. Program staff were trained on lessons and motivational strategies (e.g., providing positive reinforcement, supporting individual goal-setting, creating autonomy-supportive environments) prior to implementation.

Approximately once/month, the snack period was extended to 30 minutes and short nutrition lessons were delivered (10 total over the year). These lessons were developed collaboratively with program leaders and health center clinicians. Topics included energy balance; whole grains; fruits and vegetables; low-fat dairy; nutrition labels; and healthy beverages, breakfast, and snacks.

Study participants

Parents were contacted by phone by LGM staff and, if interested in the program, enrolled their children at program offices. While most LGM participants enrolled at the beginning of the program year (October), pediatricians referred new children on a rolling basis. At the time of enrollment, program staff notified parents that Tufts researchers sought to use data collected from participants for research purposes. Interested parents reviewed a consent form (Appendix 2.A), available in English and in Spanish, explained by a staff member certified through the Collaborative Institutional Training Initiative (CITI). Parents who provided consent also received a child assent form (Appendix 2.B), also available in English and Spanish, and were asked to discuss it with their child. The child assent form was later reviewed with individual children or small groups at program sites by CITI-certified staff, and signatures were obtained for assenting children. Both parents and children were explicitly told that children could participate in the program even if they opted not to have their data used for research purposes. A total of 137 enrolled in the program over the year; five parents did not provide consent and two children did not provide assent, leaving 130 children eligible for inclusion in our analyses.

Demographics

All data-collection protocols were developed through collaboration between Tufts University researchers, health center clinicians, and LGM program leaders and administered by trained program staff. At time of enrollment, parents completed questionnaires[28] with questions on child sex, race, ethnicity, pubertal development, and date and country of birth; mother's country of origin; and household size and income (Appendix 2.B). Parent surveys were scored and double-entered by program staff using standardized scoring sheets. Entries were compared using SAS PROC COMPARE, errors reconciled, and comparisons re-run until 0 discrepancies remained between entries.

Children were categorized yes/no for puberty based on parent-reported menarche (girls) or voice change (boys). Poverty-to-income ratios were calculated using U.S. federal poverty thresholds for 2012. Of all questions on the parent survey, the race item was most often skipped (10% missing). Program staff surmised that most participants' parents may identify themselves and their children as being Hispanic but not identify with any of the race categories (e.g., white, black). Given the high rate of missingness, race was not included in our analyses, and we instead used Hispanic ethnicity and child/mother nativity data to characterize the population.

Cardiorespiratory fitness

At baseline (October or, for later registrants, time of enrollment), midpoint (February or first session attended thereafter), and final (June) time points, children completed the Progressive Aerobic Cardiorespiratory Endurance Run (PACER), a 20-meter maximal-effort shuttle-run test that has been strongly associated with VO_2 max in children[29] and was promoted by the Institute of Medicine (IOM) Committee on Fitness Measures and Health Outcomes as a preferred field measure of cardiorespiratory fitness (CRF) in youth.[30] All children completed one practice session prior to the baseline test, and, to minimize measurement error, the ratio of children to test administrators was capped at 4:1. The FitnessGram protocol was followed [31] and scores were recorded as laps completed, using FitnessGram scoring sheets (Appendix 3.C). To contextualize fitness levels relative to norms, scores were converted to VO_2 max estimates [32] and FitnessGram cutoffs were used to classify participants' CRF levels as "healthy fitness zone," "needs improvement," or "health risk."[31] Because FitnessGram does not publish cutoffs for 8- or 9-year-olds, fitness categorizations were conducted only for children who were ≥10 years old at baseline. In our main analyses PACER data were analyzed as laps completed.

Anthropometry

At baseline, midpoint, and final time points, children's height and weight were measured in triplicate using a portable stadiometer (Seca 214) and digital scale (Health-o-Meter 752KL). Waist circumference (WC) was measured in triplicate with a flexible tape measure at the uppermost lateral border of the right ilium, according to NHANES protocol.[33] Anthropometric and fitness data were entered by staff in Microsoft Excel within 24 hours of collection and double-checked by a second staff member. Paper copies were filed in a secure cabinet; at the end of the program year, anthropometric data were checked a third time for a random 10% sample of subjects, and 0 data-entry errors were identified.

BMI was calculated as (weight in kilograms)/(height in meters)^2 and BMI z-scores calculated using growth charts from the Centers for Disease Control and Prevention (CDC).[12] We used BMI rather than BMI z-score as our outcome variable in longitudinal analyses. Prior studies have shown that, whereas BMI z-scores are preferred for assessing adiposity at a single time point, in longitudinal studies BMI provides greater statistical power and yields more precise and interpretable estimates;[34, 35] advantages of BMI over BMI z-scores appear particularly pronounced in studies with obese youth.[36]

To explore whether BMI or BMI z-scores should be used in longitudinal analyses in the present study, we examined whether within-subject variability of BMI or BMI z-scores was associated with baseline weight status or BMI z-score, consistent with approaches used in prior studies.[34, 35, 37] First, we calculated baseline-to-final changes in BMI z-score and BMI, regressed the change scores on baseline BMI z-score and time between measures, and plotted residuals against baseline BMI z-score for visual examination. Second, we compared the BMI and BMI z-score trajectories of pair-matched children who were similar in most respects except for baseline adiposity. Third, we examined within-subject standard deviations for baseline/final BMI and baseline/final BMI z-scores, limiting the sample to children with at least 200 days between measurements (n=63) to ensure comparable timeframes. We tested whether within-subject standard deviations of BMI and BMI z-score were associated with baseline weight status category (independent samples t-tests for overweight v. obese subjects) or baseline BMI z-score (Pearson's correlations). All findings are outlined in Appendix 3.A. Together, these analyses suggest that, in this sample, BMI is more consistently sensitive to changes in adiposity than is BMI z-score, independent of subjects' baseline adiposity, and therefore appears to be the more appropriate variable for our longitudinal analyses.

Waist-to-height ratios (WHtR) were calculated as (WC in cm)/(height in cm). Prior research has found that WHtR is more strongly correlated with total and trunk body fat than is WC,[38] and normal WHtR values are stable across age, sex, and race-ethnicity categories,[39, 40] facilitating comparisons within diverse samples. However, program staff reported challenges that may have compromised the reliability and validity of WC measurements and, in turn, WHtR. For example, some staff found it difficult to locate the iliac crest on palpation, particularly in the most overweight children, and others reported children "sucking in" during WC measurements. Given high potential for invalid WC data, height and weight measurements, which were deemed relatively less prone to error, were used to generate our main study variables representing adiposity. WHtR was not used in our main analyses, but pre/post data are reported in Appendix C.

General-living PA, dietary behaviors, and self-concept

Children completed surveys including three sections that gauged general-living PA, dietary behaviors, and self-concept (Appendix 2.E). Due to time-intensity of administration, surveys were completed at baseline and final only. At each time point, surveys were double-entered by program staff using standardized scoring sheets and cleaned in the same manner as baseline parent surveys.

The survey's first section was the Physical Activity Questionnaire for Children (PAQ-C),[41, 42] a nine-item survey that provides a general measure of PA over the prior 7 days. Questions gauge participation in different sports; activity during physical education and recess, after school, in the evenings, on weekends, and on each day of the week; and overall self-assessment of activity levels. The score for each item ranges from 1–5, with higher scores denoting higher activity levels. The recess item does not have a response option indicating “I do not have recess”; children who did not have recess wrote “no recess” in the margin, and a score of 1 was later imputed for that item. Test administrators noted that the majority of children attended schools that did not offer PA during lunch; therefore, the lunchtime activity item was dropped, as reported in prior research,[43] and overall scores were calculated as the mean of the remaining eight items.

The second section of the survey was the dietary-domain subscale from the HABITS questionnaire,[44] which includes 16 questions regarding weight-related dietary behaviors in the prior month, including intakes of fruits/vegetables, beverages (juice, soda, other sugared beverages, water, and milk), junk foods, and fast food as well as snacking and portion-control behaviors. It was developed for and validated with low-income, mostly Hispanic, urban children ages 7–16.[44] Aggregate dietary scores are calculated as the sum of all items (range: 0–35; higher scores denote healthier dietary behaviors). If there was one missing item, the sample mode for that item was imputed. No surveys had >1 missing item.

Perceived athletic competence and global self-worth were measured using subscales from the Harter Self-Perception Profile for Children.[45] Each of the subscales contains six items that use a structured alternative choice format, in which respondents are asked which of two sentences is truer for them (e.g., “Some kids feel that they are better than others their age at sports” vs. “Other kids don't feel they can play as well”) and whether that statement is "sort of true" or "really true" for them. Items are scored 1–4 (higher scores denote higher perceived competence) and perceived competence and global self-worth calculated as the mean of the 6 items in each scale. If there was one missing item, scores were calculated as the mean of the remaining five items.[45] No surveys had >1 missing item.

Attendance and enrollment time

Staff recorded children's attendance at each session. On testing days, the date was recorded on children's data-collection forms. For baseline-to-midpoint and baseline-to-final time periods, attendance and enrollment time were calculated, respectively, as the cumulative number of sessions attended and days elapsed between test dates.

In-program activity levels

Pedometers (Walk4Life Neo II) were used to evaluate PA during 10 program sessions spread across the program year and representing a cross-section of typical activities. Program staff checked all pedometers using a 20-step test to identify potentially problematic devices prior to the initial administration.[46] Pedometers were not administered on nutrition-lesson days. Before the first data-recording day, each site administered the devices during one program session to help children become accustomed to wearing the devices and to allow leaders to practice administration. Pedometers were worn during active time, beginning with the exercise session. Children attached the pedometer to a waistband or belt at the midline of the thigh and were instructed not to remove the device unless asked to do so. When devices were attached or removed, time of day was recorded. During snack, pedometers were removed and exercise step counts were recorded; pedometers were reattached prior to sports. After the sports session, step counts were again recorded. Anomalous events were also noted. Pedometer data were entered within 24 hours and double-checked by a second staff member, and paper copies were filed. At the end of the program year, all pedometer data for a random 10% sample of participants was checked a third time and 0 errors were identified. Notes regarding anomalous events were also reviewed and data coded as invalid under the following conditions: the pedometer fell off >3 times during the session or accidentally reset/malfunctioned (e.g., dead battery) or the child did not wear the pedometer for an extended period, did not participate in some of the lesson (e.g., sat out due to sickness/injury), or had missing measurements (e.g., left program with the pedometer before measurements could be recorded). Pedometer data were also considered invalid if there were <90 minutes between program start and end times and if total step counts were ± 2 standard deviations from the mean for that lesson.

For each child, the number of valid wear sessions and total pedometer wear time, wear time in exercise sessions, and wear time in sports sessions were calculated. Mean steps/minute in total program time, in exercise sessions, and in sports sessions were calculated as (total steps)/(total wear minutes) across valid sessions.

Data extraction

Data were de-identified prior to analysis at Tufts University. First and last names and dates of birth were removed and an ID code including month and year of birth plus four random digits was assigned to each participant. A document linking each participant's name and ID code was stored on a secure drive on the health center network.

Aim 2 analyses

For Aim 2 analyses, subjects were excluded for the following reasons: having missing baseline measurements, being <8 years old or having BMI <85th percentile at baseline, having missing parent-reported household income or puberty data, or having no follow-up fitness, anthropometry, and/or child survey data. For analyses using in-program activity level data, a subsample was created excluding subjects with no valid pedometer sessions.

Analyses were performed using SAS 9.3, and $p < 0.05$ was considered the threshold of statistical significance. Descriptive statistics were calculated for participants' demographic characteristics. Sample means and standard deviations were calculated for BMI, PACER score, general-living PA score (PAQ-C), and dietary behavior score (HABITS) at baseline and final; paired t-tests were used to test for significance of pre/post changes. Pre/post analyses were also conducted for secondary variables four secondary variables: BMI z-score, WHtR, perceived athletic competence, and global self-worth. These results are not included in Chapter 4 but are reported in Appendix 3.D. In cases where children had only two measurements, the second measurement was used as the final time point. The percentage of participants who were normal weight, overweight, and obese and (for children aged ≥10 years at baseline) percentages in the "healthy fitness zone," "needs improvement," and "health risk" CRF categories were calculated for baseline and final.

A multivariable regression model was used to test whether child baseline characteristics predicted attendance. Total attendance was regressed on the following potential predictor variables: sex, Hispanic ethnicity, household poverty-to-income ratio, and baseline age, PACER score, BMI z-score, general-living PA score, and diet quality score. The model was additionally adjusted for total enrollment time and program site.

Linear mixed models (SAS PROC MIXED) were used to test longitudinal associations between attendance and changes in PACER score and BMI (Model A analyses), taking into account repeated individual measures. The attendance predictor variable was 0 at baseline and cumulative number of sessions attended at follow-up points. Models adjusted for enrollment time (0 at baseline, cumulative days between measurements at follow-up points) and the following time-invariant variables: sex, Hispanic ethnicity, program site, and baseline age (years), parent-reported puberty (y/n), PACER score, BMI z-score, physical activity score (PAQ-C score), and dietary behaviors (HABITS score).

To test whether in-program activity levels influenced these relationships, we also ran models with in-program PA (mean pedometer steps/minute) and attendance × in-program PA variables added (Model B analyses), using the pedometer subsample. For all analyses where PACER score was the outcome, models were re-run with the PACER variable log-transformed to normalize its slightly right-skewed distribution. Results were similar following log-transformation; to facilitate interpretability, the non-transformed PACER variable was used in final analyses. Results of Aim 2 analyses are reported in Chapter 5.

Aim 3 analyses

For Aim 3 analyses, children were excluded for the following reasons: missing baseline fitness, anthropometric, or demographic data; being <8 years old or having BMI <85th percentile at baseline; or having no valid pedometer data. Children were also excluded if they had invalid response patterns for the perceived athletic competence survey questions. More specifically, in that scale, responses on the left side reflect higher perceived competence for three questions; for the other three, responses on the right reflect higher perceived competence. If a child checked only responses on one side of the scale, it was considered likely that he/she had not read or understood the items and the score was considered invalid.

Data were analyzed using SAS 9.3, and $p < 0.05$ was considered the threshold of statistical significance. Pearson correlations among perceived athletic competence and PAQ-C survey items were calculated to test internal reliability. Descriptive statistics were calculated for the full sample and gender subgroups, and differences between genders were evaluated with independent-samples t-tests, chi-square tests, Fisher's exact tests, or a Wilcoxon rank-sum test. The average, median, and interquartile range of participants' mean steps/minute were calculated for the exercise and sports sessions; box-and-whisker plots were generated for all participants and for boys and girls. Paired t-tests were used to test for differences in mean steps/minute in exercise versus sports among all participants and sex-stratified subgroups.

To test correlates of PA in general living, PAQ-C was regressed on baseline perceived athletic competence, BMI z-score, aerobic fitness (PACER laps), gender (male), and age (years). Hispanic ethnicity and poverty-to-income ratio were also included as covariates. To test correlates of PA in the structured program, these same predictors were regressed on mean steps/minute in all program time, exercise sessions, and sports sessions. These models were additionally adjusted for PAQ-C scores and number of valid pedometer sessions; in the sport-session analysis, steps/minute during exercise was also adjusted for, because exercise came first and could therefore influence sports activity. Residuals were examined to test assumptions of normality. To determine whether main predictor variables' effects were modified by age or gender, all models were re-run with appropriate interaction terms. Results of these analyses are reported in Chapter 6.

References

1. Casavale K, Rihane C, Olson R, et al. New explorations in updating the scientific evidence to inform the future Dietary Guidelines for Americans, 2015. J Acad Nutr Diet 2014; 114: A89.

2. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans*. 7th ed. Washington, DC, 2010.

3. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey: Questionnaires, Datasets, and Related Documentation, http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm (2014, accessed 10/18 2014).

4. Zipf G, Chiappa M, Porter KS, et al. National health and nutrition examination survey: plan and operations, 1999-2010. Vital Health Stat 1 2013; (56): 1-37.

5. National Cancer Institute. SAS Programs for Analyzing NHANES 2003-2004 Accelerometer Data, http://riskfactor.cancer.gov/tools/nhanes_pam/ (2007, accessed 5/22 2013).

6. Mattocks C, Ness AR, Leary SD, et al. Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision. J Phys Act Health 2008; 5: S98-S111.

7. Evenson KR, Catellier DJ, Gill K, et al. Calibration of two objective measures of physical activity for children. J Sports Sci 2008; 26: 1557-1565.

8. Trost SG, Loprinzi PD, Moore R, et al. Comparison of accelerometer cut points for predicting activity intensity in youth. Med Sci Sports Exerc 2011; 43: 1360-1368.

9. Skinner AC, Steiner MJ, Chung AE, et al. Cholesterol curves to identify population norms by age and sex in healthy weight children. Clin Pediatr 2012; 51: 233-237.

10. Paradis G, Lambert M, O'Loughlin J, et al. Blood pressure and adiposity in children and adolescents. Circulation 2004; 110: 1832-1838.

11. Moran A, Jacobs DR, Steinberger J, et al. Insulin resistance during puberty: results from clamp studies in 357 children. Diabetes 1999; 48: 2039-2044.

12. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. Adv Data 2000: 1.

13. Ganji V, Zhang X, Shaikh N, et al. Serum 25-hydroxyvitamin D concentrations are associated with prevalence of metabolic syndrome and various cardiometabolic risk

factors in US children and adolescents based on assay-adjusted serum 25-hydroxyvitamin D data from NHANES 2001-2006. Am J Clin Nutr 2011; 94: 225-233.

14. Levy JC, Matthews DR and Hermans MP. Correct homeostasis model assessment (HOMA) evaluation uses the computer program. Diabetes Care 1998; 21: 2191-2192.

15. Gungor N, Saad R, Janosky J, et al. Validation of surrogate estimates of insulin sensitivity and insulin secretion in children and adolescents. J Pediatr 2004; 144: 47-55.

16. Eisenmann JC. On the use of a continuous metabolic syndrome score in pediatric research. Cardiovasc Diabetol 2008; 7: 17.

17. Cook S, Auinger P, Li C, et al. Metabolic syndrome rates in United States adolescents, from the national health and nutrition examination survey, 1999–2002. J Pediatr 2008; 152: 165-170. e2.

18. Thivel D, Malina RM, Isacco L, et al. Metabolic syndrome in obese children and adolescents: dichotomous or continuous?. Metab Syndr Relat Disord 2009; 7: 549-556.

19. Martinez-Vizcaino V, Martinez MS, Aguilar FS, et al. Validity of a single-factor model underlying the metabolic syndrome in children: a confirmatory factor analysis. Diabetes Care 2010; 33: 1370-1372.

20. DuBose KD, Eisenmann JC and Donnelly JE. Aerobic fitness attenuates the metabolic syndrome score in normal-weight, at-risk-for-overweight, and overweight children. Pediatrics 2007; 120: e1262-e1268.

21. Benowitz NL, Bernert JT, Caraballo RS, et al. Optimal serum cotinine levels for distinguishing cigarette smokers and nonsmokers within different racial/ethnic groups in the United States between 1999 and 2004. Am J Epidemiol 2009; 169: 236-248.

22. Gidding SS, Dennison BA, Birch LL, et al. Dietary recommendations for children and adolescents: a guide for practitioners. Pediatrics 2006; 117: 544-559.

23. American Heart Association Nutrition Committee, Lichtenstein AH, Appel LJ, et al. Diet and lifestyle recommendations revision 2006: a scientific statement from the American Heart Association Nutrition Committee. Circulation 2006; 114: 82-96.

24. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: Is it time to rethink the physical activity paradigm?. Diabetes Res Clin Pract 2011; 93: 292-294.

25. Mitra A. Multicollinearity. In: Salkind N (ed) *Encyclopedia of Measurement and Statistics*. Washington, DC, 2007, p. 639.

26. Nelson MC, Neumark-Stzainer D, Hannan PJ, et al. Longitudinal and secular trends in physical activity and sedentary behavior during adolescence. Pediatrics 2006; 118: e1627-34.

27. Carson V, Ridgers ND, Howard BJ, et al. Light-intensity physical activity and cardiometabolic biomarkers in US adolescents. PLOS ONE 2013; 8: e71417.

28. Tovar A, Vikre EK, Gute DM, et al. Development of the Live Well curriculum for recent immigrants: a community-based participatory approach. Prog Community Health Partnersh 2012; 6: 195.

29. Leger L, Mercier D, Gadoury C, et al. The multistage 20 metre shuttle run test for aerobic fitness. J Sports Sci 1988; 6: 93-101.

30. Institute of Medicine. *Fitness Measures and Health Outcomes in Youth*. Washington, DC, 2012.

31. The Cooper Institute. *Fitnessgram and Activitygram Test Administration Manual*. 4th ed. Champaign, IL, 2010.

32. Zhu W, Plowman SA and Park Y. A primer-test centered equating method for setting cut-off scores. Res Q Exerc Sport 2010; 81: 400-409.

33. Centers for Disease Control and Prevention. *NHANES Anthropometry Procedures Manual*. Atlanta, GA, 2011.

34. Cole T, Faith M, Pietrobelli A, et al. What is the best measure of adiposity change in growing children: BMI, BMI%, BMI z-score or BMI centile? Eur J Clin Nutr 2005; 59: 419-425.

35. Berkey CS and Colditz GA. Adiposity in adolescents: change in actual BMI works better than change in BMI z score for longitudinal studies. Ann Epidemiol 2007; 17: 44-50.

36. Woo JG. Using body mass index Z-score among severely obese adolescents: A cautionary note. Int J Ped Obes 2009; 4: 405-410.

37. Inokuchi M, Matsuo N, Takayama JI, et al. BMI z-score is the optimal measure of annual adiposity change in elementary school children. Ann Hum Biol 2011; 38: 747-751.

38. Brambilla P, Bedogni G, Heo M, et al. Waist circumference-to-height ratio predicts adiposity better than body mass index in children and adolescents. Int J Obes 2013; 37: 943-946.

39. Ashwell M, Gunn P and Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. Obes Rev 2012; 13: 275-286.

40. Mokha JS, Srinivasan SR, DasMahapatra P, et al. Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolic risk profile among normal weight and overweight/obese children: the Bogalusa Heart Study. BMC pediatrics 2010; 10: 73.

41. Kowalski KC, Crocker PR and Donen RM. *The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual*. Saskatoon, Saskatchewan, 2004.

42. Kowalski K, Crocker P and Faulkner R. Validation of the physical activity questionnaire for older children. Pediatr Exerc Sci 1997; 9: 174-186.

43. Janz KF, Lutuchy EM, Wenthe P, et al. Measuring activity in children and adolescents using self-report: PAQ-C and PAQ-A. Med Sci Sports Exerc 2008; 40: 767.

44. Wright N, Groisman-Perelstein A, Wylie-Rosett J, et al. A lifestyle assessment and intervention tool for pediatric weight management: the HABITS questionnaire. J Hum Nutr Diet 2011; 24: 96-100.

45. Harter S. *Manual for the Self-Perception Profile for Children*. 1st ed. Denver, CO, 1985.

46. Tudor-Locke C, Sisson SB, Lee SM, et al. Evaluation of quality of commercial pedometers. Can J Public Health 2006; 97: S10-S15.

Chapter 4:
Exploring new relationships between physical activity volume and intensity and cardiometabolic risk in U.S. adolescents

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Abstract

Background: Associations between physical activity (PA) intensity and volume and adolescents' cardiometabolic health have research, policy, and practice implications. This study compares associations between cardiometabolic risk factors and 1) moderate-to-vigorous PA (MVPA) minutes versus total PA volume (accelerometer-derived total activity counts, TAC) and 2) light PA volume (counts at light intensity, L-TAC) versus moderate-to-vigorous PA volume (counts at moderate-to-vigorous intensity, MV-TAC).

Methods: 2105 adolescents from 2003–2006 NHANES were included. Independent variables were MVPA minutes, TAC, L-TAC, and MV-TAC. Regression models tested associations between PA variables and continuous metabolic risk index (CMRI), waist circumference, systolic and diastolic blood pressure, HDL, insulin, and triglycerides.

Results: TAC demonstrated a slightly stronger inverse association with CMRI (p=0.004) than did MVPA (p=0.013). TAC and MVPA were both associated with systolic and diastolic pressure, HDL, and insulin; associations were similar or slightly stronger for TAC. L-TAC and MV-TAC were both associated with CMRI and HDL. Only L-TAC was associated with diastolic pressure. Only MV-TAC was associated with waist circumference, systolic pressure, and insulin.

Conclusions: Compared with MVPA minutes, TAC demonstrates similar or slightly stronger associations with cardiometabolic risk factors. L-TAC-L and MV-TAC appear similarly associated with adolescents' clustered risk but differently associated with individual risk factors.

Background

Cross-sectional and longitudinal research in adolescents has firmly established protective associations between physical activity (PA) and cardiometabolic risk factors, including blood pressure (BP), serum lipids, and insulin, which appear to be only partially mediated by adiposity.[1-5] This research has focused principally on moderate-to-vigorous intensity PA (MVPA), in part due to historic reliance on self-report instruments, which generally capture MVPA with sufficient accuracy but are less useful for detecting light PA (LPA) or PA in more finely-partitioned intensity categories (e.g., moderate, vigorous, very vigorous).[6,7] Studies' tendency to emphasize MVPA may also stem from evidence, mainly in adults, that activity of at least moderate intensity is needed to promote gains in aerobic fitness.[8] Evidence-based guidelines, in turn, have likewise emphasized MVPA. For example, the 2008 Physical Activity Guidelines for Americans recommend that children and adolescents engage in 60 minutes of PA per day, mostly at moderate-to-vigorous intensity.[9]

Developments in PA measurement technologies, particularly accelerometers, have enabled population-based studies to evaluate PA at a broader range of intensities. Accelerometers record movement as activity counts over fixed time periods (epochs), and PA researchers generally use these data to calculate subjects' average daily minutes in different intensity categories (e.g., minutes of sedentary, light, moderate, and vigorous activity). To align their work with prior studies and policy guidelines, they often combine minutes of moderate and vigorous activity and use mean daily MVPA minutes as their primary study variable.[6] In this process, any epoch above the moderate cut-point is counted equally as one epoch of MVPA, regardless of how many counts it recorded above that threshold. For example, if a cut-point of 2,292 counts per minute (CPM) is used as the threshold for moderate intensity,[10] a 60-second epoch with 2,500 counts and another with 10,000 counts would each count equally as one minute of MVPA.

Accelerometer research can also capture overall PA volume, whether as total activity counts per day (TAC) or other similar variables, like average counts per minute of accelerometer wear time. One advantage of TAC is that it responds to variations in PA intensity above the moderate threshold. These variations may have important implications given that cardiometabolic benefits of PA, on a per-minute basis, appear to increase alongside increases in PA intensity.[7, 11] In addition, TAC accounts for levels of light physical activity (LPA); while activity behaviors below the moderate threshold were once considered relatively inconsequential,[6] a growing body of research suggests that LPA may protect against cardiometabolic risk, and sedentary time may increase risk, in adolescents.[2, 12, 13] TAC also has limitations, however. For example, it treats all counts equally, regardless of factors like intensity or duration, which may influence PA's relationship to health. Few studies have tested whether MVPA minutes or total PA volume more strongly predicts cardiometabolic risk in children or adolescents, and results have been mixed.[14-16] Therefore, it remains uncertain whether TAC's advantages outweigh disadvantages, particularly relative to the more commonly-used MVPA-minutes variable, in terms of its utility in PA research.

