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Commentary

Increasing physical activity among children and adolescents: Innovative ideas needed

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1. Introduction

For anyone paying attention, this is a disruptive time in science in general and in health promotion science in particular. Obesity is the most prevalent nutrition-related health problem around the globe.[1] The issue of whether, as is commonly thought, obesity is causative of early mortality[2] or whether it is only a marker of risk[3,4] has been raised. The lack of substantial and maintained change in child obesity prevention has been recognized,[5] and numerous limitations in our conceptual and methodological approach to obesity prevention have been identified.[6] The simple energy balance biological model upon which most obesity prevention programs have been predicated has been declared invalid,[7,8] with a multi-etiological model thought to be more appropriate.[9]

Physical activity (PA) is considered an important health-related behavior, which may be related to obesity.[10] Higher levels of PA have been associated with longer life;[11] a lower risk of cardiovascular disease;[12] lower levels of several cancers,[13] stroke,[14] and diabetes;[15] a higher quality of life;[16] better mental health;[17] higher cognitive functioning;[18] and numerous other positive health outcomes. Thus, if the citizens of all nations had optimal levels of PA throughout their adult lives, they would live to be older, healthier, happier, more sentient, make fewer demands on the health care system, and likely be more productive,[19] a state of affairs desired by many citizens, their employers, and their governments.

Regular PA is essentially a habit,[20] believed to begin in childhood. Children tend to have higher levels of PA at younger ages, but these behaviors decrease as they age.[21] Thus, there has been substantial interest in PA among children, even the youngest, to document existing levels and understand the influences on these levels of activity (positive and negative).[22] Based on this knowledge, interventions can be designed to promote and maintain optimal levels of PA throughout childhood and adolescence[23,24] for carryover into the adult years.

2. Overview of articles

The 5 articles in the December 2017 issue of the *Journal of Sport and Health Science* provide a panoramic portrait of PA among children in China based on the 2016 Physical Activity and Fitness in China–The Youth Study. No existing study has reported on the levels and correlates of PA in children using such large samples. Large samples are important to have confidence in the mean values and stability of the relationships detected.

3. Chinese children's level of PA and fitness

Using a validated 7-day retrospective PA recall (average minutes of moderate and of vigorous activity per active day and number of active days in the last 7 days), Fan and Cao[25] reported an average of 45.4 min per day among 90,712 primary (Grades 4–6), junior middle (Grades 7–9), and junior high (Grades 10–12) school students (9–17 years of age). As found in other studies, boys ($\bar{x} = 47.2$ min) were somewhat more active than girls ($\bar{x} = 43.7$ min), and activity decreased from primary ($\bar{x} = 49.2$ min) to junior middle ($\bar{x} = 47.7$ min) to junior high schools ($\bar{x} = 39.9$ min). Only about 29.9% of the children met the national PA guidelines of 60 min/day (or more). As with the average minutes, a greater proportion of boys ($\bar{x} = 31.8\%$) met the recommendation than girls ($\bar{x} = 28.2\%$), and the percentages decreased as grade level advanced.

Fitness (cardiovascular and strength) is primarily a function of PA among adults, but has a stronger physiologic component among children.[26] Using the 2014 revised Chinese National Student Physical Fitness Standard battery among 171,991 children and adolescents, Zhu et al.[27] reported that only 5.95% received a cumulative score of excellent and 8.53% received a no pass rating (i.e., less than minimally acceptable, the lowest possible category). Paralleling the PA findings, boys ($\bar{x} = 8.26\%$) were more likely to receive an excellent rating than girls ($\bar{x} = 7.51\%$), but also, surprisingly, more likely ($\bar{x} = 8.11\%$) to receive a no pass rating than girls ($\bar{x} = 5.45\%$). Excellent ratings decreased precipitously with grade (primary = 7.89%; junior middle = 3.65%; junior high = 2.00%), and a nonlinear pattern was detected across grades for the

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no pass rating (primary = 6.78%; junior middle = 11.45%; junior high = 9.32%).