While the benefits of each minute of PA appear to increase as intensity increases, research has not clearly established whether this is a function of greater volume generated at higher intensity or, alternatively, of physiologic adaptations that occur specifically above certain intensity thresholds.[6] A small number of studies, mainly in adults, have tested associations between moderate- and vigorous-intensity activity and cardiometabolic risk factors while controlling for total volume and found that higher-intensity PA may confer greater benefits.[17] However, few studies have examined these relationships in children or adolescents, and, to our knowledge, no studies have compared the cardioprotective influence of light versus moderate-to-vigorous PA while controlling for total volume. To illustrate, Figure 1 shows how two different paths, representing different durations of light and vigorous activity, might yield the same activity volume, expressed as TAC. Based on available research, it is unclear whether such equivalent volumes of PA (here, 10,000 TAC from light PA versus 10,000 TAC from vigorous PA) would be associated with different cardiometabolic benefits.

To address these gaps in the literature, this study has two main objectives: 1. to compare the strength of association between minutes of moderate-to-vigorous physical activity and total PA volume (total activity counts per day) with cardiometabolic risk factors, independent of BMI z-score, in a nationally representative sample of U.S. adolescents, and 2. to compare the associations between equivalent volumes of PA accrued at light and moderate-to-vigorous intensity with cardiometabolic markers.

Methods

Dataset and study population

The National Health and Nutrition Examination Survey (NHANES) is an ongoing evaluation of the U.S. population administered by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC). It uses a complex, multistage probability design to generate a representative sample of the non-institutionalized civilian population. Data are collected through an in-home survey and a physical examination in a mobile examination center (MEC). In 2003–2004 and 2005–2006 NHANES, accelerometers were also administered, and black, Mexican-American, and adolescent populations were oversampled.[18] NHANES collects data on an ongoing basis, using three MEC data-collection teams composed of expert clinical staff. These staff are extensively trained on standardized data-collection and analysis protocols that limit potential variability in procedures across locations and time points.[18] Detailed descriptions of NHANES operations, including staff training and other quality-control mechanisms, are available from CDC.[19]

NHANES study protocols were approved by the NCHS Research Ethics Review Board. Written informed consent was obtained from all subjects. Consent was also received from parents/guardians of those < 18 years old.

Accelerometer-based predictor variables

Non-wheelchair-bound subjects were given uniaxial accelerometers (ActiGraph AM-7164) and asked to wear them on the right hip for seven consecutive days during waking hours, except when swimming or bathing. The devices recorded activity counts in 60-second epochs.

Activity count files were processed using syntax adapted from the National Cancer Institute,[20] which facilitates identification and editing of unreliable or invalid values. Non-wear time was classified as 60+ consecutive minutes with zero counts, allowing for up to two consecutive minutes with 1-100 counts. Only subjects with ≥ 10 hours of wear time per day for ≥ 3 days were included in the analyses.[21]

The intensity of each epoch was designated using cut-points validated by Evenson and colleagues: < 100 CPM was sedentary; 100–2291 CPM was light; 2292–4007 CPM was moderate; and ≥ 4008 counts was vigorous.[10] For each subject, the number of sedentary, light, moderate, vigorous, and moderate-to-vigorous minutes were calculated for each valid day (i.e., days with ≥ 10 hours of wear time) and averaged across all valid days. TAC was calculated as the total number of accelerometer counts in valid days divided by the number of valid days. Total activity counts at light intensity (L-TAC) was calculated as the sum total of accelerometer counts in light epochs across all valid days, divided by the number of valid days. Total activity counts at moderate-to-vigorous intensity (MV-TAC) was calculated as the sum total of accelerometer counts in moderate or vigorous epochs across all valid days, divided by the number of valid days.

Cardiometabolic outcome variables

In the MEC exam, trained NHANES staff measured height and weight. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared, and BMI z-scores were determined based on CDC growth charts.[22] Waist circumference (WC) was measured at the uppermost lateral border of the ilium on the midaxillary line. Three consecutive BP measurements were taken after subjects rested quietly for five minutes while seated; systolic BP and diastolic BP were determined by averaging values for all non-zero readings. Detailed laboratory protocols for blood measures, including quality-control mechanisms, are described elsewhere.[18] In brief, blood was drawn during the MEC visit; it was processed and aliquoted into vials and then frozen and shipped to offsite laboratories for analysis. Fasting insulin was measured with a two-site immunoassay, HDL was measured directly in serum, and triglycerides were measured enzymatically in serum. HDL was evaluated for all participants, and triglycerides and insulin were measured only for participants in the morning examinations who had fasted for at least eight hours, as determined by interview. The inter-assay coefficients of variation were 2.0-4.6% for insulin, 1.5-2.1% for triglycerides, and 1.7-2.3% for HDL in 2003–2004 NHANES and 3.4-4.9% for insulin, 1.8-2.1% for triglycerides, and 1.9-2.6% for HDL in 2005–2006 NHANES.[18] Because there were equipment and laboratory changes in 2005–2006 compared with 2003–2004 for insulin analyses, the 2005–2006 values were adjusted using a regression equation provided by CDC.[18] In one case the regression equation generated a negative value, which was set to missing.[23]

Metabolic risk index

To summarize clustered cardiometabolic risk, we used a continuous metabolic risk index (CMRI) developed and validated in youth by Martinez-Vizcaino and colleagues.[24] Mean arterial pressure ([systolic BP + 2*diastolic BP]/3),[25] WC, fasting insulin, and triglycerides-to-HDL ratio were each regressed on age and sex and the residuals divided by the standard deviations of the residuals to generate z-scores; fasting insulin, WC, and triglyceride-to-HDL ratios were first log-transformed to normalize skewed distributions. The four z-scores scores were summed to yield CMRI.

Other variables

Data on age, sex, household income, household composition, pregnant/lactating status, prior diagnosis of diabetes or asthma, and physical limitations were collected through computer-assisted personal interviews conducted by NHANES household interviewers. Subjects ages 16 and older were interviewed directly; parents/caregivers served as proxy respondents for subjects ages 12–15 and for subjects unable to answer questions. Poverty-to-income ratios were calculated as the ratio between household income and federal poverty thresholds.

Serum cotinine levels were included in NHANES laboratory analyses, and subjects were categorized as smokers (cotinine $\geq$ 3 ng/mL) or nonsmokers (cotinine $<$ 3 ng/mL) based on previously published cut-points.[26] Dietary data were generated from a single 24-hour dietary recall administered by trained interviewers using the United States Department of Agriculture's Automated Multiple-Pass Method. Dietary variables (total energy; fiber; sugar; monounsaturated, polyunsaturated, and saturated fat, each as a percentage of total energy; dietary cholesterol; sodium; and potassium) were included as covariates due to their potential association with cardiometabolic risk factors, as noted in the American Academy of Pediatrics and American Heart Association (AHA) joint dietary recommendations for children and adolescents[27] and/or the AHA diet and lifestyle guidelines for all Americans.[28]

While sedentary behavior may increase cardiometabolic risk independent of PA,[29] accelerometer-derived sedentary time could not be included as a covariate due to multi-collinearity with other PA variables. Therefore, self-reported television and computer time, which represent a substantial proportion of sedentary time in U.S. adolescents,[30] were included in all models as an alternative indicator of sedentary behavior. During the household interview, subjects were asked, in two separate questions, the average daily time spent in the prior 30 days a) watching television/videos and b) using a computer/computer games, with seven response options ranging from none to ≥ 5 hours. For each variable, responses were collapsed into three categories: ≤ 1 hour, 2–3 hours, or ≥ 4 hours.

Analytic Sample

Subjects were excluded from the study sample if they had returned accelerometers out of calibration or had fewer than 3 days with ≥ 10 accelerometer wear hours; were underweight or pregnant/lactating; had previously been diagnosed as diabetic; or had missing HDL data, examination measures (missing height, weight, WC, or < 1 valid BP reading), or other covariate data. Because fasting insulin and triglycerides were measured only in NHANES subjects participating in morning examinations, a fasting subsample was created, with subjects with missing insulin or triglycerides data excluded.

Statistical Power

Our sample size was fixed based on the data available through NHANES. We conducted power calculations for analyses where TAC was the predictor variable, using estimated partial correlations based on a prior study of PA and cardiometabolic risk factors in European youth.[13] With a sample size of 2,105 (full study sample) and an alpha of 0.05, we estimated this research would have > 80% power to detect associations between TAC and WC (estimated partial correlation –0.08, 95% power), diastolic blood pressure (–0.09, 99%), and systolic blood pressure (–0.10, >99%) but not HDL cholesterol (0.02, 15%). With a sample size of 952 (fasting subsample) and an alpha of 0.05, we estimated this research would have > 80% power to detect an association between TAC and insulin (estimated partial correlation –0.013, 98% power) but not triglycerides (–0.06, 46%).

Statistical Analysis

All analyses were conducted in SAS 9.3 and accounted for NHANES's complex design and sample weights.[18] Given non-random loss of substantial numbers of subjects (>50%) from the study samples, mainly due to incomplete accelerometer data, weights were adjusted to restore national representativeness across age, sex, and racial-ethnic groups.

Participant demographic, anthropometric, and cardiometabolic characteristics were calculated for the study sample and fasting subsample. For PA and sedentary-time variables, means were calculated for the study sample as well as for sex subgroups, and independent-samples t-tests (continuous variables) or chi-square tests (categorical variables) were used to test for differences between males and females.

Multivariable regression models were used to test for associations between PA predictor variables and cardiometabolic outcome variables. Residuals were examined to test assumptions of normality, and WC, insulin, and triglycerides were log-transformed. Three main models were employed: model 1 analyses included TAC as the main predictor, model 2 analyses included MVPA minutes as the main predictor, and model 3 analyses included both L-TAC and MV-TAC as the main predictors. As secondary analyses, we also modeled TAC and MVPA together to determine whether either variable was significantly associated with cardiometabolic outcomes independent of the other. Each model was run with seven cardiometabolic outcome variables: CMRI, WC, systolic BP, diastolic BP, HDL, insulin, and triglycerides. All analyses adjusted for BMI z-score; accelerometer wear time; age; sex; race-ethnicity; self-reported television time (≤ 1 hr, 2–3 hours, ≥ 4 hrs); self-reported computer time (≤ 1 hr, 2–3 hours, ≥ 4 hrs); smoking status (y/n); poverty-to-income ratio; energy intake; dietary fiber; dietary sugar; dietary cholesterol; dietary saturated, monounsaturated, and polyunsaturated fat, each as % of total kilocalories; dietary sodium; dietary potassium; and self-reported asthma (y/n) and physical limitations (y/n). Moderation analyses were conducted to determine whether age or sex influenced associations between PA predictors and cardiometabolic outcomes. A threshold of $p < 0.05$ was used to determine statistical significance in our main analyses. To minimize potential for type-1 error, the threshold was lowered to $p < 0.001$ for moderation analyses, which were secondary to our main study objectives.[31]

Results

A total of 4,591 subjects aged 12–19 completed the NHANES household interview. Of those, 1,841 were excluded for invalid accelerometer data (device returned out of calibration or < 3 days with ≥ 10 hours of accelerometer wear time); 151 for being underweight, pregnant, or previously diagnosed diabetic; 298 for having missing WC, systolic or diastolic BP, or HDL data; and 196 for having missing covariate data. The main study sample included 2,105 total subjects. For the fasting subsample, an additional 1,153 were excluded for missing insulin or triglycerides data, leaving 952 subjects.

Table 1 shows unadjusted demographic, anthropometric, and cardiometabolic characteristics for the study sample and fasting subsample. After adjusting sample weights, the weighted demographic characteristics in the study sample and fasting subsample were similar to the overall adolescent population in 2003–2006 NHANES, which has been described in other studies.[31] Table 2 shows unadjusted descriptive statistics for PA and sedentary behavior variables, as well as subgroup data for males and females. On average, subjects spent the majority of wear time in sedentary behavior and engaged in about 35 minutes of MVPA per day. Compared with males, females engaged in significantly less TAC and less light, moderate, and vigorous PA, whether defined as minutes or as activity counts. Light activity accounted for 55% and 65% of TAC in males and females, respectively. There were no significant differences by sex in terms of self-reported computer- or TV-time category, though higher levels of TV-watching among males approached statistical significance ($p = 0.06$).

Table 3 shows the regression coefficients and standard errors for the main predictor variables in multivariable regression models. In model 1 and model 2 analyses, MVPA minutes and TAC were both significantly associated with CMRI, with a marginally stronger association for TAC. In analyses of individual outcome variables, both MVPA minutes and TAC demonstrated significant protective associations with systolic BP, diastolic BP, HDL, and insulin. The p-values were similar where insulin was the outcome variable and marginally lower for TAC where systolic BP, diastolic BP, and HDL were the outcome variables. Neither MVPA minutes nor TAC was significantly associated with WC or triglycerides, though TAC approached a statistically significant inverse association with WC.

When MVPA minutes and TAC were modelled together (results not shown), TAC remained significantly associated with CMRI ($p=0.04$), but MVPA was not significant ($p = 0.98$). MVPA minutes was not independently associated with any individual outcome variables after adjustment for TAC ($p > 0.20$). Independent of MVPA minutes, TAC demonstrated a significant inverse association with diastolic BP ($p = 0.03$) and a borderline-significant positive association with HDL ($p = 0.05$).

In model 3 analyses, fixed volumes (10,000 counts) of light (L-TAC) and moderate-to-vigorous (MV-TAC) activity demonstrated significant inverse associations with CMRI, with regression coefficients of near-identical magnitude. L-TAC and MV-TAC also both demonstrated significant positive associations with HDL cholesterol. L-TAC, but not MV-TAC, demonstrated a significant inverse association with diastolic BP. MV-TAC, but not L-TAC, demonstrated significant inverse associations with WC, systolic BP, and insulin. Moderation analyses did not reveal significant interactions by sex or age.

Discussion

While protective associations between adolescent PA and cardiometabolic risk factors have been well-established, few studies have parsed out the independent influences of activity intensity and volume. These questions have important implications for research, policy, and practice. For example, understanding the interplay between PA volume and intensity in influencing health may inform decisions around whether PA policies and programs should specifically target certain intensity thresholds or more broadly promote increases in overall activity volume. Such questions take on particular urgency as epidemic increases in obesity and decreases in PA have placed considerable numbers of adolescents at risk for cardiometabolic disorders such as hypertension, dyslipidemia, and insulin resistance.[32]

This study provides three novel findings that address these gaps. First, compared with MVPA minutes, total physical activity volume (operationalized as TAC) was similarly or more strongly associated with cardiometabolic risk factors in U.S. adolescents. Second, equivalent volumes of light and moderate-to-vigorous activity demonstrated inverse associations of similar magnitude with a summary measure of cardiometabolic risk (CMRI). Third, equivalent volumes of light and moderate-to-vigorous activity demonstrated different associations with risk factors analyzed individually rather than as a composite index: only light volume demonstrated a significant association with diastolic BP, while only moderate-to-vigorous volume demonstrated significant associations with WC, systolic BP, and insulin.

Our analysis suggests that TAC may be more strongly associated with systolic and diastolic blood pressure than is MVPA; this finding mirrors the results of a prior analysis in children ages 11-12 from the Avon Longitudinal Study of Parents and Children.[16] We also found that, compared with MVPA minutes, TAC demonstrated stronger associations with clustered metabolic risk scores and HDL cholesterol. MVPA minutes and TAC showed associations of approximately equal strength with insulin. Unlike MVPA minutes, TAC does not have an upper numeric boundary and may therefore explain a greater proportion of the variance in some health outcome variables; thus, researchers may find that using a TAC predictor variable in conjunction with the traditional MVPA-minutes predictor reduces the likelihood of type-2 error. This potential advantage should be balanced against TAC's limitations; for example, the concept of accelerometer counts may be more difficult for some audiences to interpret compared with MVPA minutes. Researchers will need to balance such considerations in the context of their research objectives.

Available research has also provided little evidence of whether increased cardiometabolic benefits observed with increasing PA intensity are a function of additive effects of greater activity volume or of physiologic adaptations that occur only at higher intensities. In the present analysis, when MVPA minutes and TAC were modelled together, MVPA minutes was not independently predictive of cardiometabolic risk factors, and equivalent PA volumes at light and moderate-to-vigorous intensity (i.e., L-TAC and MV-TAC) were similarly associated with a continuous metabolic risk score as well as with HDL cholesterol. These findings suggest that PA-related cardiometabolic health benefits may be achieved at a wider range of intensity levels than commonly assumed. For some adolescents, increasing volume through longer periods of lighter PA may be more feasible than through shorter periods of higher-intensity activity. In this study, sedentary and light activity together comprised over 95% of adolescents' daily wear time. Shifting behaviors within these activity categories—whether by displacing sedentary behavior with LPA or by increasing the intensity of LPA itself (e.g., walking instead of standing)—may therefore represent large, untapped opportunities for increasing total volume and promoting adolescent health.

Our approach of using intensity-category volume variables (L-TAC and MV-TAC) yielded interesting findings and may be useful in future studies. Although L-TAC and MV-TAC were similarly associated with a summary metabolic risk index, their associations with individual outcome variables differed. Our findings that WC and insulin are preferentially associated with MV-TAC are consistent with prior research showing that these outcomes are most responsive to higher-intensity PA;[11, 31] however, this is, to our knowledge, the first study to demonstrate this result by comparing equivalent volumes of light and moderate-to-vigorous PA. Our findings that only L-TAC was significantly associated with diastolic BP and that only MV-TAC was associated with systolic BP are also novel. The biological factors underlying this finding are difficult to explain given incomplete understanding of the pathways linking PA and blood pressure.[33] Proposed mechanisms include PA's influence on angiogenesis, sympathetic tone, and vascular responsiveness and remodeling;[33] these or other adaptations may be differentially influenced by PA intensity and also play different roles in influencing systolic and diastolic BP. Further research is needed both to elucidate these mechanisms and to test whether the findings from the present study are replicated in other populations. Ultimately, whether PA policies and programs should aim to promote activity at specific intensities, or greater overall PA volume, may require judgments regarding which outcomes are most important for the individuals or populations at hand.

Strengths of this study include a large, nationally representative sample and adjustment for a wide range of potential confounding variables, including demographic and lifestyle factors such as dietary intakes and objectively-measured smoking status. That said, several limitations should be acknowledged. As with all studies using cross-sectional data, our analyses do not allow for causal inference. While accelerometers offer advantages over self-report measurements, they do not detect certain types of activity (e.g., upper-body movement or water-based activity) or differentiate weight-bearing from non-weight-bearing PA. Some of our covariates, such as self-reported dietary intakes, may be prone to bias, and there is further potential for residual confounding by unmeasured factors. For example, aerobic fitness data were not available for the full 2003–2006 dataset; PA and aerobic fitness are moderately correlated in youth populations and, given that both also independently influence cardiometabolic health, aerobic fitness may therefore partially confound our observations.[34] Pubertal stage, which was also not measured in NHANES 2003–2006, is associated multiple cardiometabolic factors, including serum lipids, blood pressure, and insulin sensitivity,[35] and could also potentially confound our analyses. Our analysis also does not differentiate between fractionized and bouted PA, which some studies have found to have different health benefits, particularly in adults;[36] comparing bouted with fractionized PA in youth populations may be a fruitful subject of future studies. In our model 3 analyses, only two categories of PA volume (L-TAC and MV-TAC) were examined; further differences may exist among more finely partitioned intensity categories. Such analyses would have been infeasible in the present study due to our sample size and limited variability in PA, particularly above the moderate threshold. Finally, all models adjusted for BMI z-score, even though adiposity may be part of the causal pathway between PA and cardiometabolic risk. Some evidence suggests that adiposity may be more likely to inversely influence PA than PA is to inversely influence adiposity;[37,38] therefore, we opted for the conservative approach of controlling for BMI z-score in all models to minimize potential confounding. It should be noted that the results of this analysis pertain specifically to relationships between PA and cardiometabolic risk that are not mediated by total adiposity.

In summary, this research finds that TAC similarly or more robustly predicts cardiometabolic risk compared with MVPA minutes in a nationally representative sample of U.S. adolescents. While equivalent volumes of PA from light and moderate-to-vigorous intensity activity demonstrate similar associations with overall cardiometabolic risk, they demonstrate different associations with individual risk factors. Further longitudinal and experimental studies with adolescents should test how comparable volumes of PA performed at different intensities, including light activity, influence cardiometabolic health and other outcomes.

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References

1. McMurray RG and Ondrak KS. Cardiometabolic Risk Factors in Children: The Importance of Physical Activity. Am J Lifestyle Med 2013; 7: 292–303.

2. Ekelund U, Luan J, Sherar LB, et al. Moderate to Vigorous Physical Activity and Sedentary Time and Cardiometabolic Risk Factors in Children and Adolescents. JAMA 2012; 307: 704-712.

3. Hobkirk JP, King RF, Gately P, et al. Longitudinal factor analysis reveals a distinct clustering of cardiometabolic improvements during intensive, short-term dietary and exercise intervention in obese children and adolescents. Metab Syndr Relat Disord 2012; 10: 20-25.

4. Neto AS, de Campos W, dos Santos GC, et al. Metabolic syndrome risk score and time expended in moderate to vigorous physical activity in adolescents. BMC Pediatr 2014; 14: 42.

5. Brambilla P, Pozzobon G and Pietrobelli A. Physical activity as the main therapeutic tool for metabolic syndrome in childhood. Int J Obes 2010; 35: 16-28.

6. Powell KE, Paluch AE and Blair SN. Physical activity for health: What kind? How much? How intense? On top of what?. Annu Rev Public Health 2011; 32: 349-365.

7. Janssen I and LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act 2010; 7.

8. Haskell WL, Montoye HJ and Orenstein D. Physical activity and exercise to achieve health-related physical fitness components. Public Health Rep 1985; 100: 202-212.

9. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines for Americans*. Washington, DC: Washington, DC, 2008.

10. Evenson KR, Catellier DJ, Gill K, et al. Calibration of two objective measures of physical activity for children. J Sports Sci 2008; 26: 1557-1565.

11. Hay J, Maximova K, Durksen A, et al. Physical activity intensity and cardiometabolic risk in youth. Arch Pediatr Adolesc Med 2012; 166: 1022-1029.

12. Carson V and Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. BMC Public Health 2011; 11: 274.

13. Ekelund U, Anderssen S, Froberg K, et al. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. Diabetologia 2007; 50: 1832-1840.

14. Ness AR, Leary SD, Mattocks C, et al. Objectively measured physical activity and fat mass in a large cohort of children. PLOS Med 2007; 4: e97.

15. Riddoch CJ, Leary SD, Ness AR, et al. Prospective associations between objective measures of physical activity and fat mass in 12-14 year old children: the Avon Longitudinal Study of Parents and Children (ALSPAC). BMJ 2009; 339: b4544.

16. Leary SD, Ness AR, Smith GD, et al. Physical activity and blood pressure in childhood: findings from a population-based study. Hypertension 2008; 51: 92-98.

17. Swain DP and Franklin BA. Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. Am J Cardiol 2006; 97: 141-147.

18. Centers for Disease Control and Prevention. National Health and Nutrition Examination Survey: Questionnaires, Datasets, and Related Documentation, http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm (2014, accessed 10/18 2014).

19. Zipf G, Chiappa M, Porter KS, et al. National Health and Nutrition Examination Survey: plan and operations, 1999-2010. Vital Health Stat 1 2013; 56: 1-37.

20. National Cancer Institute. SAS Programs for Analyzing NHANES 2003–2004 Accelerometer Data, http://riskfactor.cancer.gov/tools/nhanes_pam/ (2007, accessed 5/22 2013).

21. Mattocks C, Ness AR, Leary SD, et al. Use of accelerometers in a large field-based study of children: protocols, design issues, and effects on precision. J Phys Act Health 2008; 5: S98-S111.

22. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. Adv Data 2000: 1.

23. Ganji V, Zhang X, Shaikh N, et al. Serum 25-hydroxyvitamin D concentrations are associated with prevalence of metabolic syndrome and various cardiometabolic risk factors in US children and adolescents based on assay-adjusted serum 25-hydroxyvitamin D data from NHANES 2001-2006. Am J Clin Nutr 2011; 94: 225-233.

24. Martinez-Vizcaino V, Martinez MS, Aguilar FS, et al. Validity of a single-factor model underlying the metabolic syndrome in children: a confirmatory factor analysis. Diabetes Care 2010; 33: 1370-1372.

25. DuBose KD, Eisenmann JC and Donnelly JE. Aerobic fitness attenuates the metabolic syndrome score in normal-weight, at-risk-for-overweight, and overweight children. Pediatrics 2007; 120: e1262-e1268.

26. Benowitz NL, Bernert JT, Caraballo RS, et al. Optimal serum cotinine levels for distinguishing cigarette smokers and nonsmokers within different racial/ethnic groups in the United States between 1999 and 2004. Am J Epidemiol 2009; 169: 236-248.

27. Gidding SS, Dennison BA, Birch LL, et al. Dietary recommendations for children and adolescents: a guide for practitioners. Pediatrics 2006; 117: 544-559.

28. American Heart Association Nutrition Committee, Lichtenstein AH, Appel LJ, et al. Diet and lifestyle recommendations revision 2006: a scientific statement from the American Heart Association Nutrition Committee. Circulation 2006; 114: 82-96.

29. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: Is it time to rethink the physical activity paradigm?. Diabetes Res Clin Pract 2011; 93: 292-294.

30. Nelson MC, Neumark-Stzainer D, Hannan PJ, et al. Longitudinal and secular trends in physical activity and sedentary behavior during adolescence. Pediatrics 2006; 118: e1627-34.

31. Carson V, Ridgers ND, Howard BJ, et al. Light-intensity physical activity and cardiometabolic biomarkers in US adolescents. PLOS ONE 2013; 8: e71417.

32. de Ferranti SD, Gauvreau K, Ludwig DS, et al. Inflammation and changes in metabolic syndrome abnormalities in US adolescents: findings from the 1988-1994 and 1999-2000 National Health and Nutrition Examination Surveys. Clin Chem 2006; 52: 1325-1330.

33. Pescatello L, Franklin B, Fagard R, et al. Exercise and hypertension: American College of Sports Medicine Position Stand. Med Sci Sports Exerc 2004; 36: 533-553.

34. Steele RM, Brage S, Corder K, et al. Physical activity, cardiorespiratory fitness, and the metabolic syndrome in youth. J Appl Physiol 2008; 105: 342–351.

35. Zimmet P, Alberti KGM, Kaufman F, et al. The metabolic syndrome in children and adolescents–an IDF consensus report. Pediatric diabetes 2007; 8: 299-306.

36. Lee IM, Sesso HD and Paffenbarger RS,Jr. Physical activity and coronary heart disease risk in men: does the duration of exercise episodes predict risk?. Circulation 2000; 102: 981-986.

37. Metcalf BS, Hosking J, Jeffery A, et al. Fatness leads to inactivity, but inactivity does not lead to fatness: a longitudinal study in children (EarlyBird 45). Arch Dis Child 2011; 96: 942-947.

38. Wilks DC, Sharp SJ, Ekelund U, et al. Objectively measured physical activity and fat mass in children: a bias-adjusted meta-analysis of prospective studies. PLOS ONE 2011; 6: e17205.

Table 1. Unadjusted characteristics of the study sample and fasting subsample

	Study sample (n=2105)	Fasting subsample (n=952)
Sex		
Male (%)	50.9 (1.3)	50.9 (2.5)
Race/ethnicity		
Non-Hispanic White (%)	63.0 (3.0)	63.2 (3.4)
Non-Hispanic Black (%)	15.1 (2.0)	15.0 (2.3)
Mexican-American (%)	11.3 (1.5)	11.3 (1.7)
Other (%)	10.6 (1.2)	10.6 (1.5)
Age		
Years	15.4 (0.1)	15.5 (0.1)
Socioeconomic Status		
Poverty-to-Income Ratio	2.7 (0.1)	2.7 (0.1)
Anthropometry		
Waist circumference (cm)[a]	80.2 (0.4)	80.0 (0.6)
BMI z-score	0.6 (0.04)	0.5 (0.1)
Overweight based on BMI (%)	17.9 (1.7)	17.6 (1.7)
Obese based on BMI (%)	16.4 (1.3)	15.9 (2.0)
Biomarkers		
Systolic blood pressure (mmHg)	110.0 (0.4)	109.5 (0.5)
Diastolic blood pressure (mmHg)	60.2 (0.5)	60.9 (0.6)
HDL cholesterol (mmol/L)	1.4 (0.01)	1.4 (0.02)
Insulin (pmol/L)[a]	-	47.6 (1.8)
Triglycerides (mmol/L)[a]	-	0.9 (0.02)
Continuous metabolic risk index[b]	-	0.0 (0.1)

Data presented as unadjusted percentages (SE) for categorical variables and unadjusted means (SE) for continuous variables. Adjusted mobile examination center and fasting sample weights applied to study sample and fasting subsample data, respectively.
[a]data reported as geometric means
[b]CMRI = sum of z-scores for mean arterial pressure, insulin, triglyceride:HDL ratio, and waist circumference

Table 2. Average daily physical activity and self-reported sedentary behaviors among U.S. adolescents in NHANES 2003–2006

	Total sample (n=2105)	Males (n=1083)	Females (n=1022)	p value[a]
Activity minutes (min/d)[b]				
Wear time	846.6 (5.0)	849.9 (5.5)	843.2 (6.1)	0.28
Sedentary	479.6 (5.1)	462.9 (5.8)	496.9 (6.5)	< 0.001
Light	331.9 (2.9)	342.6 (3.5)	320.8 (3.3)	< 0.001
Moderate	24.8 (0.7)	30.3 (1.0)	19.1 (0.7)	< 0.001
Vigorous	10.3 (0.5)	14.0 (0.7)	6.4 (0.5)	< 0.001
Moderate-to-vigorous	35.1 (1.1)	44.3 (1.7)	25.5 (1.1)	< 0.001
Activity counts (10,000 counts/d)[b]				
Total accelerometer counts	34.8 (0.6)	40.1 (0.9)	29.3 (0.6)	< 0.001
Total accelerometer counts–light	20.5 (0.2)	22.0 (0.3)	19.0 (0.2)	< 0.001
Total accelerometer counts–moderate	7.4 (0.2)	9.1 (0.3)	5.6 (0.2)	< 0.001
Total accelerometer counts–vigorous	6.1 (0.3)	8.2 (0.5)	3.8 (0.3)	< 0.001
Total accelerometer counts–moderate-to-vigorous	13.4 (0.5)	17.3 (0.7)	9.4 (0.5)	< 0.001
Television time (% of population)[c]				
≤ 1 hour	39.4 (2.0)	36.2 (2.3)	42.6 (2.5)	
2–3 hours	41.2 (1.7)	43.7 (2.1)	38.6 (2.1)	0.06
≥ 4 hours	19.5 (1.2)	20.2 (2.2)	18.7 (1.5)	
Computer time (% of population)[c]				
≤ 1 hour	67.4 (2.0)	66.1 (2.7)	68.8 (2.1)	
2–3 hours	24.6 (1.7)	25.4 (2.2)	23.7 (1.9)	0.61
≥ 4 hours	8.0 (0.9)	8.5 (1.4)	7.5 (1.0)	

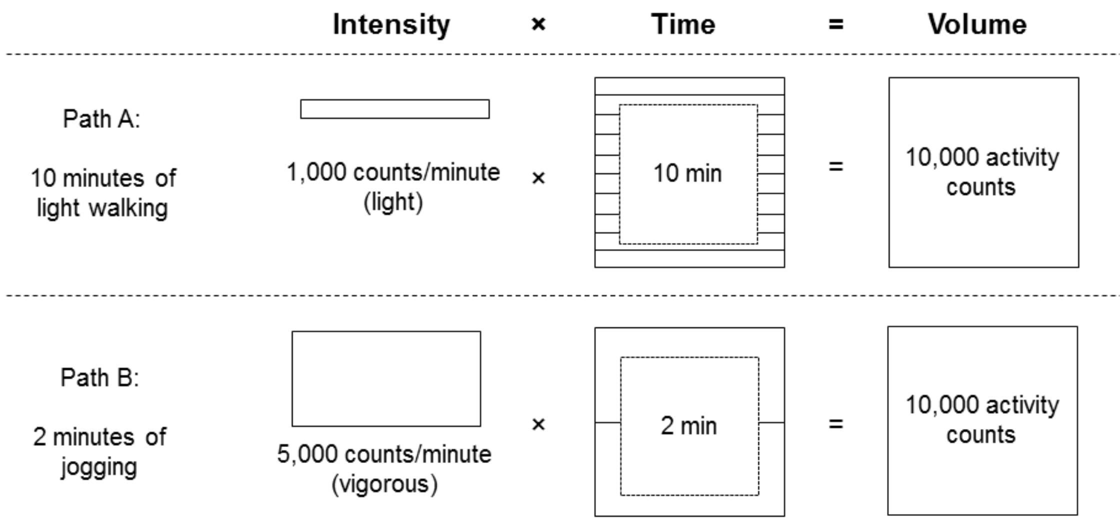
Activity duration variables = mean number of daily minutes at each intensity level; activity volume variables = mean total daily counts or counts accrued in epochs at each intensity level. Thresholds: sedentary, < 100 counts/min; light, 100-2291 counts/min; moderate, 2292-4007 counts/min; vigorous, ≥ 4008 counts/min.
Data presented as unadjusted means (SE).
[a]p-value for comparison of males with females using independent samples t-test (continuous variables) or Rao-Scott F-adjusted chi-square test (categorical variables).
[b]derived from accelerometer data
[c]derived from self-report

Table 3. Associations between physical activity predictor variables (total accelerometer counts [TAC], moderate-to-vigorous PA [MVPA] minutes, and TAC at light and moderate-to-vigorous intensity) with cardiometabolic risk factors among U.S. adolescents

	Fasting Subsample (n=952)			Full Study Sample (n=2105)			
	CMRI[a]	Insulin (pmol/L)[b]	Triglycerides (mmol/L)[b]	Waist Circ. (cm)[b]	Systolic BP (mmHg)	Diastolic DBP (mmHg)	HDL (mmol/L)
Model 1							
Total accelerometer counts[c]	**-0.019 (0.0060)**	**-0.0043 (0.0019)**	-0.0025 (0.0021)	-0.00028 (0.00014)	**-0.053 (0.018)**	**-0.083 (0.019)**	**0.0020 (0.00058)**
p-value	0.004	0.03	0.23	0.06	0.005	0.0001	0.002
Model R^2	0.537	0.385	0.173	0.813	0.222	0.104	0.205
Model 2							
MVPA minutes[d]	**-0.0095 (0.0036)**	**-0.0026 (0.0011)**	-0.0016 (0.0012)	-0.00013 (0.000081)	**-0.031 (0.011)**	**-0.038 (0.11)**	**0.00082 (0.00033)**
p-value	0.013	0.03	0.19	0.12	0.008	0.001	0.02
Model R^2	0.534	0.386	0.175	0.812	0.222	0.100	0.202
Model 3							
Total accelerometer counts–light[c]	**-0.019 (0.0090)**	0.0035 (0.0052)	-0.00048 (0.0031)	-0.00016 (0.00030)	-0.031 (0.044)	**-0.172 (0.060)**	**0.0029 (0.0013)**
p-value	0.040	0.505	0.878	0.603	0.494	0.008	0.040
Total accelerometer counts–mod/vig[c]	**-0.019 (0.0068)**	**-0.0073 (0.0024)**	-0.0033 (0.0025)	**-0.00033 (0.00015)**	**-0.062 (0.027)**	-0.047 (0.025)	**0.0016 (0.00076)**
p-value	0.009	0.004	0.194	0.032	0.028	0.066	0.042
Model R^2	0.537	0.389	0.174	0.813	0.223	0.107	0.206

Results reported as ß coefficients (SE). All models adjusted for BMI z-score; accelerometer wear time; age; sex; race-ethnicity; self-reported daily time on each television and computer (≤ 1 hr, 2–3 hours, ≥ 4 hrs); smoking status (y/n); poverty-to-income ratio; energy intake; dietary fiber; dietary sugar; dietary cholesterol; dietary saturated, monounsaturated, and polyunsaturated fat, each as % of total kilocalories; dietary sodium; dietary potassium; and self-reported asthma (y/n) and physical limitations (y/n).
Total accelerometer counts = mean accelerometer counts per day across all wear minutes; MVPA minutes = mean number of daily minutes with ≥ 2292 counts; total accelerometer counts–light = mean daily accelerometer counts accrued in minutes with 100-2291 counts; total accelerometer counts–mod/vig = mean daily accelerometer counts accrued in minutes with ≥ 2292 counts
[a]Continuous metabolic risk index = sum of z-scores for mean arterial pressure, insulin, triglyceride:HDL ratio, and waist circumference (range: -5.3 to 7.8) [b]log-transformed
[c]10,000 counts/day [d]1 minute/day

Figure 1. Illustration of how movement at different intensities could yield equivalent volumes of physical activity



Chapter 5:
Impact of a community-based physical activity program on fitness and adiposity among low-income, overweight/obese children: findings from a practice-based study

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Abstract

This study tested whether overweight/obese children's attendance in a community-based physical activity (PA) program was associated with changes in cardiorespiratory fitness (CRF) and adiposity and whether in-program activity levels influenced those associations. Program sessions (offered twice/week for two hours over 9 months) included structured exercise/sports. At baseline and follow-up, CRF was measured as Progressive Aerobic Cardiorespiratory Endurance Run (PACER) laps, and height and weight were measured and BMI calculated. Attendance was recorded as sessions attended. Children wore pedometers in 10 representative sessions; in-program activity was calculated as mean steps/minute across sessions. Linear mixed models tested associations between attendance and changes in PACER score and BMI and the influence of in-program activity on those associations. 101 (56% male, 93% Hispanic) participants completed baseline and 1-2 follow-up fitness/adiposity measurements. Attendance was associated with PACER change ($\beta=0.093$, $p=0.01$) but not BMI change ($\beta=0.00026$, $p=0.97$). There were significant interactions between attendance and in-program activity: attendance more favorably impacted PACER ($p<0.0001$) and BMI ($p=0.03$) as in-program activity levels increased. Attending community-based PA programming may improve CRF among overweight/obese children, particularly when participants are highly active. Community practitioners should not only enroll overweight/obese children in PA programs but also promote adequate attendance/in-program activity levels.

INTRODUCTION

In 2012–2013, 34% of U.S. youth ages 6–19 were overweight or obese; while this represented a plateau in prevalence relative to prior years, racial/ethnic disparities persisted among black and Hispanic youth (Ogden, Carroll, Kit, & Flegal, 2014). Excess adiposity in children is associated with increased risk of type 2 diabetes, non-alcoholic fatty liver, and early atherosclerosis in childhood as well as increased risk of obesity and related cardiometabolic diseases in later adult life (Dietz, 1998; Steinberger et al., 2009). Increasing overweight/obese children's cardiorespiratory fitness (CRF) may increase their likelihood of achieving healthy weight (McGavock, Torrance, McGuire, Wozny, & Lewanczuk, 2009; Ortega, Ruiz, Castillo, & Sjöström, 2007) and elicit adiposity-independent improvements in health markers including serum lipids, blood pressure, and insulin sensitivity (Ortega et al., 2007).

While children's CRF is partially determined by non-modifiable factors such as age, sex, and genetics, it can also be increased through physical activity (PA) (Baquet, Van Praagh, & Berthoin, 2003) Given that most U.S. youth fall short of the recommended 60 minutes of daily moderate-to-vigorous PA (Berrigan, Dodd, Masse, Tilert, & McDowell, 2008), it is unsurprising that CRF levels are likewise low. A 2012 nationally-representative study, for example, found that just 42% of all U.S. youth ages 12–15—and 29% and 17% of those who were overweight and obese, respectfully—demonstrated healthy aerobic fitness levels (Gahche et al., 2014).

Recent reviews have found that PA-focused programs for overweight/obese children may improve CRF (Vasconcellos et al., 2014) and reduce adiposity (Kelley, Kelley, & Pate, 2014; Vasconcellos et al., 2014). These reviews mainly included randomized controlled trials (RCTs) that, to maximize internal validity and potential program impact, typically demanded high levels of research expertise, financial resources, and participant burden. Such studies advance understanding of interventions' efficacy under near-optimal conditions but may not represent potential effectiveness in typical, resource-constrained practitioner settings (Ammerman, Smith, & Calancie, 2014; Brownson & Jones, 2009). Recognition of RCTs' limitations has inspired calls for practice-based evidence derived from interventions supported by researchers but administered by community practitioners under usual conditions (Ammerman et al., 2014; Brownson & Jones, 2009). Rather than tightly control study conditions (e.g., through strict inclusion criteria or standardization of intervention dose), practice-based studies can document variability in program implementation and evaluate its influence on outcomes. Although practice-based designs may make changes more difficult to detect compared with more controlled studies, they also provide policymakers and practitioners valuable insight into what happens when interventions are delivered in "real-world," resource-constrained settings.

After-school programs have been identified as a promising setting for increasing children's PA (Beets, 2012). However, such programs may face challenges around attendance, particularly when resources are unavailable for transportation, participation-based incentives, or other mechanisms for increasing child turnout. Furthermore, other studies have shown that children's PA levels when they do attend after-school programming is highly variable (Trost, Rosenkranz, & Dzewaltowski, 2011). Given evidence of a dose-response relationship between PA and changes in adiposity and fitness (Carson et al., 2013; Janssen & LeBlanc, 2010), such variability in attendance and in-program PA may have important implications for children's health outcomes. However, to our knowledge, just two prior studies have explored the impact of attendance rates in after-school PA programs on children's CRF and/or adiposity (Barbeau et al., 2007; Yin et al., 2005) and none have evaluated the influence of in-program activity levels on those associations.

To help address gaps in the literature, this study evaluated whether attendance in a nine-month, twice-weekly, community-based PA program predicted changes in CRF or BMI among overweight/obese participants ages 8–14 and whether those relationships were influenced by children's in-program activity levels.

METHODS

Program Context

This research was conducted from October 2012–June 2013 in partnership with a community-based after-school PA program in a low-income, mostly Hispanic community in Massachusetts. Founded in 2005 by the East Boston Neighborhood Health Center, the program serves overweight/obese children ages 8–14 referred by pediatricians. Our partnership was designed to both support research hypothesis-testing and provide the program with program-evaluation protocols that could be replicated in future program years; thus, methodological rigor was balanced against cost-containment and ease of implementation for program staff. Following the initial research period, the program curriculum and evaluation plans developed through this partnership have been refined and reproduced in the 2013–2014 and current (2014–2015) program years.

Participating children were assigned to one of five program sites, all in YMCA- or city-owned gymnasiums. Each site was led by two coaches hired through the federal government's AmeriCorps program; the child-to-coach ratio was capped at 13:1. Program sessions were held twice/week after school for two hours, except during school holidays; 59 total sessions were offered. Each session included semi-structured active play (10 minutes); a dynamic warmup (10 minutes); exercises, including structured aerobic and muscle-strengthening activities (40–50 minutes); snack, where a healthy item (such as a piece of fruit) was provided (10 minutes); and sports skill-building/game play (40–50 minutes). Selected exercises were acceptable/feasible for low-fit, overweight/obese boys and girls and included activities like relays and strength-building obstacle courses. Children were provided choices as possible, and popular music was played throughout. Participants reported walking/running distances completed and, based on mileage accrued, could earn medals and other small awards, like t-shirts. Sports activities included soccer, basketball, ultimate Frisbee, and football and emphasized fun, skill-building, and personal achievement over competition. Staff were trained on lesson plans and on motivational strategies (e.g., providing positive reinforcement, supporting individual goal-setting, creating autonomy-supportive environments) prior to implementation.

Approximately once/month, the snack period was extended to 30 minutes and short nutrition lessons were delivered (10 total over the year). These lessons were developed collaboratively with program leaders and health center clinicians. Topics included energy balance; whole grains; fruits and vegetables; low-fat dairy; nutrition labels; and healthy beverages, breakfast, and snacks.

Participants and recruitment

All study protocols were approved by the Tufts University Institutional Review Board and parent consent/child assent were obtained prior to data collection. Parents were contacted by phone and, if interested, enrolled their children at program offices. Most participants enrolled in October (n=73), but some (n=57) were referred/enrolled later in the program year.

Measures

Demographics. At time of enrollment, parents completed questionnaires (Tovar et al., 2012) with questions on child's sex, ethnicity, date and country of birth, and pubertal development; mother's country of origin; and household size and income. Children were categorized yes/no for puberty based on menarche (girls) or voice change (boys). Poverty-to-income ratios were calculated using U.S. federal poverty thresholds.

Cardiorespiratory fitness. At baseline (October or, for later registrants, time of enrollment), midpoint (February or first session attended thereafter), and final (June) time points, children completed the Progressive Aerobic Cardiorespiratory Endurance Run (PACER), a 20-meter maximal-effort shuttle-run test shown to be correlated with VO_2 max in children (Leger, Mercier, Gadoury, & Lambert, 1988). The FitnessGram protocol was followed (The Cooper Institute, 2010), and scores recorded as laps completed. To contextualize fitness levels relative to norms, scores were converted to VO_2 max estimates (Zhu, Plowman, & Park, 2010) and FitnessGram cutoffs were used to classify participants' CRF levels as "healthy fitness zone," "needs improvement," or "health risk"

(The Cooper Institute, 2010); because FitnessGram does not publish cutoffs for 8- or 9-year-olds, fitness categorizations were conducted only for children ≥10 years old at baseline. In our main analyses, PACER data were analyzed as laps completed.

Body mass index. At baseline, midpoint, and final, children's height/weight were measured in triplicate using a portable stadiometer (Seca 214) and digital scale (Health-o-Meter 752KL). BMI was calculated as (weight, kilograms)/(height, meters)^2 and BMI z-scores calculated using growth charts from the Centers for Disease Control and Prevention (CDC) (Kuczmarski et al., 2000). We used BMI z-scores to represent adiposity at a single time point—e.g., in models where baseline adiposity was a predictor variable. In longitudinal models examining changes in adiposity, we used BMI as the dependent variable. Prior studies have shown that BMI z-score is preferred for assessing adiposity at a single time point but that, in longitudinal analyses, using BMI rather than BMI z-score as the outcome variable provides greater statistical power and yields more precise and interpretable estimates (Berkey & Colditz, 2007; Cole, Faith, Pietrobelli, & Heo, 2005). Advantages of modeling change in BMI rather than BMI z-score appear particularly pronounced in studies with obese youth (Woo, 2009).

PA and dietary behaviors. Children completed the Physical Activity Questionnaire for Children (PAQ-C) (Kowalski, Crocker, & Donen, 2004), a nine-item survey that provides a general measure of PA over the prior 7 days. Data were scored as described previously (Hatfield, Chomitz, Chui, Sacheck, & Economos, in review); values range 1–5, with higher scores denoting higher PA levels. Children also completed the dietary-domain subscale from the HABITS questionnaire (Wright et al., 2011), which includes 16 questions regarding weight-related dietary behaviors in the prior month, including intakes of fruits/vegetables, beverages (juice, soda, other sugared beverages, water, and milk), junk foods, and fast food as well as snacking and portion-control behaviors. Aggregate diet scores are calculated as the sum of all items (range: 0–35; higher scores denote healthier dietary behaviors). Given the time-intensity of administration, surveys were completed at baseline and final time points only.

Attendance and enrollment time. Staff recorded children's attendance at each session. For baseline-to-midpoint and baseline-to-final time periods, attendance and enrollment time were calculated, respectively, as the cumulative number of sessions attended and days elapsed between measurement dates.

In-program activity levels. Pedometers (Walk4Life Neo II) were used to evaluate PA during 10 program sessions spread across the program year and representing a cross-section of typical activities. Pedometers were not administered on nutrition-lesson days. Step counts and total wear time (excluding snack) were recorded. Data were cleaned as reported previously (Hatfield et al., in review), and each child's in-program activity level was calculated as mean pedometer steps/minute across all sessions with valid pedometer data. A pedometer subsample was created including subjects with at least one valid pedometer session.

Data Analysis

Analyses were performed using SAS 9.3, and $p<0.05$ was considered the threshold of statistical significance. Descriptive statistics were calculated for participants' demographic characteristics. Sample means and standard deviations were calculated for BMI, PACER score, PA score (PAQ-C), and diet score (HABITS) at baseline and final; paired t-tests were used to test for significance of changes between the baseline and final measurements. In cases where children had only two measurements, the last available measurement was used as the final time point. The percentage of participants who were normal weight, overweight, and obese and (for children aged ≥ 10 years at baseline) percentages in the "healthy fitness zone," "needs improvement," and "health risk" aerobic fitness categories were calculated for baseline and final.

As an exploratory analysis, a multivariable regression model was used to test whether child baseline characteristics were associated with attendance. Total attendance was regressed on the following potential predictor variables: sex, Hispanic ethnicity, household poverty-to-income ratio, and baseline age (years), BMI z-score, PACER score, PA score, and diet score. The model was additionally adjusted for total enrollment time and program site.

Linear mixed models (SAS PROC MIXED) were used to test longitudinal associations between attendance and changes in PACER score and BMI (Model A analyses), taking into account repeated within-child measures. The attendance predictor variable was 0 at baseline and cumulative number of sessions attended at follow-up points. Models adjusted for enrollment time (0 at baseline, cumulative days between measurements at follow-up points) and the following time-invariant variables: sex, puberty (y/n), Hispanic ethnicity, program site, and baseline age, BMI z-score, PACER score, PA score, and diet score.

To test whether in-program activity levels influenced these relationships, we also ran models with in-program PA (mean pedometer steps/minute) and attendance × in-program PA variables added (Model B analyses), using the pedometer subsample. For all analyses where PACER score was the outcome, models were re-run with the PACER variable log-transformed to normalize its slightly right-skewed distribution. Results were similar following log-transformation; to facilitate interpretability, the non-transformed PACER variable was used in final analyses.

RESULTS

Of the 130 children with permission/assent, 29 were excluded for the following reasons: having missing baseline measurements (n=4), being <8 years old or having BMI <85th percentile at baseline (4), having missing parent-reported household income (3) or puberty (3) data, or having missing follow-up CRF, anthropometry, and/or child survey data (15). The study sample included 101 total children; 75 had measurements at three time points and 26 at two time points. The pedometer subsample included 84 children after 17 with no valid pedometer data were excluded.

Table 1 shows participants' demographic characteristics and data regarding program participation. Most participants were first-generation born in the U.S., with most mothers native to Central American countries. Mean household income was about 80% of the federal poverty line ($23,050 for a four-person household in 2012). On average, 6.4 months elapsed between baseline and final measurements and participants attended 25 program sessions. During program sessions, participants took on average about 57 pedometer steps/minute, equating to roughly 5,400 steps/session.

Table 2 shows pre/post changes in CRF, adiposity, and PA and diet scores. PACER scores increased by about 5 laps on average, and the change was statistically significant. Average BMI showed a borderline-significant ($p=0.06$) average increase of 0.2 kg/m^2 from baseline to final, with similar increases among boys and girls. Increases in BMI are expected over time in children ages 8-14 (Kuczmarski et al., 2000). To understand how the observed changes compared with typical trajectories, we used CDC growth charts to estimate BMI changes over 6 months (the mean time elapsed between baseline and final measurements) for a reference boy and girl staying at the same BMI z-score. At baseline, the median boy was 10.4 years old and had a BMI z-score of 2.1 (equivalent to 98.2th percentile for age/sex), and the median girl was 9.7 years old and had a BMI z-score of 1.9 (97.5th percentile). CDC growth charts show that remaining at the same BMI percentile over 6 months would equate to 0.7 kg/m^2 increases in BMI for both the median boy and girl (Kuczmarski et al., 2000), substantially larger changes than the 0.2 kg/m^2 increase we observed on average. The comparatively small magnitude of observed changes suggests that children's BMI trajectories trended favorably. Relatedly, there were favorable baseline-to-final changes in weight status categories: at baseline, 21% of participants were overweight and 79% were obese, and at final these proportions fell to 19% and 73%, respectively, with 8% achieving normal weight. PA and diet scores also improved on average from baseline to final, suggesting favorable changes in weight-related behaviors outside the program.

In the exploratory regression model testing whether child baseline characteristics predicted attendance, BMI z-score (ß=-8.30, p=0.01) and age (ß=-2.80, p=0.04) were significantly associated with number of sessions attended. Sex, Hispanic ethnicity, household poverty-to-income ratio, and baseline PA and diet scores were not significant predictors (p>0.15).

Table 3 shows the results of linear mixed-model analyses testing longitudinal associations between child attendance and changes in PACER scores and BMI (Model A) and the influence of mean steps/minute in program on those associations (Model B). Attendance was strongly associated with change in PACER score; for each session attended, the model predicted an average 0.09 increase in PACER laps, other factors held constant. Attendance was not associated with change in BMI in the Model A analysis.

Both Model B analyses showed significant interactions between attendance and in-program activity levels: as activity levels increased, each session attended was associated with greater average gains in PACER scores and lesser average gains in BMI, other factors held equal. To illustrate this interaction, we calculated model-predicted PACER scores and BMIs for four hypothetical children, using different combinations of the 75^{th}- and 25^{th}-percentile values for attendance and in-program activity, with other variables fixed at the sample median values. The low attendance/low in-program activity child was used as a reference. The difference in model-predicted PACER scores and BMIs were calculated for the remaining three children compared to the reference child to illustrate the synergistic relationship between attendance and in-program activity (Figure 1).

DISCUSSION

Well-controlled studies have found that PA interventions help improve CRF and reduce adiposity in overweight/obese children, but there is limited evidence of the impact of PA-focused programs delivered through community programs representing typical practice conditions. This study found that overweight/obese children participating in a community-based PA program demonstrated baseline-to-final increases in CRF and favorable shifts in weight status categories. These results are similar to another recent study of 6- to 19-year-old children participating in a parks-based PA program (1 hour/day, 5 days/week for 10 months): among overweight/obese participants (n=134) mean PACER scores increased significantly from baseline to final by about 2 laps on average, and the researchers also observed significant pre/post decreases in adiposity (Messiah et al., 2014). Taken together, these findings provide encouraging evidence that children participating in community-based PA programs may achieve improvements in CRF and body composition.

In non-randomized studies, evidence of a dose-response relationship between exposures and outcomes may strengthen potential for causal inference. The present study detected a significant dose-response relationship between attendance and changes in PACER scores but not BMI. Two prior studies of after-school PA programs included dose-response analyses evaluating the relationship between attendance and changes in CRF and/or adiposity. Both programs were administered by trained non-research staff (e.g., teachers, paraprofessionals) and had a higher maximal dose compared with the present study (5 days/week, 2 hours/session over 10 months). The first study found a significant overall dose-response relationship between attendance and improvements in both CRF and percentage body fat; however, benefits did not appear until a minimum threshold of three sessions/week of attendance (Yin et al., 2005). The second found that higher PA program attendance was associated with lower increases in BMI among child participants, but, similar to the prior study, benefits only appeared above a threshold of 2 sessions/week (Barbeau et al., 2007).