These first 2 studies, consistent with findings around the world,[28] document that most Chinese children are getting less activity than specified by guidelines, and, as a result, are not as physically fit as would be desired. Although it is not clear how much PA is needed to attain the aforementioned PA levels for optimal health and productivity, the levels needed to maximize health benefits tend to be much higher than 60 min of any PA per day. A recent meta-analysis of 18 meta-analyses[29] of controlled studies of PA (without a dietary change component) showed that PA had the desired effects on diverse aspects of body composition, cardiovascular disease risks, and fitness among overweight and obese children and adolescents. Most health-related changes, however, were obtained with much more PA (e.g., > 1500 min per intervention). Such controlled PA interventions tend not to be conducted with healthy, normal weight children, so the amount of PA necessary to prevent obesity is not clearly known.

4. Chinese children's screen media use and obesity status

Using measured height and weight to calculate body mass index (BMI) and responses to 3 questions about hours per day in the last week spent watching television and using mobile devices and computers, Cai et al.[30] reported on the obesity status and percentage of 116,615 children (9−17 years old) meeting screen time recommendations (i.e., $\leq$2 h/day). Approximately 14.4% of the children were overweight and 11.9% were obese, and 36.8% of the children exceeded the 2 h/day or less of screen media use. In contrast with the PA findings, obesity was more prevalent among boys than among girls in all 3 school grade groups, even after controlling for possibly confounding factors. Children living in urban areas were more likely to be obese in all 3 school grade groups. Boys were less likely to meet the screen media use guideline in primary and junior middle schools, but not in junior high schools. It was not reported whether children who met the screen media use guideline were less likely to be overweight or obese.

These data also reflect global patterns of increasing obesity and screen media use[31] among children and adolescents. A pooled analysis of 10 studies (among adults) revealed that reallocating 30 min of sedentary time with 30 min of even light PA resulted in improvement in waist circumference, fasting insulin, high-density lipoprotein cholesterol, and all-cause mortality;[32] reallocating 30 min of sedentary time with 30 min of moderate-to-vigorous PA (MVPA) had even more of the same health outcomes plus a desirable effect on BMI. Thus, there would be substantial health benefits to increasing PA among Chinese children.

5. Determinants of obesity among Chinese students

Increasing PA is usually attempted by identifying malleable correlates, preferably causal determinants, of PA and designing programs to change them. Interventions with families have been a particular interest to increase PA among children. Using parental responses to a 6-item questionnaire about parental support for their child's PA (encouragement, accompaniment, financial support, involvement, knowledge sharing, and role modeling; Cronbach $\alpha = 0.82$), Liu et al.[33] reported on the relationship of parental support to the level of PA among 81,857 school-aged children using structural equation modeling. Although the Cronbach α indicated these items were not independent, the authors analyzed the relationship of each item to PA separately within a structural equation model. The standardized coefficients were small, but significant, for 5 of the 6 items (not for parental knowledge sharing), indicating that parents do influence child PA, but perhaps not as much as thought. An early review of 35 family-based PA change programs tentatively suggested that more intense interventions (i.e., involving parents in organized sessions) might increase PA among children.[34] A somewhat more recent review of 35 studies found "limited evidence for the effectiveness of parental interventions".[35] The most recent meta-analysis of 47 studies detected a weak effect (Hedge's $g = 0.29$) from family-based interventions, especially when targeting family constraints, ethnicity, and parental motivation, using goal setting and reinforcement. Thus, family-based interventions, which would seem to be the most efficacious approach to increasing child PA, do not promise substantial long-lasting effects, perhaps because the relationships of family support to child PA are weak.[36]

6. Environmental correlates of Chinese students' PA

The limited or lack of effectiveness of obesity prevention programs focused on child behavior has encouraged some to call for approaches involving environmental change.[37] Wang et al.[38] used a physical education (PE) teacher completed 10-item, 4-subscale measure (principal support of PE, availability of PE facilities, access to school PE facilities, and number of minutes of school PE per week) of school support for PA, a student-completed 4-item questionnaire on neighborhood PA resources, and a student-completed 1 item on attitude to PA and 1 item on perceived academic burden. They reported the relationships of these variables to child-reported MVPA (4-item scale from the International Physical Activity Questionnaire) among 80,928 school children from 935 schools using multilevel path modeling. At the school level only, school support for PA was weakly but significantly positively related to student MVPA. At the student level, attitude, academic burden, frequency of sporting events, availability of sports clubs, and convenient access to PA facilities, but not free skill training, were weakly, but significantly, positively related to student MVPA. Perhaps more innovative analytic techniques (e.g., deep learning from artificial intelligence) are needed to better identify aspects of the environment that influence PA.[39]

Many variables have been demonstrated to be correlated with PA among children and adolescents,[22] and thereby may provide leverage to increase child PA. Most of these correlations, however, have generally been weak or inconsistent across studies,[22] and correlation does not mean causation. If one variable is not causally related to a second variable, then extensively changing the first variable will have no effect on the second variable, no matter how much we would like it to change.[6] Some correlates cannot be changed by our usual interventions and therefore need to be stratifying or tailoring factors. For example, socioeconomic status has been consistently related to behavior. Children who were poor early in life, either chronically or before later upward mobility, were more likely to be obese as adults than were other children (poor later in life but not earlier and consistently well-off categories).[40] This finding suggests that programs aimed at changing PA should be targeted at poor children, especially in the first 5 years of life. Another study among Chinese children revealed a significant interaction term between household wealth and the father's educational level, but not the mother's, with BMI,[41] suggesting that interventions should target lower income families with less well-educated fathers. Aspects of the physical environment, and change in that environment, have been related to higher PA.[42] The relationships of environmental variables to PA have generally been weak and at times confusing.[43]

7. What might be done to increase Chinese children's level of PA?

Interventions to increase PA among children have generally had weak or no effects, resulting on average in only 4 more minutes of any activity per day.[44] Unstructured active play also demonstrated no increase in MVPA.[45] Many of these interventions, however, have not been based on or guided by theories of behavior, which would be expected to enhance the effectiveness of the intervention. Some types of social cognitive theory have been frequently used as behavioral approaches to guide the design of PA change programs.[46,47] Self-efficacy (i.e., the confidence that one can do a behavior), which is a social cognitive theory construct, has been consistently shown to mediate PA change.[48] Self-determination theory, which is more concerned with the motivation to do a behavior, has also been frequently used in regard to PA.[49] More autonomous forms of motivation (e.g., intrinsic motivation, which involves doing a behavior because you enjoy it, and identified regulation, in which the outcomes of the behavior are perceived as personally valuable) have been positively associated with PA among children and adolescents.[49] A form of intrinsic motivation is fun,[50] which is often associated with playing games. Although simply providing active videogames to a child for playing at home does not increase the child's PA,[51] active videogames have been used in large programs and have increased child PA[52] and fitness.[53] Research is needed both on how to make PA change programs fun and how to make the actual PA fun, and active videogames may provide an approach for doing so. For example, embedding PA within an overarching story may increase immersion in the story[54] and thus increase the fun associated with doing the behavior.

A possible (likely?) problem with current PA interventions among children and adolescents is that everyone gets the same intervention (i.e., one size fits all).[55] Different people likely engage in PA for different reasons. For example, we know that the correlates of PA among children are largely different than the correlates of PA among adolescents.[22] The dominant patterns of PA among females (e.g., organized sports, dance, walk/run) differ from those among males (leisure active gym, leisure active individual sport).[56] Thus, causal relationships to PA must be identified specific to a target group of interest. Different people consider different activities to be fun.[57] There has been some public interest in a recent active videogame, Pokémon Go, an augmented reality game (i.e., fictitious elements superimposed on video images of the real world using smartphones).[58] Pokémon Go substantially increased PA[59] among players for up to 1 week after they started playing the game. In 2 different studies,[60] enjoyment of playing Pokémon Go was a primary predictor of PA. Although personality characteristics did not predict the total distance that players walked when playing Pokémon Go, agreeableness, perseverance, and premeditation predicted their duration of play over 6 months.[61] Further research is needed on individual characteristics that predispose some players to play such a game, as well as the characteristics of the game that help to maintain intensive game playing beyond the initial week.