Despite a comparatively low maximal dose of twice-weekly 2-hour sessions, we found a significant dose-response relationship between program attendance and changes in CRF; every 10 sessions attended were associated with about 1 additional lap improvement in PACER on average, other factors equal. Our study population was composed exclusively of overweight/obese children, whose fitness levels may respond to relatively low doses of PA (Carrel et al., 2005). Our failure to find an association between attendance and change in BMI may be due to insufficient maximal dose. However, program participation may plausibly have promoted health-behavior changes in non-dose-dependent ways (e.g., teaching basic PA skills through a small number of sessions) and contributed to the favorable baseline-to-final changes observed in children's adiposity.

We also found that the association between attendance and both CRF and BMI was influenced by in-program activity levels: benefits of each session attended were greater when children were more active during program time. While largely intuitive, this finding reinforces the importance of not merely creating and enrolling children in PA programs but also ensuring that children attend *and* participate actively. In a prior study with the same study population, we found that female sex, lower CRF, and older age were associated with lower in-program activity levels (Hatfield et al., in review), and the present study found that older age and higher BMI z-scores were associated with lower program attendance. Further studies are needed to understand factors that facilitate children's attendance and active participation in community-based PA programs and strategies that help ensure participants benefit equitably, regardless of age, sex, weight status, or other characteristics.

Several limitations of this research should be acknowledged. The evaluation procedures used (e.g., PACER tests) may be more prone to measurement error compared with gold-standard methods (e.g., direct VO_2 max measurement); however, all methods were previously validated in youth populations, and efforts were made to maximize validity (e.g., taking anthropometric measurements in triplicate) while maintaining feasibility and containing costs. In the absence of a nonintervention control group, our pre/post analyses provide limited opportunity for causal inference. While our main dose-response analyses adjusted for potential confounding variables, there may be residual confounding by unmeasured factors. Finally, this study included children who voluntarily enrolled in the PA program and who occupied a specific high-risk (low-income, overweight/obese, mostly Hispanic) demographic subgroup; these factors may limit generalizability of our findings.

CONCLUSIONS

This study has important implications for policymakers and practitioners. First, it shows that attendance in a community-based PA program may be associated with increases in CRF among overweight/obese children. We also found that associations between attendance and both CRF and BMI were influenced by participants' in-program activity levels: as activity levels increased, each program session attended was associated with greater PACER gains and smaller gains in BMI on average. This finding underscores the importance of not only enrolling children and encouraging attendance at community PA programs but also maximizing activity levels when children do attend. Further research in practice-based settings should continue to explore how PA programs influence CRF and adiposity among participants, as well as strategies for promoting high attendance and high in-program activity levels, particularly among difficult-to-engage subgroups.

REFERENCES

Ammerman, A., Smith, T. W., & Calancie, L. (2014). Practice-based evidence in public health: Improving reach, relevance, and results. *Annual Review of Public Health, 35*, 47-63.

Baquet, G., Van Praagh, E., & Berthoin, S. (2003). Endurance training and aerobic fitness in young people. *Sports Medicine, 33*(15), 1127-1143.

Barbeau, P., Johnson, M. H., Howe, C. A., Allison, J., Davis, C. L., Gutin, B., & Lemmon, C. R. (2007). Ten months of exercise improves general and visceral adiposity, bone, and fitness in black girls. *Obesity, 15*(8), 2077-2085.

Beets, M. W. (2012). Enhancing the translation of physical activity interventions in afterschool programs. *American Journal of Lifestyle Medicine,*

Berkey, C. S., & Colditz, G. A. (2007). Adiposity in adolescents: Change in actual BMI works better than change in BMI z score for longitudinal studies. *Annals of Epidemiology, 17*(1), 44-50.

Berrigan, T. R., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the united states measured by accelerometer. *Medicine and Science in Sports and Exercise, 40*, 181-188.

Brownson, R. C., & Jones, E. (2009). Bridging the gap: Translating research into policy and practice. *Preventive Medicine, 49*(4), 313-315.

Carrel, A. L., Clark, R. R., Peterson, S. E., Nemeth, B. A., Sullivan, J., & Allen, D. B. (2005). Improvement of fitness, body composition, and insulin sensitivity in overweight children in a school-based exercise program: A randomized, controlled study. *Archives of Pediatrics & Adolescent Medicine, 159*(10), 963.

Carson, V., Rinaldi, R., Torrance, B., Maximova, K., Ball, G., Majumdar, S., . . . Wozny, P. (2013). Vigorous physical activity and longitudinal associations with cardiometabolic risk factors in youth. *International Journal of Obesity, 38*(1), 16-21.

Cole, T., Faith, M., Pietrobelli, A., & Heo, M. (2005). What is the best measure of adiposity change in growing children: BMI, BMI%, BMI z-score or BMI centile? *European Journal of Clinical Nutrition, 59*(3), 419-425.

Dietz, W. H. (1998). Health consequences of obesity in youth: Childhood predictors of adult disease. *Pediatrics, 101*(Supplement 2), 518-525.

Gahche, J., Fakhouri, T., Fulton, J., Carroll, D., Wang, C., & Burt, V. (2014). Cardiorespiratory fitness levels among US adolescents (1028.4). *The FASEB Journal, 28*(1 Supplement), 1028.4.

Hatfield, D., Chomitz, V., Chui, K., Sacheck, J., & Economos, C. Demographic, physiologic, and psychosocial correlates of physical activity in low-income, overweight children. *Journal of Nutrition Education and Behavior,* in review.

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(40), 1-16.

Kelley, G. A., Kelley, K. S., & Pate, R. R. (2014). Effects of exercise on BMI z-score in overweight and obese children and adolescents: A systematic review with meta-analysis. *BMC Pediatrics, 14*(1), 225.

Kowalski, K. C., Crocker, P. R., & Donen, R. M. (2004). *The physical activity questionnaire for older children (PAQ-C) and adolescents (PAQ-A) manual*. Saskatoon, Saskatchewan: University of Saskatchewan.

Kuczmarski, R. J., Ogden, C. L., Grummer-Strawn, L. M., Flegal, K. M., Guo, S. S., Wei, R., . . . Johnson, C. L. (2000). CDC growth charts: United States. *Advance Data,* (314), 1.

Leger, L., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences, 6*(2), 93-101.

McGavock, J. M., Torrance, B. D., McGuire, K. A., Wozny, P. D., & Lewanczuk, R. Z. (2009). Cardiorespiratory fitness and the risk of overweight in youth: The healthy hearts longitudinal study of cardiometabolic health. *Obesity, 17*(9), 1802-1807.

Messiah, S. E., Diego, A., Kardys, J., Kirwin, K., Hanson, E., Nottage, R., . . . Arheart, K. L. (2014). Effect of a park-based after-school program on participant obesity-related health outcomes. *American Journal of Health Promotion,* epub ahead of print.

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the united states, 2011-2012. *JAMA, 311*(8), 806-814.

Ortega, F., Ruiz, J., Castillo, M., & Sjöström, M. (2007). Physical fitness in childhood and adolescence: A powerful marker of health. *International Journal of Obesity, 32*(1), 1-11.

Steinberger, J., Daniels, S. R., Eckel, R. H., Hayman, L., Lustig, R. H., McCrindle, B., & Mietus-Snyder, M. L. (2009). Progress and challenges in metabolic syndrome in children and adolescents a scientific statement from the american heart association atherosclerosis, hypertension, and obesity in the young committee of the council on cardiovascular disease in the young; council on cardiovascular nursing; and council on nutrition, physical activity, and metabolism. *Circulation, 119*(4), 628-647.

The Cooper Institute. (2010). *Fitnessgram and activitygram test administration manual* (4th ed.). Champaign, IL: Human Kinetics.

Tovar, A., Vikre, E. K., Gute, D. M., Kamins, C. L., Pirie, A., Boulos, R., . . . Economos, C. D. (2012). Development of the live well curriculum for recent immigrants: A community-based participatory approach. *Progress in Community Health Partnerships: Research, Education, and Action, 6*(2), 195.

Trost, S. G., Rosenkranz, R. R., & Dzewaltowski, D. (2008). Physical activity levels among children attending after-school programs. *Medicine and Science in Sports and Exercise, 40*(4), 622-629.

Vasconcellos, F., Seabra, A., Katzmarzyk, P. T., Kraemer-Aguiar, L. G., Bouskela, E., & Farinatti, P. (2014). Physical activity in overweight and obese adolescents: Systematic review of the effects on physical fitness components and cardiovascular risk factors. *Sports Medicine, 44*(8), 1-14.

Woo, J. G. (2009). Using body mass index z-score among severely obese adolescents: A cautionary note. *International Journal of Pediatric Obesity, 4*(4), 405-410.

Wright, N., Groisman-Perelstein, A., Wylie-Rosett, J., Vernon, N., Diamantis, P., & Isasi, C. (2011). A lifestyle assessment and intervention tool for pediatric weight management: The HABITS questionnaire. *Journal of Human Nutrition and Dietetics, 24*(1), 96-100.

Yin, Z., Gutin, B., Johnson, M. H., Hanes, J., Moore, J. B., Cavnar, M., . . . Barbeau, P. (2005). An environmental approach to obesity prevention in children: Medical college of georgia FitKid project year 1 results. *Obesity Research, 13*(12), 2153-2161.

Zhu, W., Plowman, S. A., & Park, Y. (2010). A primer-test centered equating method for setting cut-off scores. *Research Quarterly for Exercise and Sport, 81*(4), 400-409.

Table 1. Characteristics of participants in an after-school physical activity program (n=101)

	% or Mean (SD)
Male	56.4
Age (years)	10.4 (1.8)
Hispanic	93.1
Puberty (menarche/voice change)	32.7
Household income	
Poverty-to-income ratio	0.81 (0.47)
Below federal poverty line	74.3
Child country of birth (n=100)	
United States	93.0
El Salvador	5.0
Other	2.0
Mother's country of birth	
United States	5.0
El Salvador	54.5
Colombia	8.9
Mexico	8.9
Guatemala	5.9
Other	16.8
Program participation	
Total days enrolled	192 (66)
# sessions attended	25 (14)
In-program activity level (n=84)	
Mean pedometer steps/min	57.1 (13.5)
Mean wear minutes/session	94.5 (2.7)

Data presented as percentage for categorical variables and mean (SD) for continuous variables.

Table 2. Baseline-to-final changes in cardiorespiratory fitness, adiposity, and physical activity (PA) and diet behaviors among participants in a community-based PA program (n=101)

	Baseline	Final	p-value[a]
Cardiorespiratory fitness (PACER laps)	15.7 (8.4)	20.3 (11.4)	**< 0.0001**
Body mass index (BMI)	26.2 (4.0)	26.4 (4.1)	0.06
Normal weight (%)	0	7.9	
Overweight (%)	20.8	18.8	n/a[b]
Obese (%)	79.2	73.3	
General-living PA (PAQ-C score[c])	2.98 (0.84)	3.15 (0.87)	**0.03**
Healthy diet behaviors (HABITS score[d])	20.5 (4.5)	21.6 (4.8)	**0.03**

Data presented as percentage for categorical variables and unadjusted mean (SD) for continuous variables. Mean days between baseline and final measurements: 193.

[a]p-values for paired t-test for baseline versus final measurement

[b]no statistical test performed for weight status category due to small cells.

[c]PAQuestionnaire for Children (range: 1-5; higher scores denote higher PA levels)

[d]Summary score for HABITS dietary-domain questions (range: 0-35; higher scores denote healthier dietary behaviors)

Table 3. Longitudinal associations between attendance in a community-based physical activity program and change in Progressive Aerobic Cardiorespiratory Endurance Run (PACER) score and BMI (Model A) and moderation of associations by in-program activity level

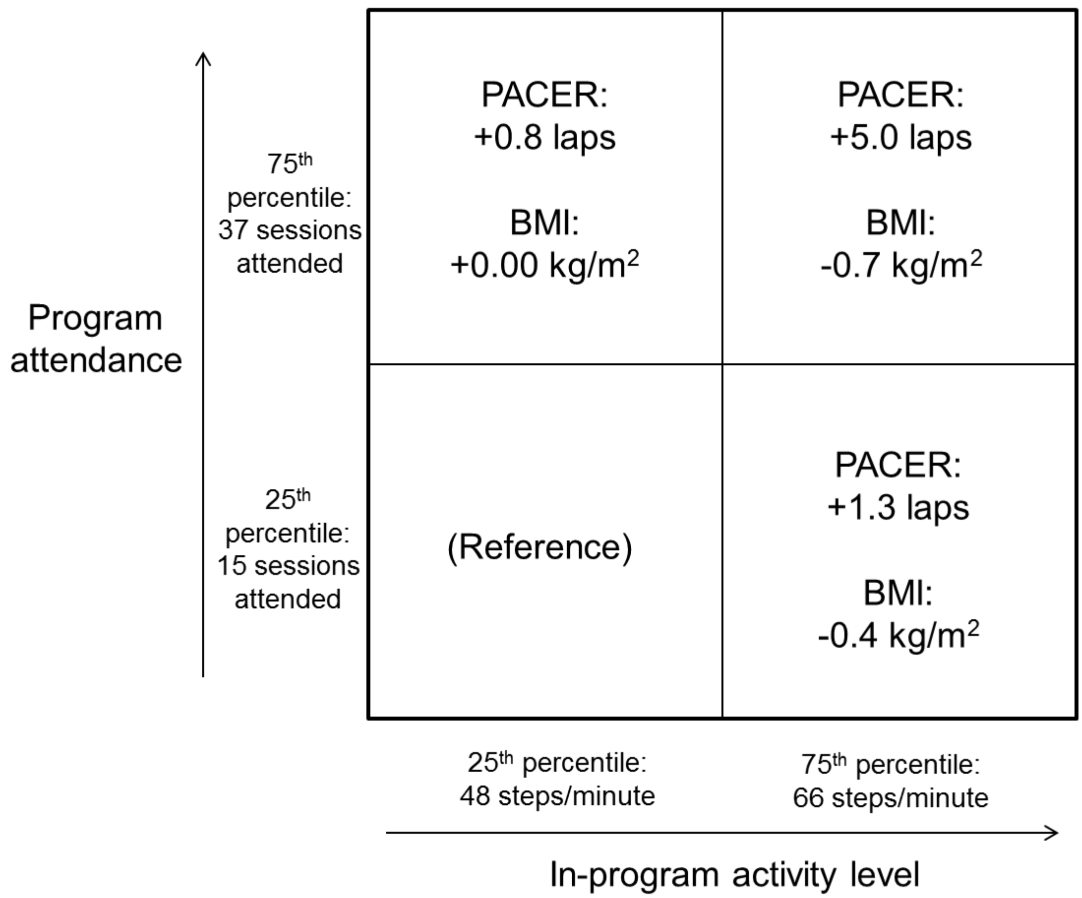
	Model A (n=101)				Model B (n=84)			
	PACER score		BMI		PACER score		BMI	
Predictor variable	**ß (SE)**	**p-value**	**ß (SE)**	**p-value**	**ß (SE)**	**p-value**	**ß (SE)**	**p-value**
Attendance (sessions attended)	0.093 (0.035)	**0.01**	0.00026 (0.00685)	0.97	-0.31 (0.10)	**0.0025**	0.027 (0.020)	0.17
In-program activity level[a]	-	**-**	-	-	0.037 (0.038)	0.33	-0.012 (0.015)	0.41
Attendance × in-program activity level	-	-	-	-	0.0072 (0.0002)	**<0.0001**[b]	-0.00060 (0.00028)	**0.03**[b]

Linear mixed models included a random intercept to account for repeated within-subject measurements; models were adjusted for time, program site, sex, Hispanic ethnicity, baseline age (years), parent-reported puberty (y/n), baseline PACER score, baseline BMI z-score, baseline physical activity score (PAQ-C survey score) and baseline diet quality (HABITS survey score)

[a]Mean steps/min, measured via pedometer

Figure 1 illustrates provides an illustration of the significant attendance × in-program activity level interactions observed in Model B analyses

Figure 1. Differences in model-predicted Progressive Aerobic Cardiorespiratory Endurance Run (PACER) score and body mass index (BMI) for different combinations of program attendance and in-program activity levels



Note: Estimated differences between conditions are based on coefficients derived from linear mixed models; factors other than attendance and in-program activity level are held constant.

Chapter 6:
Demographic, physiologic, and psychosocial correlates of physical activity in low-income, overweight children

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ABSTRACT

Objective: To describe correlates of physical activity (PA) in general living, structured exercise, and structured sports among low-income, overweight children in a community-based PA program.

Methods: PA measures included self-reported general-living PA (PA Questionnaire) and mean steps/minute in structured exercise and sports (pedometer data from 10 program sessions). Potential correlates included BMI z-score, fitness (PACER laps), perceived athletic competence (Harter self-perception profile), gender, and age. Separate regression models tested associations between correlates and PA in general living, exercise, and sports.

Results: 93 children (91% Hispanic) ages 8-14 were included. Age (ß=-0.11) and perceived competence (ß=0.35) were associated with general-living PA ($p<0.05$). In exercise, age (ß=-2.9) predicted steps/minute; in sports, age (ß=-4.3), fitness (ß=0.45), and male gender (ß=8.7) predicted steps/minute ($p<0.05$).

Conclusion and implications: General-living PA may decrease with older age and lower perceived competence. In structured activities, perceived competence may not influence PA; however, girls and older/less fit children may engage less actively, especially in sports.

INTRODUCTION

Only 42% of United States children and 8% of adolescents achieve the recommended 60 minutes of daily moderate-to-vigorous physical activity (MVPA), according to the most recent objectively-measured, nationally-representative data.[1] Among other benefits, regular physical activity (PA) promotes healthy weight and reduces risk for health problems including hypertension, dyslipidemia, and insulin resistance.[2] While all children benefit from PA, increasing activity levels among overweight/obese children may be particularly important to reduce adiposity-related metabolic risk.[2]

Efforts to increase children's activity have achieved limited success: in one review, just 43% of youth PA interventions detected significant increases in MVPA or total PA, and pooled effects were small, at only about 4 additional minutes MVPA/day.[3] Research providing fuller understanding of PA correlates may help inform more effective interventions. One challenge, however, is that correlates are largely population- and context-specific. For example, correlates may vary depending on individual-level factors such as child gender, age, and weight status[4,5] and on whether activities are structured or unstructured.[6,7]

Examining PA correlates within specific population subgroups, and within well-defined PA contexts, may enable tailoring of PA policies and programs to different populations and environments. Studies investigating PA correlates among low-income and racial/ethnic minority children, who disproportionately experience obesity, are needed to inform efforts to increase PA in underserved populations and close health disparities.[8] This study's objective was to evaluate demographic (age, gender), physiologic (aerobic fitness, body fatness), and psychosocial (perceived athletic competence) correlates of PA, including both self-reported PA in general living and objectively-measured PA in structured exercise and sports sessions, among overweight/obese children participating in an after-school PA program.

METHODS

Program Context

Data were collected in partnership with a community-based PA program in a low-income Hispanic community in East Boston, Massachusetts. The program was administered by a community health center and served overweight/obese children ages 8–14 referred by pediatricians. Two-hour sessions were held twice/week from October 2012–June 2013, except during school vacations/holidays; 59 total sessions were offered. Children were assigned to one of five sites (in YMCA- or city-owned gymnasiums), each led by two staff hired through the US federal government's AmeriCorps program. Child-to-staff ratios were capped at 13:1. Sites followed standardized lesson plans aiming to achieve >50% of time in MVPA and to build fundamental exercise/sport skills.

For the first 10 minutes of program, children engaged in semi-structured free play (e.g., tag games). The remaining time included two main sessions: exercise and sports. The exercise session included a dynamic warmup (10 minutes), walking/running activities (20-30 minutes), and strength-building activities (10-20 minutes). Exercises were designed to be feasible for low-fit children. Participants were provided choices as possible (e.g., choosing to walk or run), and popular music was played throughout. Children reported walking/running laps completed and earned small awards, such as medals, for meeting mileage thresholds over time. After the exercise session was a 10-

minute break with a healthy snack (e.g., piece of fruit). The sport session included sports drills and game play (40-50 minutes), which emphasized fun/skill-building over competition and included soccer, basketball, ultimate Frisbee, and football. Program staff were trained on lessons and motivational strategies prior to implementation.

Participants and recruitment

Referred children's parents were contacted by phone and completed enrollment at program offices. Most participants (n=73) enrolled in October; 57 newly-referred children joined throughout the program year. The Tufts University Institutional Review Board provided approval for protection of human subjects. Parental consent and child assent were obtained prior to participation.

Measures

Evaluation protocols were developed collaboratively by researchers, health center clinicians, and program leaders and administered by trained program staff. Parents completed surveys adapted from another study with recent-immigrant, Boston-area Latina mothers;[9] questions included child's country/date of birth, ethnicity, and gender; household size and income; and mother's birth country. Household poverty-to-income ratios were calculated using US federal poverty thresholds. Children's baseline height and weight were measured in triplicate using a portable stadiometer (Seca 214, Seca, Chino, CA) and digital scale (Health-o-Meter 752KL, Health-o-meter, Bridgeview, IL). Body mass index (BMI) was calculated ([weight, kilograms]/[height, meters]^2) and BMI-z scores determined using CDC growth charts.[10] Baseline aerobic fitness was measured with the Progressive Aerobic Cardiorespiratory Endurance Run (PACER)[11] following FitnessGram's protocol;[12] scores were recorded as laps completed.

Baseline perceived athletic competence was measured using the Harter Self-Perception Profile for Children's athletic-competence subscale.[13] The subscale's six items each ask respondents which of two sentences is truer for them (e.g., "Some kids feel that they are better than others their age at sports" vs. "Other kids don't feel they can play as well") and whether that statement is "sort of true" or "really true" for them. Items are scored 1-4 (higher scores denote higher perceived competence) and perceived competence calculated as the mean of all items.

PA in general living was measured at baseline using the Physical Activity Questionnaire for Children (PAQ-C), a nine-item survey that measures overall PA in the prior seven days.[14] Items evaluate participation in different physical activities/sports; effort during physical education; activity during lunch, after school, in evenings and on weekends; overall self-assessment of PA level; and overall PA for each day. Items are scored from 1-5 (higher scores indicate higher activity). Because area schools did not provide lunch-period PA, the lunchtime item was dropped and PAQ-C scores calculated as the mean of the remaining 8 items.

Pedometers (Walk4Life Neo II, Walk4Life, Oswego, IL) were used to evaluate PA during 10 program sessions spread evenly across the program year and representing a cross-section of typical activities. Pedometers were worn during active time, beginning with the exercise session. When devices were attached or removed, time of day was recorded. During snack, pedometers were removed; exercise step counts were recorded and pedometers reattached prior to sports. After the sports session, step counts were again recorded. Anomalous events (e.g., reset device, child injury) were also noted. For each child, total pedometer wear time, exercise wear time, and sports wear time were calculated. Pedometer data were considered invalid if there were <90 minutes between program start and end times; total step counts were +/- 2 standard deviations from the mean for that lesson; or anomalous events rendered data invalid or non-representative. For each child, the number of valid wear sessions was calculated. Mean steps/minute in total program time, in exercise sessions, and in sports sessions were calculated as (total steps)/(total wear minutes) across valid sessions.

Evaluation protocols were designed to balance methodological rigor against practical constraints (e.g., program staff time/expertise). For example, PAQ-C and pedometers were used instead of accelerometers to measure general-living and in-program PA given accelerometers' high cost and complexity of administration/data-reduction. Since this research was completed, the community program has continued to use these protocols for program-evaluation purposes.

Data Analysis

Data were analyzed using SAS 9.3 (SAS Institute, Cary, NC, 2012). Pearson correlations among perceived athletic competence and PAQ-C survey items were calculated to test internal reliability. Descriptive statistics were calculated for the full sample and gender subgroups; differences between genders were evaluated with independent-samples t-tests, chi-square tests, Fisher's exact tests, or Wilcoxon rank-sum test. The average, median, and interquartile range of participants' mean steps/minute were calculated for the exercise and sports sessions; box-and-whisker plots were generated for all participants and for boys and girls. Paired t-tests were used to test for differences in mean steps/minute in exercise versus sports among all participants and sex-stratified subgroups. To test correlates of PA in general living, PAQ-C was regressed on baseline perceived athletic competence, BMI z-score, aerobic fitness (PACER laps), gender (male), and age (years). Hispanic ethnicity and poverty-to-income ratio were also included as covariates. To test correlates of PA in the structured program, these same predictors were regressed on mean steps/minute in all program time, exercise sessions, and sports sessions. These models were additionally adjusted for PAQ-C scores and number of valid pedometer sessions; in the sport-session analysis, steps/minute during exercise was also adjusted for, because exercise came first and could therefore influence sports activity. Residuals were examined to test assumptions of normality. To determine whether main predictor variables' effects were modified by age or gender, all models were re-run with appropriate interaction terms. A threshold of $p<0.05$ was used to determine statistical significance for all analyses.

RESULTS

Of 130 children who enrolled and provided consent/assent, 38 were excluded due to the following factors: missing fitness or demographic data (n=7), being <8 years old or having BMI <85th percentile at baseline (n=4), having invalid perceived athletic competence response patterns (n=2), or having no valid pedometer data (n=24). The final sample included 93 children.

Internal consistency was good for PAQ-C (Chronbach's α=0.74) and acceptable for perceived athletic competence (α=0.63). Table 1 shows descriptive statistics for the full sample and gender subgroups. The total sample included low-income, mostly first-generation Hispanic children. Compared with girls, boys had higher BMI-z scores, were more likely to be obese, had higher PACER scores, and took more steps during total program time. There were no significant differences between boys' and girls' PAQ-C or perceived competence scores. In the structured program, children averaged 94.4 pedometer wear minutes/session, including 53.4 minutes in exercise sessions and 41.0 minutes in sports sessions. The figure shows the distribution of mean pedometer steps/minute for exercise and sports for the full sample and gender subgroups. Steps/minute in exercise sessions (mean: 59.9, median: 59.0, interquartile range [IQR]: 52.4-75.9) were higher and less variable compared with sports sessions (mean: 53.6, median: 54.5, IQR: 42.7-79.9) ($p=0.0002$ for paired t-test). In sex-stratified analyses, mean steps/minute were significantly higher in exercise than in sports among girls ($p<0.001$) but not boys ($p=0.67$).

Table 2 shows results of multivariable regression analyses. Age and perceived athletic competence were significantly associated with self-reported general-living PA; BMI z-score, PACER laps, and gender were not significant predictors. Other factors held equal, for a one-year increase in age, the model would predict a 0.11 lower PAQ-C score on average. For a 0.9-point increase in perceived competence (equivalent to shifting from the first-quartile score, 2.3, to the third-quartile score, 3.2), the model would predict a 0.32 higher PAQ-C score on average. To put these values in context, a 2014 calibration study found that each unit change in PAQ-C score was associated with 55.1 minutes of weekly accelerometer-measured MVPA.[15]

Age, gender, and aerobic fitness were significant predictors of steps/minute during total program time. Other factors held constant, each additional year of age was associated with 4.3 fewer steps/minute, equating to about 410 fewer steps/session. Being male was associated with 8.3 more steps/minute, or about 780 more steps/session. Higher fitness predicted higher activity levels; for a 7-lap increase in PACER score (equivalent to shifting from the first-quartile score, 11, to the third-quartile score, 18), the model would predict an additional 2.7 steps/minute, or about 260 steps/session. During exercise, the association between age and pedometer steps/minute was significant but substantially smaller compared with in total program time; betas for gender and PACER score were also smaller and did not reach statistical significance ($0.05<p< 0.10$). During sports sessions, age, male gender, and aerobic fitness were significantly associated with mean steps/minute, and the betas larger compared with those for overall program time. There were no significant interactions between age or gender and other predictor variables.

DISCUSSION

Prior research has shown that correlates of PA vary by individual characteristics and environmental contexts.[4-6] To our knowledge, this is the first study to explore correlates of general-living PA and PA in structured exercise and sports sessions among overweight/obese, low-income, mostly Hispanic youth. Our finding that general-living PA is associated with age (−) and perceived athletic competence (+) is consistent with prior research[5,16] and reinforces the importance of these correlates in this demographic group. High perceived competence may be particularly necessary for overweight/obese children living in low-income communities to proactively seek/act upon opportunities for PA. While most prior studies have found that boys are more active than girls,[5] we found no significant association between gender and general-living PA. This may be related to the young mean age (9.9 years) in our sample; prior studies have found the gap between young boys' and girls' PAQ-C scores is small but widens with age.[17] Our finding that BMI z-score was not associated with general-living PA, or PA in the structured program, should be interpreted cautiously. Our sample included only overweight/obese children, and adiposity may be significantly predictive in more heterogeneous samples.

On average, children took about 5,400 steps per structured program session. Given evidence that taking about 9,000 pedometer steps/day predicts achievement of 60 minutes of MVPA in children,[18] this activity volume represents considerable progress toward meeting recommendations. However, high variability around mean activity levels, particularly during sports, suggests children engaged variably. Perceived competence was not a significant predictor of structured-program PA; for children with low perceived competence, structured environments may blunt the influence of those self-perceptions. Our findings that gender, age, and aerobic fitness predicted activity in overall program time and in sports are consistent with prior research.[5] However, during exercise, age was the only significant predictor. Compared with sports, exercises like walking and running, which are structured, repetitive, and intuitive, may be less dependent on age, sex, or fitness level. Importantly, this analysis examined steps/minute in program as the main outcome; other important unmeasured variables (e.g., enjoyment or PA outside program time) may also respond differently to structured exercise versus sports.

Strengths of this research include evaluation of multiple dimensions of PA, including self-reported PA in general living and objectively-measured PA in structured exercise and sports sessions. The analysis provides novel insight into an understudied, high-risk population to which prior correlates research may not generalize. However, results of our cross-sectional analysis, where general-living PA is the outcome variable, do not allow for causal inference. Self-reported measures may be prone to bias, and there is potential for residual confounding by unmeasured factors, such as environmental influences. Finally, the homogeneity of our study sample, while advantageous for understanding a high-risk population subgroup, may limit generalizability.

IMPLICATIONS FOR RESEARCH AND PRACTICE

Our findings suggest that higher perceived athletic competence may be associated with higher general-living PA levels among low-income, overweight/obese children; further research, including longitudinal and intervention studies, is needed to test whether policies/programs that increase children's perceived competence lead to higher levels of PA. Policymakers and interventionists should also be attuned to opportunities to stem age-related declines in PA, such as designing facilities/programs that are accessible for and appealing to older children.

In structured programs, overweight/obese children's PA levels may not be dependent on their levels of perceived competence. While girls, older children, and less fit children may engage less actively overall, structured exercise appears to elicit more consistent levels of activity compared with sports. Particularly if designed in enjoyable ways, structured exercise can be a beneficial component of PA programs for overweight/obese children. Further studies are needed to evaluate how different types of structured activities influence other outcomes, such as enjoyment and PA outside program time.

REFERENCES

1. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the united states measured by accelerometer. *Med Sci Sports Exerc*. 2008;40:181.

2. McMurray RG, Ondrak KS. Cardiometabolic risk factors in children: The importance of physical activity. *Am J Lifestyle Med*. 2013;7:292–303.

3. Metcalf B, Henley W, Wilkin T. Effectiveness of intervention on physical activity of children: Systematic review and meta-analysis of controlled trials with objectively measured outcomes. *BMJ*. 2012;345:e5888.

4. Taylor WC, Sallis JF, Dowda M, Freedson PS, Eason K, Pate RR. Activity patterns and correlates among youth: Differences by weight status. *Pediatr Exerc Sci*. 2002;14:418.

5. Biddle SJ, Atkin AJ, Cavill N, Foster C. Correlates of physical activity in youth: A review of quantitative systematic reviews. *Int Rev Sport Exerc Psychol*. 2011;4:25-49.

6. Mota J, Esculcas C. Leisure-time physical activity behavior: Structured and unstructured choices according to sex, age and level of physical activity. *Int J Behav Med*. 2002;9:111-121.

7. Spink KS, Shields CA, Chad K, Odnokon P, Muhajarine N, Humbert L. Correlates of structured and unstructured activity among sufficiently active youth and adolescents: A new approach to understanding physical activity. *Pediatr Exerc Sci*. 2006;18:203.

8. Whitt-Glover MC, Taylor WC, Floyd MF, Yore MM, Yancey AK, Matthews CE. Disparities in physical activity and sedentary behaviors among US children and

adolescents: Prevalence, correlates, and intervention implications. *J Public Health Policy*. 2009:S309-S334.

9. Tovar A, Vikre EK, Gute DM, et al. Development of the live well curriculum for recent immigrants: A community-based participatory approach. *Prog Community Health Partnersh*. 2012;6:195.

10. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United states. *Adv Data*. 2000(314):1.

11. Leger L, Mercier D, Gadoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci*. 1988;6:93-101.

12. The Cooper Institute. *Fitnessgram and activitygram test administration manual-updated 4th edition.* Human Kinetics; 2010.

13. Harter S. *Manual for the self-perception profile for children.* University of Denver; 1985.

14. Kowalski K, Crocker P, Faulkner R. Validation of the physical activity questionnaire for older children. *Pediatr Exerc Sci*. 1997;9:174-186.

15. Saint-Maurice PF, Welk GJ, Beyler NK, Bartee RT, Heelan KA. Calibration of self-report tools for physical activity research: The physical activity questionnaire (PAQ). *BMC Public Health*. 2014;14:461.

16. Babic MJ, Morgan PJ, Plotnikoff RC, Lonsdale C, White RL, Lubans DR. Physical activity and physical self-concept in youth: Systematic review and meta-analysis. *Sports Med*. 2014:1-13.

17. Voss C, Ogunleye AA, Sandercock GR. Physical activity questionnaire for children and adolescents: English norms and cut-off points. *Pediatr Int*. 2013;55:498-507.

18. Adams MA, Johnson WD, Tudor-Locke C. Steps/day translation of the moderate-to-vigorous physical activity guideline for children and adolescents. *Int J Behav Nutr Phys Act*. 2013;10:49.

Table 1. Baseline Characteristics of Low-Income, Overweight/Obese Children Participating in a Community-Based Physical Activity Program

	Study sample (n=93)	Boys (n=51)	Girls (n=42)	p-value[c]
Gender				
Male (%)	55	-	-	-
Age				
Years	9.9 (1.7)	9.9 (1.7)	9.8 (1.6)	0.76
Ethnicity				
Hispanic (%)	91	92	90	0.99
Household income				
Poverty-to-Income Ratio	0.8 (0.5)	0.8 (0.4)	0.9 (0.6)	0.16
Below federal poverty line (%)	73	75	71	0.71
Country of Birth (%, n=91)				
United States	92	88	98	
El Salvador	4	8	0	0.23
Other	3	4	2	
Mother's Country of Birth (%)				
United States	6	8	5	
El Salvador	51	53	48	
Guatemala	10	10	10	
Mexico	10	6	14	0.67
Colombia	8	10	5	
Other	16	14	19	
Anthropometry				
BMI z-score	2.0 (0.4)	2.1 (0.3)	1.9 (0.5)	**0.01**
Overweight (%)	20	10	33	**0.005**
Obese (%)	80	90	67	
Aerobic Fitness				
PACER laps completed	15.8 (8.0)	17.4 (9.4)	13.9 (5.4)	**0.03**
Self-Reported Physical Activity				
PAQ-C score	3.0 (0.8)	3.0 (0.7)	3.0 (0.9)	0.84
Perceived Athletic Competence				
Perceived competence score[a]	2.7 (0.6)	2.8 (0.6)	2.6 (0.6)	0.10
Physical Activity in Program				
Average total steps/session[b]	5393.3 (1270.1)	5837.2 (1109.0)	4854.3 (1255.9)	**0.0001**
# sessions with valid pedometer wear	3.8 (2.5)	3.9 (2.5)	3.7 (2.6)	0.46

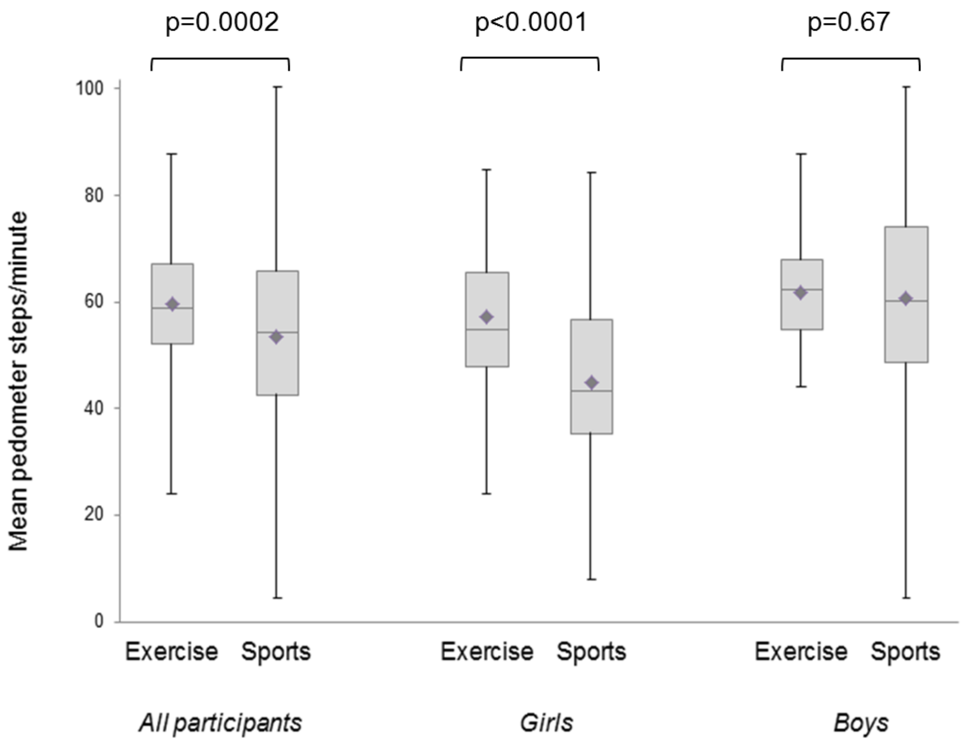
Data are percentages for categorical variables and means (SD) for continuous variables.
PACER=Progressive Aerobic Cardiorespiratory Endurance Run
PAQ-C=Physical Activity Questionnaire for Children score; range: 1-5
[a]Perceived athletic competence subscale score from Harter Self-Perception Profile for Children; range: 1-4
[b]Measured via pedometer in a sample of 10 structured program sessions spread over 10 months
[c]p-values for difference between boys and girls; differences tested with independent-samples t-tests, except for % below poverty line and % overweight/obese (chi-square tests), ethnicity and child/mother country of birth (Fisher's exact test), and # of sessions with valid wear (Wilcoxon rank-sum test)

Table 2. Associations between Child Characteristics and Self-Reported Physical Activity (PA) in General Living and Pedometer-Measured PA in Structured Exercise and Sports Sessions (n=93)

	General-Living PA		Mean Pedometer-Measured Steps/Minute in Structured Program					
	PAQ-C Score[a]		All Program Time[a,b]		Exercise Sessions[a,b]		Sports Sessions[a,b,c]	
Predictor variables	ß (SE)	p-value	ß (SE)	p-value	ß (SE)	p-value	ß (SE)	p-value
BMI z-score	-0.24 (0.21)	0.25	-2.5 (3.2)	0.44	-3.1 (3.3)	0.34	-1.0 (4.5)	0.81
Aerobic fitness (PACER laps)	0.0021 (0.011)	0.85	**0.39 (0.16)**	**0.01**	0.26 (0.16)	0.10	**0.45 (0.20)**	**0.03**
Perceived athletic competence	**0.35 (0.14)**	**0.01**	-3.3 (2.1)	0.11	-3.4 (2.1)	0.11	-1.1 (2.6)	0.67
Age (years)	**-0.11 (0.051)**	**0.04**	**-4.3 (1.2)**	**0.0007**	**-2.9 (1.2)**	**0.02**	**-4.3 (1.6)**	**0.007**
Gender (male)	0.010 (0.17)	0.95	**8.3 (2.8)**	**0.004**	5.3 (2.8)	0.07	**8.7 (3.5)**	**0.02**
Model fit								
R^2	0.218		0.478		0.296		0.522	

PAQ-C = Physical Activity Questionnaire for Children; range: 1-5.
Model additionally adjusted for: [a]Hispanic ethnicity, poverty-to-income ratio, [b]PAQ-C score, program site, # valid pedometer sessions, [c]mean steps/minute in exercise session

Figure 1. Means (diamonds) and quartiles (boxplots) of children's pedometer steps/minute in structured exercise and sports: all program participants (n=93), girls (n=42), and boys (n=51).



Among all participants, activity levels were less variable and higher on average (p=0.0002 for paired t-test) during structured exercise sessions compared with structured sports sessions. In subgroup analyses, activity in structured exercise was significantly higher than in structured sports among girls but not boys.

Chapter 7: Summary and Discussion

Summary

Physical activity (PA) confers numerous health benefits for children and adolescents, including promoting maintenance or achievement of a healthy weight, increasing cardiorespiratory fitness (CRF) levels, improving cardiometabolic risk profiles, and promoting self-esteem.[1, 2] However, the majority of children in the United States (U.S.) fall short of recommended levels of PA, and PA levels decrease further as children move into adolescence.[3] While PA is an important public-health priority for all children and adolescents, those who are overweight/obese may experience particular benefits in terms of weight reduction and attenuation of cardiometabolic risk.[4-7] Efforts that increase PA among low-income and racial/ethnic minority youth are also of particular public-health importance, given that those youth are at disproportionate risk of overweight/obesity and related comorbities[8] and also face particular barriers to PA, such as limited access to facilities and programs.[9]

This dissertation aims to inform future research, policy, and practice by addressing three gaps in the literature. First, most research on associations between PA and cardiometabolic health has focused specifically on moderate-to-vigorous PA (MVPA), but emerging evidence shows that PA may also be beneficial at lighter intensities.[10-12] Studies comparing associations between cardiometabolic risk factors and MVPA minutes and total PA volume are needed to inform whether PA research, policies, and programs should focus specifically on MVPA or more broadly promote increases in total movement.[13,2] Second, randomized controlled trials (RCTs) have demonstrated that PA-focused interventions are efficacious for improving CRF and adiposity among overweight/obese youth,[6, 14] but it is unclear whether such evidence translates to community settings, where PA dose received tends to be highly variable and difficult to control.[15-20] Research that evaluates the impact of participation in PA programs delivered in typical practitioner settings will provide important evidence to help bridge the gap from randomized controlled efficacy trials to community practice.[21-23] Third, recent evidence has shown that correlates of PA vary both by individual-level characteristics (e.g., overweight versus normal-weight children)[24, 25] and contextual factors (e.g., whether activities are structured or unstructured).[26, 27] Research is needed on correlates of PA in understudied, high-risk subgroups, and in multiple environmental contexts, to support tailoring of PA policies and programs to priority populations and settings.

To address these gaps, we analyzed two different datasets. For our first aim, we used data from the National Health and Nutrition Examination Survey (NHANES) to compare the strength of cross-sectional associations between minutes of MVPA and total PA volume, as well as volume at each light and moderate-to-vigorous intensity, with individual cardiometabolic risk factors and clustered risk among U.S. adolescents. Our other aims used original data collected in partnership with Let's Get Movin' (LGM), a community-based, after-school PA program for low-income, overweight/obese youth ages 8–14 in East Boston, MA. Aim 2 tested whether attendance in the program was associated with changes in CRF and adiposity, as well as whether participants' in-program activity levels moderated those relationships. Aim 3 evaluated demographic, physiologic, and psychosocial correlates of PA in this high-risk population; correlates were examined in multiple contexts, including PA in general living as well as PA in structured exercise and sports sessions.

The following sections briefly summarize the results of these analyses, and subsequent sections discuss their collective implications and limitations. One common theme that emerges across these analyses is the importance of viewing the extent to which children are active through a multidimensional lens. In fact, our own conceptualization of PA evolved considerably over the course of this research. Our original conceptual model identified two dimensions of PA that were of interest: "level," denoting how much children/adolescents move in general, and "participation," denoting attendance in the PA program. Over time, it became clear that these two concepts did not adequately describe other important, nuanced dimensions of PA. In Aim 1, for example, the concept of PA "level" was ultimately parsed into different variables representing total PA volume, MVPA minutes, and PA volume at light and moderate/vigorous intensity. Similarly, in our analyses of LGM data, "level" was viewed through a variety of contextual lenses, including not just PA in general living (the focus of our original proposal), but also PA in structured exercise and structured sports sessions during the after-school program. Likewise, our conceptualization of "participation" was ultimately examined from multiple angles, including not only program attendance but also participants' activity levels when they did attend. Our findings reflect the importance of these dimensions in terms of understanding youth PA and its impact on health.

Physical activity volume and intensity and cardiometabolic risk

Our first paper showed that both MVPA minutes and total PA volume demonstrated significant protective associations with clustered cardiometabolic risk, systolic and diastolic blood pressure, insulin, and HDL cholesterol, but not with waist circumference

(WC) or triglycerides. These associations were slightly stronger for total PA volume than for MVPA minutes for all outcomes except insulin, where associations were of near-identical strength. MVPA minutes was not associated with any outcome variables independent of total volume. These findings suggest that, in U.S. adolescents, total volume of movement, including activity at any intensity, may demonstrate similarly strong, or marginally stronger, associations with cardiometabolic markers compared with time spent in MVPA.

The results of our analyses comparing volume accrued at each light and moderate-to-vigorous intensity, however, reflect further nuance. On one hand, summary cardiometabolic risk scores were similarly associated with light PA volume (ß=–0.019, p=0.04) and moderate-to-vigorous PA volume (ß=–0.019, p=0.009), and HDL cholesterol was also significantly associated (+) with both variables. On the other, associations between light volume and moderate-to-vigorous volume and other individual cardiometabolic markers were different. Moderate-to-vigorous volume was preferentially associated with insulin (–), WC (–), and systolic blood pressure (–), while light volume was preferentially associated with diastolic blood pressure (–). Our findings regarding insulin and WC are consistent with other evidence,[28, 29] but those regarding blood pressure are more difficult to explain, particularly given incomplete understanding of the pathways linking PA and blood pressure.[30] Proposed mechanisms include PA's influence on angiogenesis, sympathetic tone, and vascular responsiveness and remodeling;[30] these or other adaptations may be differentially influenced by PA intensity and also play different roles in influencing systolic and diastolic blood pressure. Further research is needed, but ultimately whether PA policies and programs should aim to promote activity at specific intensities or greater total PA volume may depend on which outcomes are most important for the individuals or populations at hand.

Impact of a community PA program on overweight/obese children's CRF and adiposity

Our second paper found that overweight/obese youth participating in a community-based PA program demonstrated pre/post increases in CRF as well as favorable shifts in weight status categories. Our analyses examining associations between program attendance and changes in CRF showed a significant dose-response relationship: other factors equal, every 10 sessions of attendance were associated with about 1 lap greater gain in PACER score. However, attendance was not significantly associated with change in BMI. It is plausible that non-dose-dependent aspects of program participation (e.g., learning basic skills through a small number of sessions) promoted improvements in PA and diet behaviors outside the program, and that these changes may have contributed to the favorable baseline-to-final changes we observed in terms of adiposity. Alternatively, our failure to detect a significant relationship between attendance and changes in BMI may have been related to limitations of this outcome variable, which does not differentiate lean mass from fat mass. If attendance was associated with both reductions in fat mass and increases in lean mass, we may have detected no association between attendance and changes in BMI even in the presence of favorable associations between attendance and changes in body composition.

While evidence from RCTs has demonstrated efficacy of PA interventions for increasing CRF and reducing adiposity among overweight/obese youth, effectiveness in resource-constrained community settings has remained less clear. Our findings build on a small body of prior evidence showing pre/post improvements in CRF and adiposity among overweight/obese youth participating in community-based PA programming.[31] In the absence of a controlled study design, the association between program attendance and CRF strengthens potential for inference of a causal relationship between program participation and improvements in aerobic fitness. However, our findings also suggest that attendance in a community-based program with a maximal dose of two sessions/week may not be associated with reductions in BMI. Two other studies of after-school PA programs held for two hours, five days/week over nine months found evidence of a dose-response relationship between PA program attendance and improvements in adiposity,[32, 33] so it is plausible that attendance at LGM may have been associated with changes in BMI had the program offered a higher maximal dose (e.g., daily rather than twice-weekly sessions).

We also found evidence that the associations between attendance and both CRF and BMI were influenced by children's in-program activity levels, such that each session attended was associated with greater increases in CRF and greater decreases in BMI as in-program activity levels increased. Our moderation models predicted that, other factors held equal, a child at the 75th percentile for both attendance and activity level (37 sessions attended, 66 pedometer steps/minute) would have an average 0.7 kg/m^2 less gain in BMI and an average of 5 more laps gained in PACER score compared with a child in the 25th percentile for both attendance and activity level (15 sessions attended, 48 pedometer steps/minute). Other factors equal, this equates to about 1.5 kg less gain in body weight and additional gain in PACER laps equivalent to about 30% of the average baseline score (16 laps). In light of other evidence of a dose-response relationship between PA and changes in adiposity and fitness,[2, 34] the synergistic relationship between PA program attendance and activity levels seems largely intuitive. However, in the context of community programming, it underscores the practical importance of the real-world variability in PA dose received by children in after-school settings and other community contexts. Looking exclusively at one dimension of PA participation—enrollment or attendance, for example—may not provide a sufficiently complete understanding of dose.

Multicontextual correlates of PA in low-income, overweight, Hispanic youth

Our research examined correlates of PA in four different ways: Paper 2 included an analysis of correlates of attendance at the PA program, and paper 3 examined correlates of PA in general living, PA in exercise sessions, and PA in sports sessions. Together, these analyses showed that age, sex, aerobic fitness, adiposity, and perceived competence were each associated with some dimension of PA level/participation in a cohort of low-income, overweight/obese, mostly Hispanic boys and girls. However, the importance of those correlates depended on situational/contextual factors. For example, correlates of PA in general living differed from correlates of PA in structured exercise and sports sessions.

Age was the only correlate associated with all four PA variables: other factors equal, older age was associated with less self-reported PA in general living, fewer program sessions attended, and less activity in both structured exercise and sports sessions. Other studies have likewise consistently found that age is inversely associated with PA levels in children and adolescents,[25, 35] but this research provides further evidence that those patterns appear to hold across multiple dimensions of PA. While prior studies have generally found that female sex is associated with lower levels of PA,[25, 35] in our analysis sex was not associated with general-living PA, program attendance, or structured exercise. However, during sports sessions, being female was associated with fewer steps/minute. It is plausible that girls typically had less prior experience with sports compared with boys and therefore were unable to engage as actively. This seems likely given my own anecdotal observations that sports participation seems largely non-normative for girls, particularly overweight girls, in this community.

We found that perceived athletic competence was the strongest predictor of PA in general living. This is consistent with a recent review that found perceived competence to be the dimension of self-concept that was most strongly associated with PA in children and adolescents.[35] We cannot infer a causal relationship between perceived competence and general-living PA given the cross-sectional nature of this analysis, and reverse causation is highly plausible. Still, our results provide some evidence that high perceived competence may be necessary for overweight/obese youth to proactively seek/act upon opportunities for PA; this may be especially true in low-income communities, where such opportunities are often limited.[9] Notably, perceived competence did not predict attendance at or activity levels in the structured PA program. A program like LGM, which focuses on building basic skills and stresses personal achievement and fun over competition, may engage participants with low perceived competence as effectively as those with higher perceived competence.

Among physiologic correlates, CRF was not significantly associated with general-living PA or with attendance at the program, but it was associated with in-program activity levels, especially in sports sessions. In contrast, during structured exercise, CRF was not a significant predictor. In sports, activities are generally less structured compared with exercise, particularly during game-play, when participants must make choices about whether, for example, to run down the field to score a goal or to sit back on defense. For an unfit child, physical discomfort may make the latter option more attractive. That BMI z-scores were not associated with activity levels in either general living or in the structured program should be interpreted cautiously, given that all participants were overweight/obese. However, other studies have likewise found only mixed evidence of an association between adiposity and PA in populations including overweight/obese and normal-weight youth.[25, 36] On the other hand, higher BMI z-scores were associated with lower levels of attendance in the community PA program, even though the program was tailored to the needs of overweight/obese youth. It is plausible that, even in this setting, for the most obese individuals participation was difficult, stigmatizing, or otherwise unappealing in ways that compromised attendance.

Discussion

Research and policies surrounding children's PA tend to deal with neatly-packaged constructs. Randomized trials, for example, often deliver a specific PA dose in highly controlled settings, and policy recommendations tend to stress specific objectives like "60 minutes of daily MVPA" or "mandatory physical education." In reality, though, the way children and adolescents move is more difficult to pin down: different kids move in many different ways in many different contexts for many different reasons. This research attempted to explore some of those differences and their importance for research, policy, and practice.

Our findings highlight the importance of PA's multidimensionality in several respects. Adolescents' total PA volume, for example, may be as strongly, or more strongly, associated with overall cardiometabolic health as are daily minutes of MVPA. At the same time, volume accrued at different intensities may demonstrate different associations depending on the individual cardiometabolic variable at hand. The impact of interventions delivered in uncontrolled community settings may depend not merely on the efficacy of the intervention, but also on what program dose is actually received—and in practice settings that dose inevitably varies across multiple dimensions. Furthermore, the factors that are associated with youth PA appear highly complex, varying in large part among different populations and contexts in which children move. The following sections discuss the implications of such complexity for the research, practitioner, and policy communities.

Implications for the research community

Moving beyond MVPA minutes

PA research and policy documents, like the 2008 Physical Activity Guidelines for Americans,[37] have to date largely stressed the importance of children and adolescents achieving 60 minutes of daily MVPA, in part due to historic reliance on self-report instruments that generally capture MVPA.[13,2] For example, the Physical Activity Guidelines Advisory Committee Report, which informed the 2008 guidelines, noted that the recommendations for youth were limited by their general reliance on self-report as well as by the "very limited data" available on the dose-response relationship between PA and health outcomes in children and adolescents.[38] In the intervening years since

2008, accelerometer data have become much more widely available, but research studies continue to routinely reduce that data to MVPA minutes, at least in part to align their work with current guidelines and previous studies.[13]

Our findings build on emerging evidence that the health benefits of PA extend beyond MVPA minutes and that light PA and total PA volume also confer benefits.[10-12] In light of this evidence, PA researchers may benefit from more regularly examining dimensions of PA beyond MVPA minutes. Increasing access to accelerometer technologies expands such opportunities.[13] Operationalizing PA as total activity counts (TAC) or mean counts per minute of wear time may offer several important advantages. Unlike MVPA minutes, TAC does not have an upper numeric boundary within a fixed duration of time and may therefore explain a greater proportion of the variance in some outcome variables and, in turn, potentially reduce the likelihood of type-2 error. In addition, using TAC rather than MVPA may reduce potential bias introduced by non-random differences in mean counts/minute above intensity cut-points (Appendix 1.A).