Some studies have shown that people who increase their activity as part of an intervention decrease their nonexercise PA or nonexercise activity thermogenesis later in the day.[62] One study using adult participants revealed that those who changed from an inactive to an active occupation decreased their activity (in comparison with a stable employment group), whereas those who changed from an active to an inactive occupation increased their activity.[63] Thus, increasing PA with an intervention may be a biologically self-defeating endeavor. Obesity has been proposed as having multiple etiologies, other than the simple energy balance model.[9] Perhaps PA is also governed by complex biological influences (and not just psychosocial or behavioral influences). For example, 226 unique candidate biomarkers of PA have been identified in the urine[64] and in serum.[65,66] Research is needed on the possible ways in which these biomarkers lead to more, place limits on, or simply reflect PA.

8. Limitations

All studies have limitations. The 5 studies with Chinese children reported in the December 2017 issue of the *Journal of Sport and Health Science* all involved cross-sectional analyses, thereby precluding causal inference from detected relationships. The large number of tests on a common data set increased the risk of type 1 statistical error (i.e., errors in detecting significant differences or relationships that are not truly different or related). Although admirable from many perspectives, very large samples increase the likelihood of detecting substantially significant but small (weak) effects. As recognized by the authors, it is unfortunate that these data relied on self-reported rather than objectively assessed PA, but more objective measures may not have been feasible when obtained from so many children in a short period of time. Because these were mostly self-reported variables (except for BMI and fitness), we cannot be sure how much of the detected relationships can be accounted for by errors common to both variables (e.g., social desirability and positive response biases), because they were often reported by the same person.[67] Recently, there has been substantial interest in seasonal differences in adiposity accretion (higher obesity during the summer than during the school year)[68] and in whether these differences might be due to different behaviors (e.g., PA) related to energy balance.[68] Unfortunately, the data from China were collected in 1 season, which precludes our ability to address this puzzling and important issue.

9. Conclusion

The 5 studies from China provide an important country-wide baseline assessment of PA, fitness, BMI, and related variables among children. Innovative approaches need to be conceptualized, designed, and tested to capitalize on this baseline assessment and promote the health of Chinese children who are on their paths to becoming adults.

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Competing interests

The author declares that he has no competing interests.