Researchers may also find that using variables representing volume by intensity category (e.g., light volume, L-TAC, and moderate-to-vigorous volume, MV-TAC, as used in the present research) provides nuanced insights into the relationships between PA at different intensities and cardiometabolic risk factors or other health outcomes. Research using larger datasets, like the International Children's Accelerometer Database (ICAD),[39] may offer additional statistical power and, in turn, support analyses using volume variables in more finely partitioned intensity categories. Basic-science studies that help illuminate the pathways through which PA at different intensities influence health outcomes are also needed to complement epidemiologic and intervention research.

Two potential limitations of variables like TAC are their misalignment with current policy documents like the Physical Activity Guidelines for Americans as well as the potential difficulty of interpreting results of analyses using volume-based variables. However, pushing beyond the boundaries of what is emphasized in current policy is critical; otherwise, the relationship between policy and research will largely be cyclical rather than forward-moving. Challenges regarding interpretability are important in terms of making research actionable for practitioners, policymakers, and the mainstream public. In studies using PA volume variables, it may be important to contextualize what those data mean in more intuitive terms (Figure 1 in our first paper provides one potential example). At the same time, growing access to accelerometers in devices like Fitbits and smartphones may ultimately lead to raw accelerometer data or other volume-based variables, like step counts, being more widely comprehensible in mainstream populations and, in turn, appropriate for future PA guidelines.

Our use of novel variables such as TAC, L-TAC, and MV-TAC has broader implications for researchers in terms of stretching boundaries of research conventions. We also challenged convention in our second aim, using BMI rather than BMI z-score as our outcome variable for longitudinal analyses. We found that, while BMI z-score may be the more appropriate outcome variable in some longitudinal analyses,[40] in our study sample, which included many individuals in the far right tail of the BMI distribution for their age and sex, z-scores would have failed to account for significant changes in adiposity over time (Appendix 3.A). Of course, convention-breaking decisions must be made judiciously: in our case, for example, the decision to use BMI rather than BMI z-score required careful analysis of the data from multiple angles and extensive discussion among authors. Still, our experience highlights the potential benefits of questioning whether standard ways of operationalizing variables are in fact appropriate to a given dataset or set of research questions.

Examining correlates of PA in diverse environmental contexts and population subgroups

This research also provides evidence that correlates of youth PA may vary depending both on the contexts/situations in which activity happens (e.g., general living vs. structured programs) and on the characteristics of the population being studied. These findings are unsurprising in the context of behavioral theories that emphasize the importance of dynamic relationships between individual and environmental factors in determining health behaviors.[41, 42]

Future studies that separately analyze PA in different, well-defined environmental contexts may provide important new insights. Social-ecological frameworks may be useful for identifying environments where PA occurs, including organizational and community contexts (e.g., home, school, community programs). These contexts themselves might contain multiple sub-domains. For example, in research on PA in schools, separate analyses of correlates in recess, physical education, or extracurricular sports programs may reveal important nuances. Even within well-defined contexts, research might also test multiple dimensions of children's engagement; for example, in sports programs, separate analyses might test correlates of children's propensity to enroll, to attend, and to participate actively. Parsing out PA in the different contexts where children are active will present challenges, but emerging approaches show promise in this area. For example, one recent study in Danish schoolchildren combined accelerometer data with geographic positioning system (GPS) monitoring, school-reported schedule information (e.g., recess and physical education times), and child PA diary data to evaluate PA patterns in a variety of broad contexts (e.g., PA in leisure time, at school, in transport, and at home) and subdomains (e.g., urban green spaces and sports facilities).[43] Such techniques may open new opportunities for better understanding youth PA patterns and to evaluate context-specific correlates.

Analyses that are sufficiently powered to test interactions among correlates are also needed to advance understanding of differences among population subgroups. For example, testing weight status × age, × sex, or × race/ethnicity interaction terms might advance understanding of whether the relationship between weight status and PA differs among demographic subgroups. Multifaceted evidence extending from such research will help practitioners to more effectively tailor programs to the populations they serve and environments they work in, while also informing the design of PA policies that promote PA equitably among children/adolescents, regardless of weight status, age, sex, or other characteristics.

Advantages of practice-based evidence

Our analyses using evidence gathered in partnership with LGM yielded novel insights about correlates of PA in a high-risk population subgroup, as well as about the implications of variability inherent to "real-world" community practice. There are, without question, limitations of practice-based research, and there are many questions that well-controlled trials can answer, particularly regarding efficacy, that practice-based studies cannot. Practice-based studies also present unique challenges and require researchers to prioritize community partner relationship-building and to be responsive to partners' needs, limitations, and priorities. However, practice-based research also has unique potential to advance knowledge around how, or if, evidence from efficacy trials relates to effectiveness in community settings, knowledge that is critical to accelerate the translation of current research knowledge to real-world practice.

Practice-based study designs offer other advantages beyond the unique types of insight they generate. For one, they are inexpensive, particularly compared with traditional efficacy trials. Our partnership with LGM required no incremental funding beyond the program's preexisting operating budget, and, even considering the time invested by researchers, total costs were relatively low. Particularly amid dramatic cuts to U.S. federal research funding,[44] such partnerships may represent important untapped opportunities to generate new insights at relatively limited cost. Working with a community partner on practice-based research may also have important learning and development advantages for young investigators. For example, having to navigate the practical constraints faced by community practitioners may help researchers to subsequently design studies that are relevant to practice settings and to more effectively translate learning from such studies in ways that are practically useful. Practice-based research may also provide unique opportunities to train young investigators to design and implement program monitoring and evaluation plans, to use monitoring/evaluation data to inform real-time programmatic adjustments, and to disseminate those findings in ways that inform future research, policy, and community practice in other settings.

A continued challenge in community-engaged, practice-based research studies will be navigating the tension between feasibility in community settings and adequate methodological rigor to test research hypotheses. In the present research, we were unable to randomize children to LGM, given the health center's policy to make the program available to all children who were referred and interested. This limits potential for causal inference, even in our dose-response analyses, in which high-attenders may differ from low-attenders in systematic, unmeasured ways. In other practice settings, group-randomized trials—e.g., where schools or even entire communities are randomized to intervention and control conditions—may be more feasible than traditional RCTs and offer substantial advantages in terms of methodological rigor.[23] Step-wedged study designs, where an intervention is rolled out sequentially to different individuals or groups, are also promising for testing PA interventions in practice settings where it is considered unethical to withhold the intervention.[45]

Accelerating the production of practice-based studies may require paradigm shifts within the PA research community. For example, researchers might look to develop long-term research agendas that extend beyond the discovery stage, systematically extending evidence from efficacy trials to practice settings and, in turn, helping bridge the gap from research to practice. Such extended efforts will benefit from research planning processes that account for factors like dissemination and scalability from the outset.[46] Funding mechanisms that support such extended research efforts will also be needed; the National Institutes of Health's growing funding of dissemination and implementation research is encouraging, though those investments remain small in comparison with those made in discovery-focused research.[47] Also critical will be opportunities for dissemination of findings from practice-based studies to those settings where evidence can be applied, as well as guidelines for reporting results in ways that maximize their utility for end-users.[48]

Implications for the practitioner community

The importance of PA dose delivered in community PA programs

For community-based PA programs, our findings highlight that it is not enough to merely create PA programs and enroll participants in them: efforts must be made to ensure that children attend *and* participate as actively as possible. These findings have implications in a range of practice settings beyond after-school programs. In schools, for example, providing opportunities for physical education (PE) may not meaningfully influence health if students regularly receive exemptions from participation or do not actively engage when they are present.[49]

In practice, the dose of activity that children and adolescents receive in PE, recess, after-school programs, sports programs, and other settings varies widely, and some studies have found that activity levels are disproportionately low among high-risk populations, including overweight/obese youth.[17-20] However, school administrators, community program leaders, and other stakeholders may operate on the false assumption that dedicating a certain amount of time for PA (e.g., providing 30 minutes of PE) is equivalent to participants spending that same amount of time moving (e.g., getting 30 minutes of MVPA). Finding strategies to optimize the level of movement during active time is critical. In many cases, relatively modest changes within existing settings, like providing PA equipment during recess or adopting standardized PE curricula, may have a substantial impact on activity levels.[18, 50] Using low-cost tools, like pedometers, may help PE staff, after-school program facilitators, coaches, or other practitioners to gauge the extent to which participants are moving during times dedicated to PA and to inform programmatic improvements.[51] In LGM, for example, pedometer data have been used to guide adaptations to lesson plans, to identify underperforming sites, and to help coaches pinpoint individual children who may require targeted attention.

The importance of perceived competence for overweight/obese children

While maximizing near-term activity levels is important for PA programs, it is important to also acknowledge other important goals, including encouraging PA outside program time. Findings in our third paper suggest that higher perceived athletic competence may be associated with higher general-living PA among overweight/obese children, and other research has shown that strong athletic self-concept in adolescence predicts levels of PA in adulthood.[52] In some cases, competence-building activities may not elicit maximal levels of activity; for example, teaching a child to dribble a basketball requires instructional time and may, in the short term, prompt limited movement. However, the potential benefits in terms of increasing PA outside program time, and over the life course, may make such relatively inactive time worthwhile. It is also important to note broader risks in programs' being singularly focused on maximizing short-term activity levels. For example, pressuring an unfit child to engage in high-intensity PA when he or she is not ready to do so may compromise his/her sense of competence or engender negative attitudes towards PA. Therefore, while PA dose delivered is one important indicator of PA program effectiveness, that goal should also be balanced against other important priorities, like building PA skills and shifting overall PA behaviors beyond program time.

Tailoring PA programs by population and context

This research provides new insight into the factors that predict PA among low-income, overweight/obese, mostly Hispanic youth participating in structured settings. While conventional thinking might suggest that traditional sports are most engaging, our study found that, compared with sports, structured exercise activities, like relays and strength-building obstacle courses, elicited higher levels of PA among LGM participants. Furthermore, activity levels in exercise were more consistent among participants, regardless of their age, sex, or fitness levels. Compared with sports, activities like walking and running, which are structured, repetitive, and generally intuitive, may be less dependent on individual characteristics. Walking and running also create natural opportunities for youth of all abilities to quantifiably monitor personal achievement (e.g., number of laps completed) and progress (e.g., ability to jog two laps today versus one lap a month ago). In addition, walking and running require minimal equipment and are readily translatable outside program time, especially for children with access to safe spaces amenable to active transportation and active living more generally. Especially if designed in enjoyable ways, structured exercise can be a beneficial and empowering component of PA programs for overweight/obese, low-income youth.

Interventions that specifically target overweight/obese youth may be advantageous in that they can be tailored to unique needs and preferences. However, care must be taken to promote a positive, non-stigmatizing environment, particularly given the adverse emotional and behavioral consequences for youth experiencing weight-related bias.[53] In LGM, for example, coaches are specifically instructed to avoid discussing weight and to focus instead on benefits like building fitness, feeling good, and achieving personal goals. In settings such as schools, separating overweight/obese from normal-weight participants would likely be inherently stigmatizing. In contexts that include both normal-weight and overweight/obese participants, efforts should be made to ensure that activities are sensitive to the needs, preferences, and abilities of all participants, regardless of their weight status.

Our findings also provide early evidence that might help with tailoring PA interventions for Hispanic children and adolescents. Prior evidence has shown that correlates of PA vary substantially among racial/ethnic groups[54] and that correlates among Hispanic youth may be influenced by factors like culturally-specific gender norms surrounding PA participation or parenting practices that mediate or moderate the influence of environmental characteristics on children's PA.[55, 56] While our findings may not generalize to other racial/ethnic groups, research in Hispanic youth may be of particular public-health importance, given that Hispanic Americans are the fastest-growing ethnic group in the U.S.[57] and that obesity prevalence is disproportionately high among Hispanic children and adolescents.[8] At the same time, further research is needed exploring correlates of PA in a wider range of Hispanic subgroups, which are socially and culturally heterogeneous and tend to show different patterns of lifestyle changes during acculturation to the U.S.[58, 59] This research mainly included first-generation U.S. born children of Central American (mostly Salvadoran) parents; further research will be needed to understand how our findings compare with correlates in Hispanic children with other cultural heritages and at different stages in the acculturation process.

The population- and context-specific nature of PA correlates has more general implications for physical educators, after-school PA program leaders, and other practitioners serving a range of populations. Providing children with opportunities to select among multiple options may maximize engagement among diverse participants. While such choices may be difficult in resource-constrained settings, some school districts have made progress in this area. In Miami-Dade Country, for example, schools offer diversified options to meet the needs of children/adolescents with different fitness levels, developmental needs, and personal preferences. While team sports continue to be offered, the district has expanded options to include activities like structured exercise and water sports, which may appeal to students for whom traditional competitive athletics may not be engaging.[60] Creating opportunities for children to opt in to those activities that are most enjoyable for them may support longer-term engagement and also help stem later declines in PA typically seen as children move through adolescence.

To effectively tailor programming, practitioners may benefit from evaluating factors that predict PA in the particular populations they serve and realigning programs to meet the needs of that population or subgroups within it. In LGM, for example, we recently adapted programming for older (11-14 years old) girls, recognizing that, based on pedometer data, their activity levels were disproportionately low during sports. On one hand, we recognized the importance of challenging gender norms by engaging girls in sports, but we also found it important to respond to girls' preferences and to capitalize on opportunities to increase their activity levels. To balance those priorities, a split program model was developed: one session each week, these girls participate in standard programming, including exercise and sports, and the other session they participate exclusively in exercise activities—including spinning, Zumba, and treadmill exercise—at a local YMCA.

Benefits of research partnerships

Just as researchers benefit from partnerships with community practitioners, practitioners may likewise benefit in diverse ways. Chapters 5 and 6 note that the curriculum and evaluation plans built through this partnership have continued to be utilized, but that brief statement may not fully capture the breath of beneficial changes within LGM extending from our partnership. Having a consistent curriculum and evaluation protocols has markedly elevated the quality and consistency of programming while also enabling LGM to present internal stakeholders and potential funders a more cohesive and compelling story about the program and its impact on participants. Data generated through the new evaluation systems also facilitate targeted program investments that help improve outcomes. For example, our finding that attendance influenced fitness outcomes helped justify the case for LGM to hire a part-time Family Engagement Specialist, whose job description includes systematically contacting parents whose children miss program and devising solutions for maximizing attendance. Particularly if researchers are willing to make tradeoffs to prioritize community partners' needs in addition to their own research objectives, these partnerships can represent tremendous win-win propositions.

Implications for the policy community

Importance of continued emphasis on physical activity

Broadly speaking, this research provides evidence of the benefits of PA for children's health: independent of adiposity, higher levels of PA are associated with improvements in cardiometabolic profiles, and participation in PA programs may elicit gains in aerobic fitness, which itself promotes healthy weight and confers other benefits. Given that pediatric obesity and cardiometabolic risk factors tend to track from youth into adulthood,[61] policies that promote PA among children and adolescents may have important benefits for population health both in the short and long terms. Policy strategies that increase youth PA may also have important behavioral benefits over the life course, given evidence that PA in childhood and adolescence is predictive of PA in adulthood.[7] For these reasons, policymakers should continue to make promoting youth PA a high priority, particularly for low-income and racial/ethnic minority youth who bear disproportionate burden of overweight/obesity and related health risks.[8, 9]

Designing policies that account for quality

Physical activity-focused policy initiatives sometimes treat PA in unidimensional ways. For example, two of the objectives in Healthy People 2020 are to "Increase the proportion of the Nation's public and private schools that require daily physical education for all students" and to "Increase regularly scheduled elementary school recess in the United States."[62] These are important goals, particularly given decreases in school-based PA, largely resulting from test-score pressures extending from the 2002 No Child Left Behind legislation.[63] However, our analysis highlights the importance of quality: just as our analysis showed that the impact of attendance in after-school programs was dependent on in-program activity levels, the impact of increases in PE and in recess likewise might depend in large part on the quality of those opportunities, including the extent to which they are responsive to the needs of high-risk subgroups. Policy guidelines that extend beyond simply providing PA opportunities, and also set targets for quality in terms of both activity levels and other important goals, like skill-building, may make PA policies more impactful.

Moving beyond "60 minutes of MVPA"

Similar to the Healthy People goals, policy documents like the Physical Activity Guidelines for Americans, with its central emphasis on achieving 60 minutes of moderate-to-vigorous PA per day for children and adolescents, also may not fully capture the multidimensionality of the way young people move. Our research provides early evidence that benefits of PA may accrue not only through MVPA but also through total PA volume, including light PA. Given that adolescents in our NHANES sample spent about 95% of their waking hours in either sedentary or light activity, policies that shift activity patterns within these categories—whether by displacing sedentary behavior with LPA or by increasing the intensity of LPA itself (e.g., walking instead of standing)—may meaningfully advance health, even if MVPA remains unchanged. For example, city ordinances that enhance pedestrian safety, zoning laws that promote mixed commercial and residential community designs, and school policies that promote brief classroom breaks among elementary-age children may increase overall PA mainly by increasing light ambulatory activity.[64, 65] Recognizing the importance of contextual factors in influencing PA levels, as well as inter-individual differences in terms of PA patterns and correlates, policy guidelines that account for those contextual factors and provide room for flexibility beyond “60 minutes of MVPA” might help increase PA and advance the health of youth in diverse populations and communities.

Evolution in U.S. nutrition policy makes for an interesting analogy in terms of how PA guidance might come to evolve. Whereas only one set of PA guidelines for Americans have been issued, in 2008, the Dietary Guidelines for Americans were first published in 1980 and are refreshed every five years. The first few sets of recommendations offered fairly prescriptive guidance on foods and nutrients to consume or to avoid, and by 1990 they even quantified recommendations for limiting nutrients like dietary fat as a percentage of total calorie intakes.[66-68] The 1995, 2000, and 2005 guidelines became increasingly nuanced and multidimensional, taking more of a whole-diet approach, incorporating attention to PA, and acknowledging benefits of vegetarian dietary patterns.[69-71] The 2010 Guidelines for the first time included a directive to “enjoy your food,” stressed the importance of energy-balance and healthy weight, and included two chapters emphasizing that multiple dietary patterns can be health-promoting and that social and environmental factors play critical roles in Americans’ diets.[72] Efforts currently underway to inform the 2015 Guidelines are incorporating attention to new diet-related health outcomes, like cancer, as well as the implications of Americans’ diets in other domains, including environmental sustainability.[73] Two of the Dietary Guidelines Advisory Committee’s five subcommittees have explicitly been directed to address PA alongside diet/food (Subcommittee 3 focuses on “Diet and Physical Activity Behavior Change,” and Subcommittee 4 on “Food and Physical Activity Environments”).

Our findings in this dissertation provide evidence that PA policy guidelines may likewise need to move away from prescriptive recommendations and place increasing emphasis on concepts such as the health-promoting benefits of a range of PA patterns for youth, representing different combinations of mode, intensity, duration, and frequency. They might also place increasing emphasis on social, cultural, and contextual factors that influence PA as well as on PA's reciprocal relationships to diet and other health behaviors.

Limitations

Several important limitations of this research should be acknowledged. These include methodological limitations, like potential sources of measurement error or residual confounding, which are detailed in prior chapters and summarized briefly here. Discussed in fuller detail are larger conceptual limitations that apply both to this research and to the research literature more broadly.

Methodological limitations

Results of our cross-sectional analyses, including both associations between accelerometer-derived PA and cardiometabolic risk (Aim 1) and perceived athletic competence and general living PA (Aim 3), do not allow for causal inference. All three aims used self-report measures, including main outcome and predictor variables like general-living PA (Aims 2 and 3) and perceived competence (Aim 2) as well as secondary outcomes and important covariates like dietary variables (Aims 1 and 2) and household income (Aims 1, 2, and 3), which may be prone to bias. Such bias may be especially problematic in our analysis where self-reported general-living PA is the main outcome variable and self-reported perceived athletic competence is a main predictor variable; for example, social-desirability biases may have caused some children to inflate responses to both the general living PA (PAQ-C) and perceived competence (Harter profile) questions, thus biasing results away from the null. Alternatively, some sub-groups may have systematically over- or under-reported certain behaviors; for example, if more obese children systematically over-reported their PA levels on the PAQ-C survey, as has been observed in prior studies,[74, 75] such bias may have prevented us from detecting a significant inverse association between BMI z-scores and PAQ-C scores even if adiposity and general-living PA were in fact inversely associated.

Our objective measurements likewise have limitations; for example, neither accelerometers (Aim 1) nor pedometers (Aims 2 and 3) detect isometric PA or differentiate weight-bearing from non-weight-bearing activity. For Aims 2 and 3, we needed to balance methodological rigor against practical constraints like cost and program staff capacity, particularly given our objective to ensure evaluation methods could be replicated by LGM in future program years. In some cases, these choices may have increased potential for measurement error; however, all tools were previously validated in youth populations, and efforts were made to maximize validity (e.g., taking anthropometric measurements in triplicate) in the context of program limitations.

Given that neither of our datasets used randomized controlled designs, there is also considerable potential for residual confounding by unmeasured factors. For example, in our NHANES analyses, aerobic fitness and pubertal stage may be associated both with PA and with cardiometabolic risk factors, but those variables were unavailable and therefore could not be adjusted for. We were also unable to randomize participants to the LGM program, limiting potential for causal inference; for example, in our dose-response analyses, the association we detected between attendance and CRF may plausibly have been confounded by unmeasured factors, like parental support or child motivation. Our LGM study population included low-income, overweight/obese, mostly Hispanic youth who voluntarily enrolled in the PA program, and this may limit generalizability of our findings. That said, these analyses do provide novel insight into a particularly high-risk, understudied population subgroup.

Conceptual limitations

This research includes cross-sectional analyses and longitudinal analyses over a nine-month PA program and therefore does not address longer-term relationships among PA, fitness, adiposity, self-perceptions, and other variables. Similar limitations appear in the larger body of PA research: many studies rely on cross-sectional designs, and those that do follow participants over time tend to have short windows. For example, one recent review of PA interventions for overweight/obese children found that the average program duration was 14 weeks.[6] In another review of PA interventions, "longer term studies" were defined as those lasting over six months.[76] Research on PA in children and adolescents over the span of years is limited.

A comparatively small body of evidence has followed subjects over such long time periods and found important longitudinal associations. For example, one recent study evaluated adolescents' attitudes toward sports, exercise, and fitness and then measured their levels of PA at five and ten years follow-up; the analysis showed that subjects with favorable attitudes toward PA in adolescence engaged in approximately 30–40% more weekly MVPA at follow-up compared with those who had less favorable attitudes.[77] Further research incorporating longer time periods is needed to understand questions like whether there are critical skill-building windows in childhood that are important to lifelong PA habits, particularly among overweight/obese youth. It is also unclear how the relationships among PA and related physiologic and psychosocial factors evolve and interact over time. Our findings from LGM suggest that participants who were fitter at baseline moved more in program, and those who moved more in program saw greater gains from each session attended. Multiple years of participation in LGM or similar programs may plausibly lead to gradual gains in fitness, which may in turn enable higher in-program activity levels and, ultimately, changes in adiposity. Having worked with LGM for nearly five years, I have found that the most profound changes in fitness, adiposity, and PA outside the program do in fact unfold gradually, over the course of years rather than months, among the overweight/obese youth who participate. This research and other intervention studies with similarly short study timeframes are limited in their inability to explore the ways in which these long-term patterns unfold.

This research and other studies also are limited in the scope of outcomes they test. While we investigated several outcomes with which PA may be associated—fitness, adiposity, and cardiometabolic risk—there are many others that we did not evaluate, like social development, cognition, and academic performance. Those outcomes themselves may plausibly respond to PA differently depending on factors like intensity or type of PA programming (e.g., exercise versus sports). Other studies on the comparative effectiveness of PA interventions tend to focus on proximal outcomes like minutes of daily MVPA or energy expenditures.[50] Such comparisons are an important first step toward synthesizing the research evidence in ways that are useful for those with the capacity to drive change. However, reducing the impact of a PA intervention to a single, proximal variable likely understates the full range of outcomes influenced by PA. Further research is needed examining the impact of policy and intervention strategies not only on PA but also other more distal outcomes, like physical and emotional health and academic performance. Barriers to such broad-based, long-term research include high costs, difficulty of sustaining participant engagement (e.g., loss to follow-up), and short-term publication pressures. Extended partnerships with community programs may help address some of these concerns. In LGM, for example, many participants re-enroll in the program year-over-year, and even those who do not (or who "graduate out" of the program due to age) overwhelmingly tend to remain patients at the health center and to complete regular well visits with their physicians. Particularly if data collected through the program could be matched with identification codes in electronic medical records, there could be rich opportunities to analyze longitudinal changes in participants over the course of years or even decades at relatively limited cost.

Conclusion

This research explores the multidimensionality of PA in children and adolescents, both in terms of how PA influences health and in terms of what it might take to get young people moving more. Our analyses provide new insights into questions surrounding how PA volume and intensity relate to cardiometabolic health, including novel evidence that total PA volume may be more strongly associated with cardiometabolic risk compared with

MVPA minutes. Through our analyses of data collected in partnership with a community-based PA program for overweight/obese youth, we found evidence that participation in such a program may be associated with favorable outcomes, particularly when participants attend regularly and engage actively. We also used data from this community partnership to provide new evidence of the demographic, physiologic, and psychosocial factors associated with PA in multiple contexts in a cohort of low-income, overweight/obese, mostly Hispanic children and adolescents.

At the same time, by highlighting the complexity inherent to PA behaviors and their relationship to health, this research also draws attention to the many gaps that remain. Future studies are needed to understand the interplay among factors that influence youth PA as well as the ways in which PA influences a broader range of outcomes not only in youth but also over the life course. Such research will help guide policy and practice decisions that account for the diverse ways in which young people move and the mutifaceted implications of PA for child and adolescent health and well-being.

References

1. Biddle SJ and Asare M. Physical activity and mental health in children and adolescents: a review of reviews. Br J Sports Med 2011; 45: 886-895.

2. Janssen I and LeBlanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. Int J Behav Nutr Phys Act 2010; 7: 1-16.

3. Berrigan TR, Dodd KW, Masse LC, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Ex 2008; 40: 181-188.

4. Brambilla P, Pozzobon G and Pietrobelli A. Physical activity as the main therapeutic tool for metabolic syndrome in childhood. Int J Obes 2010; 35: 16-28.

5. Ho M, Garnett SP, Baur LA, et al. Impact of dietary and exercise interventions on weight change and metabolic outcomes in obese children and adolescents: a systematic review and meta-analysis of randomized trials. JAMA Pediatrics 2013; 167: 759-768.

6. Kelley GA, Kelley KS and Pate RR. Effects of exercise on BMI z-score in overweight and obese children and adolescents: a systematic review with meta-analysis. BMC Pediatrics 2014; 14: 225.

7. Telama R, Yang X, Viikari J, et al. Physical activity from childhood to adulthood: a 21-year tracking study. Am J Prev Med 2005; 28: 267-273.

8. Ogden CL, Carroll MD, Kit BK, et al. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA 2014; 311: 806-814.

9. Whitt-Glover MC, Taylor WC, Floyd MF, et al. Disparities in physical activity and sedentary behaviors among US children and adolescents: prevalence, correlates, and intervention implications. J Public Health Policy 2009: S309-S334.

10. Carson V and Janssen I. Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study. BMC Public Health 2011; 11: 274.

11. Ekelund U, Luan J, Sherar LB, et al. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. JAMA 2012; 307: 704-712.

12. Ekelund U, Anderssen S, Froberg K, et al. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. Diabetologia 2007; 50: 1832-1840.

13. Powell KE, Paluch AE and Blair SN. Physical activity for health: What kind? How much? How intense? On top of what?. Annu Rev Public Health 2011; 32: 349-365.

14. Vasconcellos F, Seabra A, Katzmarzyk PT, et al. Physical activity in overweight and obese adolescents: systematic review of the effects on physical fitness components and cardiovascular risk factors. Sports Med 2014: 1-14.

15. Garn AC, McCaughtry N, Kulik NL, et al. Successful after-school physical activity clubs in urban high schools: perspectives of adult leaders and student participants. J Teach Phys Educ 2014; 33: 112-133.

16. Maljak K, Garn A, McCaughtry N, et al. Challenges in offering inner-city after-school physical activity clubs. Am J Health Educ 2014; 45: 297-307.

17. Trost SG, Rosenkranz RR and Dzewaltowski D. Physical activity levels among children attending after-school programs. Med Sci Sports Exerc 2011; 40: 622-629.

18. Verstraete SJ, Cardon GM, De Clercq DL, et al. Increasing children's physical activity levels during recess periods in elementary schools: the effects of providing game equipment. Eur J Public Health 2006; 16: 415-419.

19. Sacheck JM, Nelson T, Ficker L, et al. Physical activity during soccer and its contribution to physical activity recommendations in normal weight and overweight children. Pediatr Exerc Sci 2011; 23: 281-292.

20. McKenzie TL, Marshall SJ, Sallis JF, et al. Student activity levels, lesson context, and teacher behavior during middle school physical education. Res Q Exerc Sport 2000; 71: 249-259.

21. Brownson RC and Jones E. Bridging the gap: translating research into policy and practice. Prev Med 2009; 49: 313-315.

22. Glasgow RE, Green LW, Taylor MV, et al. An evidence integration triangle for aligning science with policy and practice. Am J Prev Med 2012; 42: 646-654.

23. Ammerman A, Smith TW and Calancie L. Practice-based evidence in public health: improving reach, relevance, and results. Annu Rev Public Health 2014; 35: 47-63.

24. Taylor WC, Sallis JF, Dowda M, et al. Activity patterns and correlates among youth: differences by weight status. Pediatr Exerc Sci 2002; 14: 418.

25. Biddle SJ, Atkin AJ, Cavill N, et al. Correlates of physical activity in youth: a review of quantitative systematic reviews. Int Rev Sport Exerc Psychol 2011; 4: 25-49.

26. Mota J and Esculcas C. Leisure-time physical activity behavior: structured and unstructured choices according to sex, age and level of physical activity. Int J Behav Med 2002; 9: 111-121.

27. Spink KS, Shields CA, Chad K, et al. Correlates of structured and unstructured activity among sufficiently active youth and adolescents: A new approach to understanding physical activity. Pediatr Exerc Sci 2006; 18: 203.

28. Carson V, Ridgers ND, Howard BJ, et al. Light-intensity physical activity and cardiometabolic biomarkers in US adolescents. PLOS ONE 2013; 8: e71417.

29. Hay J, Maximova K, Durksen A, et al. Physical activity intensity and cardiometabolic risk in youth. Arch Pediatr Adolesc Med 2012; 166: 1022-1029.

30. Pescatello L, Franklin B, Fagard R, et al. Exercise and hypertension: American College of Sports Medicine Position Stand. Med Sci Sports Exerc 2004; 36: 533-553.

31. Messiah SE, Diego A, Kardys J, et al. Effect of a park-based after-school program on participant obesity-related health outcomes. Am J Health Promot 2014: epub ahead of print.

32. Yin Z, Gutin B, Johnson MH, et al. An environmental approach to obesity prevention in children: Medical College of Georgia FitKid Project year 1 results. Obes Res 2005; 13: 2153-2161.

33. Barbeau P, Johnson MH, Howe CA, et al. Ten months of exercise improves general and visceral adiposity, bone, and fitness in black girls. Obesity 2007; 15: 2077-2085.

34. Carson V, Rinaldi R, Torrance B, et al. Vigorous physical activity and longitudinal associations with cardiometabolic risk factors in youth. Int J Obes 2013; 38: 16-21.

35. Babic MJ, Morgan PJ, Plotnikoff RC, et al. Physical activity and physical self-concept in youth: systematic review and meta-analysis. Sports Med 2014: 1-13.

36. Sallis JF, Prochaska JJ and Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc 2000; 32: 963-975.

37. U.S. Department of Health and Human Services. *Physical Activity Guidelines for Americans*. Washington, DC, 2008.

38. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, Washington, DC, 2008.

39. Sherar LB, Griew P, Esliger DW, et al. International children's accelerometry database (ICAD): design and methods. BMC Public Health 2011; 11: 485.

40. Inokuchi M, Matsuo N, Takayama JI, et al. BMI z-score is the optimal measure of annual adiposity change in elementary school children. Ann Hum Biol 2011; 38: 747-751.

41. Bandura A. Health promotion from the perspective of social cognitive theory. Psychol Health 1998; 13: 623-649.

42. McLeroy KR, Bibeau D, Steckler A, et al. An ecological perspective on health promotion programs. Health Educ Behav 1988; 15: 351-377.

43. Klinker CD, Schipperijn J, Kerr J, et al. Context-specific outdoor time and physical activity among school-children across gender and age: using accelerometers and GPS to advance methods. Front Public Health 2014; 2: 1-15.

44. Gewin V. Funding: Flirting with disaster. Nature 2013; 498: 527-528.

45. Bonell CP, Hargreaves J, Cousens S, et al. Alternatives to randomisation in the evaluation of public health interventions: design challenges and solutions. J Epidemiol Community Health 2011; 65: 582-587.

46. Klesges LM, Estabrooks PA, Dzewaltowski DA, et al. Beginning with the application in mind: designing and planning health behavior change interventions to enhance dissemination. Ann Behav Med 2005; 29: 66-75.

47. Glasgow RE, Vinson C, Chambers D, et al. National Institutes of Health approaches to dissemination and implementation science: current and future directions. Am J Public Health 2012; 102: 1274-1281.

48. Neta G, Glasgow RE, Carpenter CR, et al. A framework for enhancing the value of research for dissemination and implementation. Am J Public Health 2014: e1-e9.

49. National Association for Sport and Physical Education and the American Heart Association. Shape of the nation report: Status of physical education in the USA. 2012.

50. Bassett DR, Fitzhugh EC, Heath GW, et al. Estimated energy expenditures for school-based policies and active living. Am J Prev Med 2013; 44: 108-113.

51. Scruggs PW, Beveridge SK, Watson DL, et al. Quantifying physical activity in first- through fourth-grade physical education via pedometry. Res Q Exerc Sport 2005; 76: 166-175.

52. Wichstrøm L, von Soest T and Kvalem IL. Predictors of growth and decline in leisure time physical activity from adolescence to adulthood. Health psychology 2013; 32: 775.

53. Puhl RM and Heuer CA. Obesity stigma: important considerations for public health. Am J Pub Health 2010; 100: 1019-1028.

54. Kelly EB, Parra-Medina D, Pfeiffer KA, et al. Correlates of physical activity in black, Hispanic, and white middle school girls. J Phys Act Health 2010; 7: 184-193.

55. Lindsay AC, Greaney ML, Sussner KM, et al. Socio-cultural, organizational, and community level influences on physical activity levels of latino preschool-age children: a qualitative study. Int J Child Health Nutr 2014; 3: 41-47.

56. Teresia M, Cerin E, Lee RE, et al. Environmental and cultural correlates of physical activity parenting practices among Latino parents with preschool-aged children: Ninos Activos. BMC Public Health 2014; 14: 707.

57. Bernstein R. US census bureau projections show a slower growing, older, more diverse nation a half century from now. www.census.gov/newsroom/releases/archives/population/cb12-243.html (2012, accessed 11/20 2014).

58. Vega WA and Amaro H. Latino outlook: good health, uncertain prognosis. Annu Rev Public Health 1994; 15: 39-67.

59. Wojcicki JM, Schwartz N, Jiménez-Cruz A, et al. Acculturation, dietary practices and risk for childhood obesity in an ethnically heterogeneous population of Latino school children in the San Francisco Bay area. J Immigr Minor Health 2012; 14: 533-539.

60. Let's Move Active Schools. Miami-Dade schools adopt “fitness focus”, www.letsmoveschools.org/latest-stories/2014/7/18/miami-dade-schools-adopt-fitness-focus (2014, accessed 11/8 2014).

61. Baker JL, Olsen LW and Sørensen TI. Childhood body-mass index and the risk of coronary heart disease in adulthood. N Engl J Med 2007; 357: 2329-2337.

62. US Department of Health and Human Services and Office of Disease Prevention and Health Promotion. Healthy People 2020 2012.

63. Trost SG and van der Mars H. Why we should not cut PE. Educ Leadership 2009; 67: 60-65.

64. Erwin HE, Beighle A, Morgan CF, et al. Effect of a Low-Cost, Teacher-Directed Classroom Intervention on Elementary Students' Physical Activity. J Sch Health 2011; 81: 455-461.

65. Ding D, Sallis JF, Kerr J, et al. Neighborhood environment and physical activity among youth: a review. Am J Prev Med 2011; 41: 442-455.

66. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 1st ed. Washington, DC, 1980.

67. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 2nd ed. Washington, DC, 1985.

68. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 3rd ed. Washington, DC, 1990.

69. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 4th ed. Washington, DC, 1995.

70. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Nutrition and Your Health: Dietary Guidelines for Americans*. 5th ed. Washington, DC, 2000.

71. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans*. 6th ed. Washington, DC, 2005.

72. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans*. 7th ed. Washington, DC, 2010.

73. Casavale K, Rihane C, Olson R, et al. New explorations in updating the scientific evidence to inform the future Dietary Guidelines for Americans, 2015. J Acad Nutr Diet 2014; 114: A89.

74. McMurray RG, Ward DS, Elder JP, et al. Do overweight girls overreport physical activity? Am J Health Behav 2008; 32: 538.

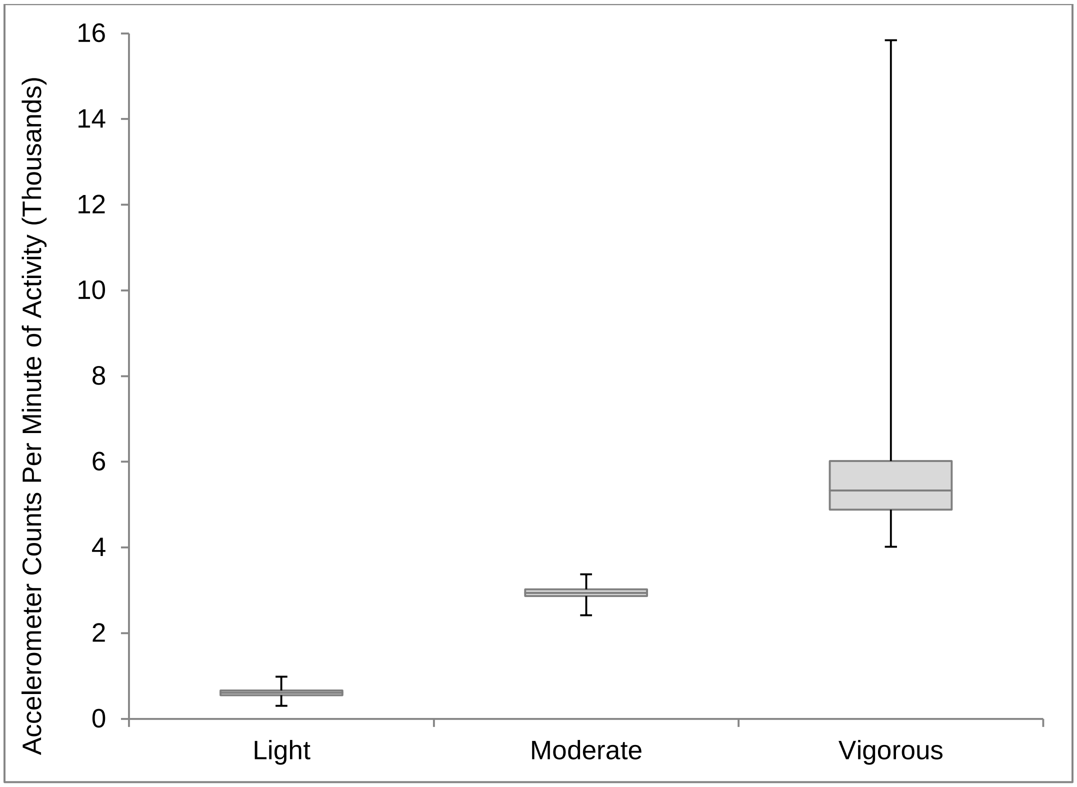
75. Warner ET, Wolin KY, Duncan DT, et al. Differential accuracy of physical activity self-report by body mass index. Am J Health Behav 2012; 36: 168-178.

76. Metcalf B, Henley W and Wilkin T. Effectiveness of intervention on physical activity of children: systematic review and meta-analysis of controlled trials with objectively measured outcomes. BMJ 2012; 345: e5888.

77. Graham DJ, Sirard JR and Neumark-Sztainer D. Adolescents' attitudes toward sports, exercise, and fitness predict physical activity 5 and 10years later. Prev Med 2011; 52: 130-132.

Appendix 1: Supplementary NHANES analyses

Appendix 1.A. Distribution of subjects' mean pedometer counts per minute of light, moderate, and vigorous PA



There is considerable variety in terms of what a minute of light PA, moderate PA, and, in particular, vigorous PA (VPA) mean in terms of number of counts.

Counts per minute of light PA (LPA): Mean: 612, Median: 608, IQR: 554-668

Counts per minute of moderate PA (MPA): Mean: 2937, Median: 2940, IQR: 2863-3020

Counts per minute of vigorous PA: Mean: 5650, Median: 5332, IQR: 4889-6014

Counts per minute of moderate-to-vigorous PA (MVPA): Mean: 3609, Median: 3476, IQR: 3170-3855

Appendix 1.B. Results of regression models regressing mean counts/min of LPA on sex, age, BMI z-score, poverty-to-income ratio, and race-ethnicity

	ß (SE)	p-value
Predictor variables		
Male sex	45.3 (5.7)	<.0001
Age (years)	-8.3 (1.1)	<.0001
BMI z-score	5.8 (3.2)	0.09
Poverty-to-income Ratio	-2.8 (1.9)	0.16
Mexican American*	-12.6 (6.7)	0.07
Black*	8.0 (5.3)	0.14
Other*	-19.0 (8.5)	0.03

*White is the omitted race category

Appendix 1.C. Results of regression models regressing mean counts/min of MVPA on sex, age, BMI z-score, and poverty-to-income ratio, and race-ethnicity

	ß (SE)	p-value
Predictor variables		
Male sex	292.2 (45.1)	<.0001
Age (years)	-28.8 (11.8)	0.02
BMI z-score	-84.6 (19.0)	0.0001
Poverty-to-income Ratio	-2.0 (12.3)	0.87
Mexican American*	56.2 (48.6)	0.26
Black*	-27.7 (51.6)	0.60
Other*	-21.1 (74.3)	0.78

*White is the omitted race category

Appendix 1.D. Unadjusted subject characteristics: all subjects ages 12–19 years in 2003–2006 NHANES sample and subjects in study sample and fasting subsample

	2003–2006 NHANES (n=4591)	Study sample (n=2105)	Fasting subsample (n=953)
Age (years)	15.4 (0.1)	15.4 (0.1)	15.5 (0.1)
Male (%)	50.9 (0.9)	50.9 (1.3)	50.9 (2.5)
Race/ethnicity			
NH White (%)	63.3 (2.8)	63.0 (3.0)	63.2 (3.4)
NH Black (%)	15.1 (1.8)	15.1 (2.0)	15.0 (2.3)
Mexican-American (%)	11.3 (1.4)	11.3 (1.5)	11.3 (1.7)
Other (%)	10.4 (1.1)	10.6 (1.2)	10.6 (1.5)

Appendix 1.E. Associations between moderate-to-vigorous and light physical activity and continuous metabolic syndrome scores (CMRI) and component risk factors and moderation of those associations by BMI z-score

	Clustered Risk	Component Risk Factors			
	CMRI[a]	MAP (mmHg)	Insulin[b] (pmol/L)	TG:HDL Ratio[b]	Waist circumference[b]
Models including MVPA					
Model 1					
MVPA (min/d)	-0.00948 (0.00357)*	-0.02926 (0.01383)*	-0.00261 (0.0011)*	-0.00244 (0.00142)	-0.00016 (0.00015)
BMI z-score	1.32438 (0.04831)***	0.89292 (0.3326)*	0.3449 (0.02276)***	0.16397 (0.02833)***	0.13487 (0.00335)***
Model 2					
MVPA (min/d)	-0.00947 (0.00407)*	-0.02401 (0.01454)	-0.00314 (0.00128)*	-0.00299 (0.00145)*	0.00002 (0.00016)
BMI z-score	1.32541 (0.11278)***	1.2632 (0.43218)**	0.30782 (0.04508)***	0.12553 (0.04857)*	0.14692 (0.00709)***
MVPA × BMI z-score	-0.00003 (0.00272)	-0.01125 (0.01065)	0.00113 (0.00113)	0.00116 (0.00086)	-0.00037 (0.00016)*
Models including LPA					
Model 1					
LPA (min/d)	-0.00107 (0.00071)	-0.01085 (0.00393)**	0.00024 (0.0004)	-0.00016 (0.00034)	-0.00003 (0.00005)
BMI z-score	1.33513 (0.05065)***	0.96094 (0.34743)**	0.34541 (0.02371)***	0.16619 (0.02862)***	0.13509 (0.00343)***
Model 2					
LPA (min/d)	-0.00175 (0.00092)	-0.01162 (0.00458)*	-0.00011 (0.00053)	-0.0002 (0.00032)	-0.00006 (0.00006)
BMI z-score	0.95107 (0.26012)**	0.52442 (1.1431)	0.14678 (0.12382)	0.14031 (0.08541)	0.11634 (0.01764)***
LPA × BMI z-score	0.00115 (0.00074)	0.00131 (0.00335)	0.00059 (0.00035)	0.00008 (0.00023)	0.00006 (0.00005)

Results reported as ß coefficients (SE). All models adjusted for BMI z-score; accelerometer wear time; age; sex; race-ethnicity; self-reported daily time on each television and computer (≤ 1 hr, 2–3 hours, ≥ 4 hrs); smoking status (y/n); poverty-to-income ratio; energy intake; dietary fiber; dietary sugar; dietary cholesterol; dietary saturated, monounsaturated, and polyunsaturated fat, each as % of total kilocalories; dietary sodium; dietary potassium; and self-reported asthma (y/n) and physical limitations (y/n).
MAP = mean arterial pressure; TG = triglycerides
[a] CMRI = sum of z-scores for MAP, insulin, TGs:HDL ratio, and waist circumference [b] log-transformed * $p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

Appendix 1.F. Association between daily minutes of moderate-to-vigorous PA and HOMA%S and interaction by race/ethnicity (n=976)

	MVPA (min)	**Mexican-American**	**Black**	**Other Race**	**MVPA × Mex-Am**	**MVPA × Black**	**MVPA × Other**
Insulin (uU/mL)[a]	-0.00058 (0.00106)	0.19511 (0.08347)*	0.10253 (0.06560)	0.11164 (0.15124)	-0.00222 (0.00150)	-0.00204 (0.00111)	-0.00310 (0.00355)
HOMA%S[a]	0.00058 (0.00108)	-0.20053 (0.08312)*	-0.10221 (0.06559)	-0.11551 (0.15031)	0.00227 (0.00151)	0.00209 (0.00113)	0.00309 (0.00355)

Results reported as ß coefficient (SE). [a] Data log-transformed * $p < 0.05$, ** $p < 0.01$
All models additionally adjusted for BMI z-score; accelerometer wear time; age; sex; self-reported daily time on each television and computer (≤ 1 hr, 2–3 hours, ≥ 4 hrs); smoking status (y/n); poverty-to-income ratio; energy intake; dietary fiber; dietary sugar; dietary cholesterol; dietary saturated, monounsaturated, and polyunsaturated fat, each as % of total kilocalories; dietary sodium; dietary potassium; and self-reported asthma (y/n) and physical limitations (y/n).

Appendix 2: Let's Get Movin' enrollment documents and instrumentation

Appendix 2.A. Parent consent and child assent forms

Parent Permission Form

Your child is invited to join a Tufts University study conducted in partnership with Let's Get Movin' (LGM). The purpose of the study is to understand how participation in programs like LGM affects children's physical fitness, health, and emotional well-being.

LGM uses several measurements to understand how the program affects your child's health. They include physical fitness tests (like running tests) and measurements of your child's height, weight, and waist size. Your child will also complete short surveys on their diet, physical activity, and self-perceptions, and wear a pedometer during some LGM sessions to measure their activity level. In order to better understand the different characteristics and needs of LGM children and their families, the program also asks parents/caregivers to complete a short demographics survey. All children participating in LGM will complete these measurements.

If your child joins this study, LGM will also share this information with researchers from Tufts University. Your child's information will first be coded with an ID number to ensure individual information is kept confidential.

Risks and Benefits
This research presents few risks or benefits beyond those associated with participation in LGM. There is limited risk of emotional distress should your child's data be revealed to anyone other than research staff. However, we will protect your child's information to minimize this risk.

If your child joins this research study, their information will help LGM and other groups understand how to better support children's health through physical activity programs.

Voluntary Participation & Withdrawal
Your child's participation in this study is voluntary. He or she may withdraw at any time or for any reason and may also refuse to answer any questions.

Your child can participate in all LGM program components regardless of whether or not he or she is in the study.

Confidentiality
Your child's personal information will be kept confidential and will not be released without your written permission, except as required by law. Outside of EBNHC, a code will be used in place of your child's name on all data. Your child's name will not be reported in any publication.

Study Contacts
For any questions about this research, please contact Daniel Hatfield, MS, at

(617) 636-0952 or at daniel.hatfield@tufts.edu. For questions about your child's rights as a research subject, call Lara Sloboda at the Tufts University Institutional Review Board at (617) 627-3417.

Statement of Consent
I understand that my child's participation is voluntary and that my child can withdraw from the study at any time without prejudice. Signing this form does not waive any of my or my child's legal rights.

By signing, I acknowledge that I understand the study and my child's role in it. I agree to complete the attached demographics survey. I understand how data may be used and how my and my child's privacy will be protected. I have read the study explanation, my questions have been satisfactorily answered, and **I give permission for my child to participate and agree to complete a demographic questionnaire.**

☐ Yes, I give my child permission to participate and agree to fill out a demographics questionnaire (Please sign below).

____
Child's full name (printed)

______________________________ ______________________________
Parent/guardian's full name (printed) **Parent's contact number**

______________________________ ______________________________
Parent/guardian's signature **Date**

☐ No, I do not give my child ______________________ permission to participate.
(print child's full name)

For office use only
I certify that I have explained fully to the above subject the nature and purpose, procedures, and the possible risks and benefits of this research study.

______________________________ ____________
Signature of researcher or designate *Date*

Formulario de Permiso Paterno

Invitamos a su niño/a a participar en un estudio de la Universidad de Tufts llevado a cabo en colaboración con Let's Get Movin' (LGM). El propósito del estudio es entender cómo la participación en programas como LGM afecta la aptitud y estado físico, salud, y bienestar emocional de los niños.

LGM utiliza varias medidas para entender cómo afecta el programa a la salud de su niño. Utilizan pruebas de aptitud física (como pruebas de correr) y medidas de la altura de su hijo/a, peso y la circunferencia de la cintura. Su hijo/a también completará cuestionarios sobre su dieta, actividad física, y auto-percepciones, y llevará un podómetro durante alguna de las sesiones de LGM para medir su nivel de actividad. Para entender mejor las distintas características y necesidades del los niños de LGM y sus familias, el programa también pide a los padres/tutores legales que cumplimenten un breve cuestionario demográfico. Todos los niños que participan en LGM completarán estas medidas.

Si su hijo/a participa en este estudio, LGM también compartirá esta información con investigadores de Tufts University. La información de su hijo será codificada primero con un número de identificación para asegurar que la información individual se mantiene confidencial.

Riesgos y Beneficios
Este estudio presenta pocos riesgos o beneficios más allá de los riesgos asociados con la participación en LGM. Existe un mínimo riesgo de estrés emocional si los datos de su hijo/a son revelados a alguien fuera del personal de la investigación. De todas formas, protegeremos la información de su hijo/a para minimizar este riesgo.

Si su hijo participa en este estudio, su información ayudará a LGM y a otros grupos a entender como mejorar de forma más eficaz la salud de los niños mediante programas de actividad física.

Participación Voluntaria y Retirada
La participación de su niño/a en este estudio es voluntaria. Su niño/a pude retirarse en cualquier momento o por cualquier razón y puede también negarse a responder a cualquier pregunta.

Su niño/a puede participar en todos los componentes de LGM independientemente de su participación es el estudio.

Confidencialidad
La información personal de su niño/a se mantendrá confidencial y no será comunicada sin su permiso por escrito, excepto si se requiere por ley. Fuera de la clínica (EBNHC), se usará un código en vez del nombre del niño/a en todos los datos. No se utilizará el nombre del niño/a en ninguna publicación.

Contactos del estudio
Para cualquiera pregunta sobre este estudio, por favor contacte con Daniel Hatfield, MS, en el teléfono (617) 636-0952 o a través de daniel.hatfield@tufts.edu. Para cualquiera pregunta sobre los derechos del su niño/a como sujeto del estudio, contacte con Lara Sloboda del Tufts University Institutional Review Board (Comité de revisión institucional de Tufts University) llamando al (617) 627-3417.

Declaración de consentimiento
Entiendo que la participación de mi niño/a es voluntaria y que mi niño/a puede retirarse del estudio en cualquier momento sin prejuicio. Al firmar este formulario, no renuncio a ninguno de los derechos legales de mi niño/a.

Al firmar, reconozco que comprendo el estudio y el papel de mi niño/a en este estudio. Accedo a llenar la encuesta demográfica adjunta. Entiendo como se puedes usar los datos y como se protegerá mi privacidad y la de mi niño/a. He leído la explicación del estudio, mis preguntas han sido contestadas de manera satisfactoria y **doy permiso a mi niño/a para participar y estoy de acuerdo en completar el cuestionario demográfico.**

☐ Sí, doy permiso a mi niño/a para participar y estoy de acuerdo en rellenar el cuestionario demográfico (Por favor firme abajo).