References

1. Mitchell NS, Catenacci VA, Wyatt HR, Hill JO. Obesity: overview of an epidemic. *Psychiatr Clin North Am* 2011;**34**:717–32.
2. Nyberg ST, Batty GD, Pentti J, Virtanen M, Alfredsson L, Fransson EI, et al. Obesity and loss of disease-free years owing to major non-communicable diseases: a multicohort study. *Lancet Public Health* 2018;**3**:490–7.
3. Hernan MA, Taubman SL. Does obesity shorten life? The importance of well-defined interventions to answer causal questions. *Int J Obes (Lond)* 2008;**32**:(Suppl. 3):S8–14.
4. Chiolero A. Why causality, and not prediction, should guide obesity prevention policy. *Lancet Public Health* 2018;**3**:e461–2.
5. Waters E, de Silva-Sanigorski A, Hall BJ, Brown T, Campbell KJ, Gao Y, et al. Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2011;(12):CD001871. doi:10.1002/14651858.CD001871.pub3.
6. Baranowski T, Lytle L. Should the IDEFICS outcomes have been expected? *Obes Rev* 2015;**16**:(Suppl. 2):S162–72.
7. Ludwig DS, Ebbeling CB. The carbohydrate-insulin model of obesity: beyond "calories in, calories out". *JAMA Intern Med* 2018;**178**:1098–103.
8. Hall KD, Guyenet SJ, Leibel RL. The carbohydrate-insulin model of obesity is difficult to reconcile with current evidence. *JAMA Intern Med* 2018;**178**:1103–5.
9. Baranowski T, Motil KJ, Moreno JP. The need for different models of biological etiology upon which to predicate child obesity prevention efforts. *Curr Nutr Rep* 2018; [accepted article, in preparation].
10. Jimenez-Pavon D, Kelly J, Reilly JJ. Associations between objectively measured habitual physical activity and adiposity in children and adolescents: systematic review. *Int J Pediatr Obes* 2010;**5**:3–18.
11. Arem H, Moore SC, Patel A, Hartge P, Berrington de Gonzalez A, Visvanathan K, et al. Leisure time physical activity and mortality: a detailed pooled analysis of the dose-response relationship. *JAMA Intern Med* 2015;**175**:959–67.
12. Swift DL, McGee JE, Earnest CP, Carlisle E, Nygard M, Johannsen NM. The effects of exercise and physical activity on weight loss and maintenance. *Prog Cardiovasc Dis* 2018;**61**:206–13.
13. Brown JC, Winters-Stone K, Lee A, Schmitz KH. Cancer, physical activity, and exercise. *Compr Physiol* 2012;**2**:2775–809.
14. Middleton LE, Corbett D, Brooks D, Sage MD, Macintosh BJ, McIlroy WE, et al. Physical activity in the prevention of ischemic stroke and improvement of outcomes: a narrative review. *Neurosci Biobehav Rev* 2013;**37**:133–7.
15. Aune D, Norat T, Leitzmann M, Tonstad S, Vatten LJ. Physical activity and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis. *Eur J Epidemiol* 2015;**30**:529–42.
16. Vagetti GC, Barbosa Filho VC, Moreira NB, Oliveira V, Mazzardo O, Campos W. Association between physical activity and quality of life in the elderly: a systematic review, 2000-2012. *Rev Bras Psiquiatr* 2014;**36**: 76–88.
17. Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics* 2016;**138**: e20161642. doi:10.1542/peds.2016-1642.
18. Bidzan-Bluma I, Lipowska M. Physical activity and cognitive functioning of children: a systematic review. *Int J Environ Res Public Health* 2018;**15**:800. doi:10.3390/ijerph15040800.
19. White MI, Dionne CE, Warje O, Koehoorn M, Wagner SL, Schultz IZ, et al. Physical activity and exercise interventions in the workplace impacting work outcomes: a stakeholder-centered best evidence synthesis of systematic reviews. *Int J Occup Environ Med* 2016;**7**:61–74.
20. Gardner B, de Bruijn GJ, Lally P. A systematic review and meta-analysis of applications of the Self-Report Habit Index to nutrition and physical activity behaviours. *Ann Behav Med* 2011;**42**:174–87.
21. Reilly JJ. When does it all go wrong? Longitudinal studies of changes in moderate-to-vigorous-intensity physical activity across childhood and adolescence. *J Exerc Sci Fit* 2016;**14**:1–6.
22. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc* 2000;**32**:963–75.
23. Lakshman R, Mazarello Paes V, Hesketh K, O'Malley C, Moore H, Ong K, et al. Protocol for systematic reviews of determinants/correlates of obesity-related dietary and physical activity behaviors in young children (preschool 0 to 6 years): evidence mapping and syntheses. *Syst Rev* 2013;**2**:28. doi:10.1186/2046-4053-2-28.
24. MacMillan F, Kirk A, Mutrie N, Matthews L, Robertson K, Saunders DH. A systematic review of physical activity and sedentary behavior intervention studies in youth with type 1 diabetes: study characteristics, intervention design, and efficacy. *Pediatr Diabetes* 2014;**15**:175–89.
25. Fan X, Cao ZB. Physical activity among Chinese school-aged children: national prevalence estimates from the 2016 Physical Activity and Fitness in China—The Youth Study. *J Sport Health Sci* 2017;**6**:388–94.
26. Armstrong N. Aerobic fitness and physical activity in children. *Pediatr Exerc Sci* 2013;**25**:548–60.
27. Zhu Z, Yang Y, Kong Z, Zhang Y, Zhuang J. Prevalence of physical fitness in Chinese school-aged children: findings from the 2016 Physical Activity and Fitness in China—The Youth Study. *J Sport Health Sci* 2017;**6**:395–403.
28. Guthold R, Stevens GA, Riley LM, Bull FC. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. *Lancet Glob Health* 2018;**6**:e1077–86.
29. Garcia-Hermoso A, Ramirez-Velez R, Saavedra JM. Exercise, health outcomes, and paediatric obesity: a systematic review of meta-analyses. *J Sci Med Sport* 2018. doi:10.1016/j.jsams.2018.07.006. [Epub ahead of print].
30. Cai Y, Zhu X, Wu X. Overweight, obesity, and screen-time viewing among Chinese school-aged children: national prevalence estimates from the 2016 Physical Activity and Fitness in China—The Youth Study. *J Sport Health Sci* 2017;**6**:404–9.
31. Robinson TN, Banda JA, Hale L, Lu AS, Fleming-Milici F, Calvert SL, et al. Screen media exposure and obesity in children and adolescents. *Pediatrics* 2017;**140**:(Suppl. 2):S97–101.