____
Nombre de niño/a (impreso)

______________________________	______________________________
Nombre completo de padre o persona a cargo (impreso)	**Número de contacto del padre o persona a cargo**
______________________________	______________________________
Firma de padre o persona a cargo	**Fecha**

☐ No, no doy permiso a mi niño/a ______________________________ permiso para participar.
nombre completo de niño/a (impreso)

For office use only
I certify that I have explained fully to the above subject the nature and purpose, procedures, and the possible risks and benefits of this research study.

______________________________ ______________
Signature of researcher or designate *Date*

CHILD ASSENT FORM

Review this form with your child and keep it for your records.
We will use a copy of this form with your child at LGM.

We are doing a research study. Research studies are one way to figure out how things work. We want to learn how programs like Let's Get Movin' help kids get healthier.

You are being asked to join this study because you're an LGM participant. This year, LGM will ask you to complete surveys about yourself and things you do. You'll also do fitness tests, have some body measurements taken, and wear a pedometer, which tells how active you are during the program. These measurements will help you, your parents, and LGM understand your progress. LGM gets this information from all participating kids.

If you join this study, LGM will also share this information with researchers from Tufts University. LGM will first take first take your name off the information to protect your privacy. There's a small risk that someone other than the researchers could see your information. However, we'll protect your information to make sure this risk is very low.

If you join this study, you'll help LGM and other groups understand how to help kids get healthier.

Your parents have given permission for you to participate in this study. Even though your parents said "yes," you can still say "no" and not join. Even if you say "yes" first, you may change your mind later. All you have to do is tell us. If you choose not to let LGM share your information with the Tufts researchers, you can still participate in all LGM activities.

Before you say "yes" or "no," we will answer any questions you have. If you say "yes" and join the study, you can still ask questions. You or your parent can contact Dan Hatfield, the leader of this study, at (703) 795-8454. If you have any questions about anything that happens during the study, there is a special office at Tufts University called the Institutional Review Board that will listen to you and answer your questions. Your parents have the phone number for that office and can help you reach them.

Signing your name means that you agree to be in this study.

____
Child's full name

__________________________________ _________________
Child's signature **Date**

For office use only
I certify that I have explained fully to the above subject the nature and purpose, procedures, and the possible risks and benefits of this research study.

____ _____________
Signature of researcher or designate *Date*

FORMULARIO DE CONSENTIMIENTO DEL NIÑO

Revise este formulario con su hijo y guárdeselo para su información.
Utilizaremos una copia de este formulario con su hijo en LGM.

Estamos haciendo un estudio de investigación. Los estudios de investigación son una forma de averiguar como funcionan las cosas. Queremos aprender cómo programas como Let's Get Movin' ayudan a los niños a mejorar su salud.

Te invitamos a tomar parte en este estudio porque participas en Let's Get Movin'. Este año Let's Get Movin' te pedirá que rellenes cuestionarios sobre ti mismo y cosas que haces. También harás pruebas de tu estado físico, tomaremos algunas medidas corporales, y vas a llevar un podómetro que indica lo activo que estás durante el programa. Estas medidas te ayudarán a ti, a tus padres y a LGM a entender tus progresos. LGM recoge esta información de todos los chicos/as participantes.

Si participas en este estudio, Let's Get Movin' compartirá esta información con investigadores de la Universidad de Tufts. Let's Get Movin' quitará primero tu nombre de la información para proteger tu privacidad. Hay un pequeño riesgo de que alguien aparte de los investigadores pueda ver tu información. De todas formas, protegeremos tu información para asegurarnos de que este riesgo es muy bajo.

Si participas en este estudio, ayudarás a LGM y a otros grupos a entender como ayudar a otros chicos/as a estar más sanos.

Tus padres han dado permiso para que participes en este estudio. Aunque tus padres nos han dicho que "si", tu todavía puedes decir que "no" y no participar. Aunque digas que "si" primero, puedes cambiar de opinión luego. Sólo tienes que avisarnos. Si decides no dejar a LGM que comparta tu información con los investigadores de Tufts, puedes igualmente venir a LGM y participar en todas las actividades de LGM. Decidas lo que decidas, no habrá ningún cambio en lo que tanto tú como tu familia reciben de LGM.

Antes de decir "si" o "no", podemos contestar cualquier pregunta que tengas. Si dices que "si" y participas en el estudio, también puedes hacer preguntas. Tú o tus padres podéis contactar con Dan Hatfield, persona a cargo de este estudio, llamando por teléfono al (703) 795-8454. Si tienes preguntas sobre cualquier cosa que ocurra durante el estudio, hay una oficina especial en la Universidad de Tufts que se llama el Institutional Review Board (Comité de revisión institucional) que te escuchará y contestará tus preguntas. Tus padres tienen el número de teléfono de esta oficina y te pueden ayudar a contactar con ellos.

Firmar con tu nombre significa que estás de acuerdo en participar en este estudio.

____
Nombre entero del niño

________________________________ ____________________
Firma del niño **Fecha**

For office use only
I certify that I have explained fully to the above subject the nature and purpose, procedures, and the possible risks and benefits of this research study.

____ ______________
Signature of researcher or designate *Date*

Appendix 2.B. Parent demographic questionnaire

Demographic Questionnaire

Please answer the following questions about your child who is participating in LGM:

1. What is your child's date of birth? Month_______ Day_______ Year________

2. In what country was your child born? ______________________________________

3. Is your child Latino / Hispanic?

   ☐ Yes

   ☐ No

4. What is your child's race? Please check all that apply.

   ☐ White

   ☐ Black / African American

   ☐ American Indian or Alaska Native

   ☐ Asian

   ☐ Native Hawaiian / Pacific Islander

   ☐ Unknown

   ☐ Other

5. What is your child's sex?

   ☐ Male

   ☐ Female

6a. If your child is **female**: Has your daughter begun to menstruate (started to have her period)?

   ☐ Yes

   ☐ No

6b. If your child is **male**: Have you noticed a deepening of your son's voice?

   ☐ voice has not yet started changing

   ☐ voice has barely started changing

   ☐ voice changes are definitely underway

   ☐ voice changes seem complete

   ☐ I don't know

Please answer the following questions about your household:

1. Including you, how many total people live in your household? ____________People

   Of these, how many are under the age of 18?___________ Children

2. What is your **weekly** household income level?

   - ☐ $0 - $50 per week
   - ☐ $50-$100
   - ☐ $100 - $200
   - ☐ $200 - $300
   - ☐ $300 - $400
   - ☐ $400 - $500
   - ☐ $500 - $600
   - ☐ $600 - $700
   - ☐ $700 - $800
   - ☐ $800 - $900
   - ☐ $900 - $1000
   - ☐ $1000 and- UP

OR

3. What is your **annual** household income?

   - ☐ $15,000 or less
   - ☐ $15,000-$30,000
   - ☐ $30,000-$45,000
   - ☐ $45,000-$60,000
   - ☐ $60,000-$75,000
   - ☐ more than $75,000

4. Does anyone in your household receive assistance from any of these sources? Please check all that apply.

   - ☐ Free/Reduced-price school breakfast or lunch
   - ☐ WIC (Women, Infants & Children)
   - ☐ Food Stamps/Supplemental Nutrition Assistance Program (SNAP)
   - ☐ None

Please answer the following questions about LGM participant's mother:

1. In what country was the child's mother born? ________________________________

2. What is the mother's height and weight?

   Mother's Height __________________ Mother's Weight __________________

3. What is the highest level of education / schooling the child's mother has completed?
   - ☐ Less than 8th grade
   - ☐ 8th grade or more, but less than high school
   - ☐ High school graduate (finished 12th grade) or GED
   - ☐ Post high school trade or technical school
   - ☐ 1-3 years of college (including 2-year college degrees)
   - ☐ College graduate or more

Cuestionario Demográfico

Por favor responda a las siguientes preguntas sobre su hijo, participante en el estudio:

1. ¿Cual es la fecha de nacimiento de su hijo/a?

   Mes _____/Día_____/Año______

2. ¿En qué país nació su hijo/a? ________________________________

3. ¿Es su hijo/a Latino/Hispano?

   ☐ Si
   ☐ No

4. ¿De qué raza es su hijo/a? Por favor marque todas las opciones que procedan.

   ☐ Blanco
   ☐ Negro / Afroamericano
   ☐ Nativo Americano o Nativo de Alaska
   ☐ Asiático
   ☐ Nativo de Hawai o de otra Isla del Pacífico
   ☐ Desconocida
   ☐ Otra

5. ¿Cual es el sexo de su hijo/a?

   ☐ Masculino
   ☐ Femenino

6a. Si su hija es **mujer**: ¿Ha comenzado con la menstruación (ha comenzado su periodo)?

   ☐ Si
   ☐ No

6b. Si su hijo es **hombre**: ¿Ha observado un tono más grave en su voz?

   ☐ la voz no ha empezado a cambiar
   ☐ la voz apenas ha empezado a cambiar
   ☐ los cambios en la voz han comenzado definitivamente
   ☐ los cambios en la voz parece que han terminado
   ☐ No lo se

Por favor responda a las siguientes preguntas sobre su hogar:

1. Incluyéndose a usted, ¿cuántas personas viven en su casa? ____________Personas

   De estas personas, ¿cuántas tienen menos de 18 años de edad? ___________ Niños

2. ¿Cual es el nivel de ingresos **semanal** de su casa?

   - ☐ $0 - $50 por semana
   - ☐ $50-$100
   - ☐ $100 - $200
   - ☐ $200 - $300
   - ☐ $300 - $400
   - ☐ $400 - $500
   - ☐ $500 - $600
   - ☐ $600 - $700
   - ☐ $700 - $800
   - ☐ $800 - $900
   - ☐ $900 - $1000
   - ☐ $1000 ó- MAS

O

3. ¿Cuales son los ingresos **anuales** en su casa/hogar?

   - ☐ $15,000 o menos
   - ☐ $15,000-$30,000
   - ☐ $30,000-$45,000
   - ☐ $45,000-$60,000
   - ☐ $60,000-$75,000
   - ☐ más de $75,000

4. ¿Recibe alguien en su casa asistencia de alguno de estos programas? Marque por favor todos los que procedan.

   - ☐ Desayuno o comida/lunch de la escuela gratuita o a precios reducidos
   - ☐ WIC (Mujeres, Bebés & Niños)
   - ☐ Estampas de comida. Programa suplementario de asistencia nutricional (SNAP).
   - ☐ Ninguno

<u>Por favor responda a las siguientes preguntas sobre la madre del participante de LGM:</u>

1. ¿En qué país nació la madre del niño/a? ______________________________

2. ¿Cual es la estatura y peso de la madre?

   Estatura de la madre _________________ Peso de la madre _________________

3. ¿Cuál es el nivel de educación <u>más alto</u> / estudios que la madre del niño/a ha realizado?
   - ☐ Menos del grado 8
   - ☐ Grado 8 o más, pero menos que escuela secundaria (High School)
   - ☐ Graduado de la escuela secundaria (terminó el grado 12) o GED
   - ☐ Instituto profesional después de secundaria o escuela técnica
   - ☐ De 1 a 3 años de universidad (incluye títulos de 2 años de universidad)
   - ☐ Graduado universitario o más

Appendix 2.C. PACER data-collection sheet

FITNESSGRAM

The PACER Group Score Sheet

Teacher ______________________________ Class period __________ Date ______________

Lap = one 20-meter length

Level	Laps													
1	1	2	3	4	5	6	7							
2	8	9	10	11	12	13	14	15						
3	16	17	18	19	20	21	22	23						
4	24	25	26	27	28	29	30	31	32					
5	33	34	35	36	37	38	39	40	41					
6	42	43	44	45	46	47	48	49	50	51				
7	52	53	54	55	56	57	58	59	60	61				
8	62	63	64	65	66	67	68	69	70	71	72			
9	73	74	75	76	77	78	79	80	81	82	83			
10	84	85	86	87	88	89	90	91	92	93	94			
11	95	96	97	98	99	100	101	102	103	104	105	106		
12	107	108	109	110	111	112	113	114	115	116	117	118		
13	119	120	121	122	123	124	125	126	127	128	129	130	131	
14	132	133	134	135	136	137	138	139	140	141	142	143	144	
15	145	146	147	148	149	150	151	152	153	154	155	156	157	

Lane	Student name	Laps completed	Lane	Student name	Laps completed

FIGURE B.8

From *FITNESSGRAM/ACTIVITYGRAM Test Administration Manual, Updated Fourth Edition* by The Cooper Institute, 2010, Champaign, IL: Human Kinetics.

Appendix 2.D. Anthropometric data-collection sheet

HEIGHT AND WEIGHT DATA COLLECTION SHEET

Today's Date: _____ / _____ / 20___

Child's name: ____

I. HEIGHT MEASUREMENT
- Must have at least THREE measurements
- The three readings should be all within 1/8 inch of each other (round up)

1st measurement: _______ ___ / 8

2nd measurement: _______ ___ / 8

3rd measurement: _______ ___ / 8

4th measurement: _______ ___ / 8

5th measurement: _______ ___ / 8

6th measurement: _______ ___ / 8

Recorder's Name: ________________

NOTES

If the hairstyle affects the height measurement … use a plastic ruler to estimate how much is contributed by the hairstyle to the nearest half an inch:

______.____ inch

II. WEIGHT MEASUREMENT
- Must have at least THREE measurements
- The three readings should be all within 0.5 lb of each other

1st measurement: ______.___

2nd measurement: ______.___

3rd measurement: ______.___

4th measurement: ______.___

5th measurement: ______.___

6th measurement: ______.___

Recorder's Name: ________________

III. WAIST CIRCUMFERENCE MEASUREMENT
- Must have at least THREE measurements
- The three readings should be all 0.1 cm of each other (round up)

1st measurement: ______.___

2nd measurement: ______.___

3rd measurement: ______.___

4th measurement: ______.___

5th measurement: ______.___

6th measurement: ______.___

Recorder's Name: ________________

Appendix 2.E. Child Survey

Name: ____

Part 1:

What Do You Eat and Drink?

In this section, we are trying to find out about things you ate or drank in the ***last month***. This includes what you had for breakfast, lunch, dinner, after school, while watching TV, at bedtime, and on the weekend.

This is ***not a test.*** There are no right or wrong answers.

Please answer all the questions as honestly as you can.

1. In the past month, how often did you eat three meals per day?
   - ☐ Never
   - ☐ Sometimes
   - ☐ Often
2. In the past month, how often did you eat fruit?
   - ☐ Never
   - ☐ Sometimes
   - ☐ Often
3. In the past month, how often did you eat vegetables?
   - ☐ Never
   - ☐ Sometimes
   - ☐ Often
4. Do you sometimes eat an extra meal, a snack, a bowl of cereal, or "seconds"?
   - ☐ Yes
   - ☐ No
5. In the past month, how often did you drink juice at home (like apple or orange)?
   - ☐ Never or less than once per week
   - ☐ Several times a week
   - ☐ Once a day
   - ☐ Twice or more a day
6. In the past month, how often did you drink other drinks at home? (like iced tea, lemonade, fruit punch, Kool- Aid, Capri Sun, Sunny Delight, Snapple, Gatorade, Vitamin Water)
   - ☐ Never or less than once per week
   - ☐ Several times a week
   - ☐ Once a day
   - ☐ Twice or more a day
7. In the past month, how often did you drink soda?
   - ☐ Never or less than once per week
   - ☐ Several times a week
   - ☐ Once a day
   - ☐ Twice or more a day
8. What kind of soda did you drink?
   - ☐ Diet
   - ☐ Regular
   - ☐ Both
   - ☐ None

9. In the past month, how often did you drink milk or other milk products?
    - ☐ Never or less than once per week
    - ☐ Several times a week
    - ☐ Once a day
    - ☐ Twice or more a day
10. What kind of milk did you drink?
    - ☐ Whole
    - ☐ Low fat (2%)
    - ☐ Low fat (1%)
    - ☐ Skim
11. In the past month, how many times did you drink water?
    - ☐ Never or less than once per week
    - ☐ Several times a week
    - ☐ Once a day
    - ☐ Twice or more a day
12. In the past month, how many times did you eat a fast food meal? (pizza, Chinese, hamburgers, fried chicken)?
    - ☐ Never
    - ☐ Once a week
    - ☐ Twice or more a week
13. In the past month, how many times did you eat junk food (candy bars, potato chips, cookies)?
    - ☐ Never or less than once per week
    - ☐ Several times a week
    - ☐ Once a day
    - ☐ Twice or more a day
14. Do you own a measuring cup?
    - ☐ Yes
    - ☐ No
15. Do you use a measuring cup to portion your meals?
    - ☐ Yes
    - ☐ No

PLEASE STOP HERE!

Part 2:

What Kinds of Physical Activity Do You Do?

In this section, we are trying to find out about your level of physical activity in the ***last 7 days.*** This includes sports or dance that make you sweat or make you feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

This is ***not a test.*** There are no right or wrong answers.

Please answer all the questions as honestly as you can.

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping	O	O	O	O	O
Rowing/canoeing	O	O	O	O	O
In-line skating	O	O	O	O	O
Tag	O	O	O	O	O
Walking for exercise	O	O	O	O	O
Bicycling	O	O	O	O	O
Jogging or running	O	O	O	O	O
Aerobics	O	O	O	O	O
Swimming	O	O	O	O	O
Baseball, softball	O	O	O	O	O
Dance	O	O	O	O	O
Football	O	O	O	O	O
Badminton	O	O	O	O	O
Skateboarding	O	O	O	O	O
Soccer	O	O	O	O	O
Street hockey	O	O	O	O	O
Volleyball	O	O	O	O	O
Floor hockey	O	O	O	O	O
Basketball	O	O	O	O	O
Ice skating	O	O	O	O	O
Cross-country skiing	O	O	O	O	O
Ice hockey/ringette	O	O	O	O	O
Other:					
________________________	O	O	O	O	O
________________________	O	O	O	O	O

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

- I don't do PE .... O
- Hardly ever .... O
- Sometimes .... O
- Quite often .... O
- Always .... O

3. In the last 7 days, what did you do most of the time *at recess*? (Check one only.)

- Sat down (talking, reading, doing schoolwork)...... O
- Stood around or walked around .... O
- Ran or played a little bit .... O
- Ran around and played quite a bit .... O
- Ran and played hard most of the time .... O

4. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork)…....❍
Stood around or walked around ....❍
Ran or played a little bit ....❍
Ran around and played quite a bit ....❍
Ran and played hard most of the time ....❍

5. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

None ....❍
1 time last week ....❍
2 or 3 times last week ....❍
4 times last week ....❍
5 times last week ....❍

6. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

None ....❍
1 time last week ....❍
2 or 3 times last week ....❍
4 or 5 last week ....❍
6 or 7 times last week ....❍

7. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None ....❍
1 time ....❍
2 — 3 times ....❍
4 — 5 times ....❍
6 or more times ....❍

8. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

A. All or most of my free time was spent doing things that involve little physical effort ....❍

B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ....❍

C. I often (3 — 4 times last week) did physical things in my free time ....❍

D. I quite often (5 — 6 times last week) did physical things in my free time ....❍

E. I very often (7 or more times last week) did physical things in my free time ....❍

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday	❍	❍	❍	❍	❍
Tuesday	❍	❍	❍	❍	❍
Wednesday	❍	❍	❍	❍	❍
Thursday	❍	❍	❍	❍	❍
Friday	❍	❍	❍	❍	❍
Saturday	❍	❍	❍	❍	❍
Sunday	❍	❍	❍	❍	❍

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes ....❍
No ....❍

If Yes, what prevented you? ________________________________

PLEASE STOP HERE!

Part 3:

What Kind of Kid Are You?

The next section has pairs of sentences talking about two kinds of kids. We'd like you to decide whether you are more like the kids on the left side, or more like the kids on the right side.

Then we would like you to decide whether that is only sort of true for you or really true for you and mark your answer.

Fill in only one circle for each pair of sentences.

Example:

	Really true for me	Sort of true for me				Sort of true for me	Really true for me	C
1.	O	O	Some kids would rather play outdoors in their spare time.	BUT	Other kids would rather watch T.V.	O	O	Cf-sw2

Remember:

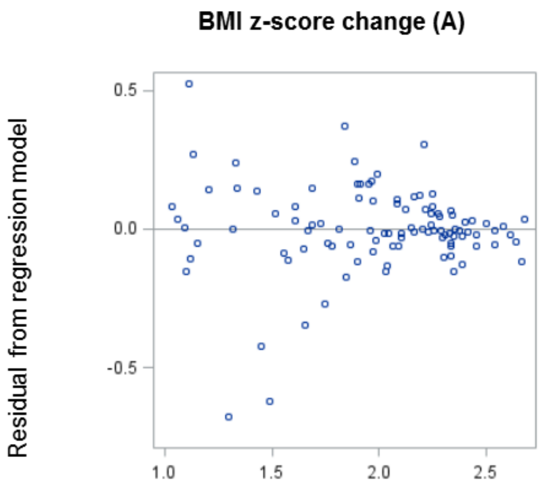
This is ***not a test.*** There are no right or wrong answers.

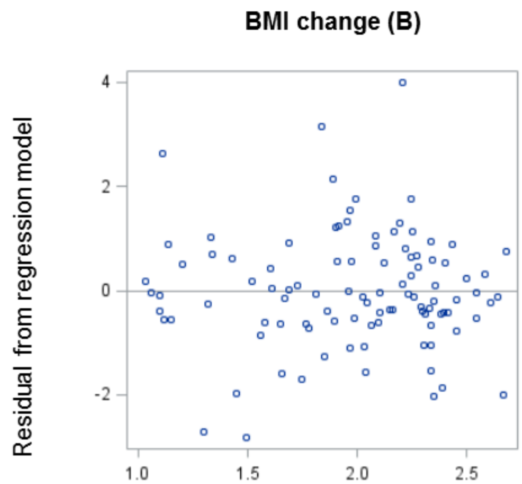
Please answer all the questions as honestly as you can.

	Really true for me	Sort of true for me				Sort of true for me	Really true for me	C
1.	O	O	Some kids often get *mad* at themselves.	BUT	Other kids are pretty *pleased* with themselves.	O	O	Cf-sw2
2.	O	O	Some kids do very *well* at all kinds of sports	BUT	Others *don't* feel that they are very good when it comes to sports	O	O	Cm-pc2
3.	O	O	Some kids don't like the way they are leading their life.	BUT	Other kids do like the way they are leading their life.	O	O	Cf-sw2
4.	O	O	Some kids think they could do well at just about any new outdoor activity they haven't tried before.	BUT	Other kids are afraid they might not do well at outdoor things they haven't ever tried.	O	O	Cm-pc2
5.	O	O	Some kids are happy with themselves most of the time.	BUT	Other kids are often not happy with themselves.	O	O	Cf-sw2
6.	O	O	Some kids feel that they are better than others their age at sports.	BUT	Other kids don't feel they can play as well.	O	O	Cm-pc2
7.	O	O	Some kids like the kind of person they are.	BUT	Other kids often wish they were someone else.	O	O	Cf-sw2
8.	O	O	Some kids are very happy being the way they are.	BUT	Other kids wish they were different.	O	O	Cf-sw2
9.	O	O	Some kids *don't* do well at new outdoor games.	BUT	Other kids are good at new games right away.	O	O	Cm-pc2
10.	O	O	Some kids *aren't* very happy with the way they do a lot of things.	BUT	Other kids think the way they do things is fine.	O	O	Cf-sw2
11.	O	O	In games and sports, some kids usually watch instead of play.	BUT	Other kids usually play rather than just watch.	O	O	Cm-pc2
12.	O	O	Some kids wish they could be a lot better at sports.	BUT	Other kids feel they are good enough at sports.	O	O	Cm-pc2

Appendix 3: Supplementary Let's Get Movin' analyses

Appendix 3.A. Results of models regressing baseline-to-final changes in BMI z-score (Model A) and BMI (Model B) on baseline BMI z-score and time: residuals plotted against baseline BMI z-score (n=101)





Appendix 3.B. Comparison baseline-to-final anthropometric changes in individual children who were similar in most respects but different in terms of baseline adiposity

	Child A: 9-year-old boy Overweight (87th %ile) at baseline	**Child B: 9-year-old boy Very obese (99.6th %ile) at baseline**
Time between measures	226 days	242 days
Weight change	+0.9 kg (39.5 to 40.4)	-0.03 kg (60.6 to 60.6)
Height change	+2.4 cm (141.9 to 144.4)	+3.9 cm (129.8 to 133.5)
BMI change	-0.2 (19.6 to 19.4)	-1.5 (28.9 to 27.4)
z-score change	-0.19 (1.12 to 0.92)	-0.17 (2.64 to 2.56)

Compared with Child A, Child B has substantially greater decrease in BMI but a slightly smaller decrease in BMI z-score.

	Child C: 8-year-old girl Obese (95th %ile)	**Child D: 9-year-old girl Very obese (99.6th %ile)**
Time between measures	247 days	245 days
Weight change	-0.3 kg (40.4 to 40.1)	+0.4 kg (63.9 to 64.3)
Height change	+3.7 cm (138.3 to 142.0)	+3.9 cm (137.3 to 141.2)
BMI change	-1.22 (21.1 to 19.9)	-1.65 (33.9 to 32.3)
z-score change	-0.42 (1.65 to 1.24)	-0.15 (2.66 to 2.51)

Compared with Child C, Child D has slightly greater decrease in BMI but a nearly 3-fold smaller decrease in BMI z-score.

	Child E: 8-year-old girl Overweight (87th %ile)	**Child F: 8-year-old boy Very obese (99.2th %ile)**
Time between measures	229 days	238 days
Weight change	+6.0 kg (34.4 to 40.4)	+6.3 kg (48.6 to 54.9)
Height change	+6.7 cm (134.6 to 141.4)	+5.3 cm (136.7 to 142.0)
BMI change	+1.2 (18.9 to 20.2)	+1.2 (26.0 to 27.2)
z-score change	+0.18 (1.13 to 1.31)	-0.01 (2.43 to 2.42)

Both children have an increase in BMI that is greater than typical for children this age. Child E shows a substantial increase in BMI z-score, but Child F (who started out in the far right tail of the BMI distribution) has nearly no change in BMI z-score, despite gaining about 14 pounds over 8 months.

Appendix 3.C. Results of analyses of within-subject standard deviations (SD) of baseline/final BMI and BMI z-score measurements among subjects with at least 200 days between measurements (n=63)

SDs of BMI z-scores were:	**SDs of BMI were:**
• Higher (borderline significant) in overweight v. obese children (0.36 v. 0.26), p = 0.056 for independent-samples t-test	• Not significantly different in overweight vs. obese children (0.77 v. 0.77), p = 0.94 for independent-samples t-test
• Significantly correlated with baseline BMI z-score (Pearson's r=-0.392, p=0.002)	• Not significantly correlated with baseline BMI z-score (Pearson's r=-0.039, p=0.76)

Appendix 3.D. Pre/post changes in waist-to-height ratio, perceived athletic competence, and global self-worth

	Baseline	Final	p-value
BMI-z score	1.98 (0.42)	1.93 (0.47)	**0.001**
Waist-to-height ratio[a]	0.597 (0.059)	0.592 (0.059)	**0.02**
Perceived athletic competence[b]	2.72 (0.62)	2.73 (0.70)	0.86
Global self-worth[b]	3.12 (0.63)	3.11 (0.67)	0.84

p-values are for paired t-tests
[a]Interpretation note: a cutoff of 0.5 is commonly used as a cut-point for central obesity
[b]Based on domain-level questions from the Harter Self-Perception Profile for Children; range: 1-4, with higher scores indicating higher esteem