32. Del Pozo-Cruz J, Garcia-Hermoso A, Alfonso-Rosa RM, Alvarez-Barbosa F, Owen N, Chastin S, et al. Replacing sedentary time: meta-analysis of objective-assessment studies. *Am J Prev Med* 2018;**55**:395–402.
33. Liu Y, Zhang Y, Chen S, Zhang J, Guo Z, Chen P. Associations between parental support for physical activity and moderate-to-vigorous physical activity among Chinese school children: a cross-sectional study. *J Sport Health Sci* 2017;**6**:410–5.
34. O'Connor TM, Jago R, Baranowski T. Engaging parents to increase youth physical activity: a systematic review. *Am J Prev Med* 2009;**37**: 141–9.
35. Kader M, Sundblom E, Elinder LS. Effectiveness of universal parental support interventions addressing children's dietary habits, physical activity and bodyweight: a systematic review. *Prev Med* 2015;**77**:52–67.
36. Xu H, Wen LM, Rissel C. Associations of parental influences with physical activity and screen time among young children: a systematic review. *J Obes* 2015;**2015**: 546925. doi:10.1155/2015/546925.
37. Weihrauch-Bluher S, Kromeyer-Hauschild K, Graf C, Widhalm K, Korsten-Reck U, Jodicke B, et al. Current guidelines for obesity prevention in childhood and adolescence. *Obes Facts* 2018;**11**:263–76.
38. Wang L, Tang Y, Luo J. School and community physical activity characteristics and moderate-to-vigorous physical activity among Chinese school-aged children: a multilevel path model analysis. *J Sport Health Sci* 2017;**6**:416–22.
39. Maharana A, Okanyene Nsoesie E. Use of deep learning to examine the association of the built environment with prevalence of neighborhood adult obesity. *JAMA Network Open* 2018;**1**: e181535. doi:10.1001/jamanetworkopen.2018.1535.
40. Li M, Mustillo S, Anderson J. Childhood poverty dynamics and adulthood overweight/obesity: unpacking the black box of childhood. *Soc Sci Res* 2018;**76**:92–104.
41. Liu Y, Ma Y, Jiang N, Song S, Fan Q, Wen D. Interaction between parental education and household wealth on children's obesity risk. *Int J Environ Res Public Health* 2018;**15**:1754. doi:10.3390/ijerph15081754.
42. Karmeniemi M, Lankila T, Ikaheimo T, Koivumaa-Honkanen H, Korpelainen R. The built environment as a determinant of physical activity: a systematic review of longitudinal studies and natural experiments. *Ann Behav Med* 2018;**52**:239–51.
43. Saelens BE, Glanz K, Frank LD, Couch SC, Zhou C, Colburn T, et al. Two-year changes in child weight status, diet, and activity by neighborhood nutrition and physical activity environment. *Obesity (Silver Spring)* 2018;**26**:1338–46.
44. 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 (EarlyBird 54). *BMJ* 2012;**345**: e5888. doi:10.1136/bmj.e5888.
45. Johnstone A, Hughes AR, Martin A, Reilly JJ. Utilising active play interventions to promote physical activity and improve fundamental movement skills in children: a systematic review and meta-analysis. *BMC Public Health* 2018;**18**:789. doi:10.1186/s12889-018-5687-z.
46. Plotnikoff RC, Costigan SA, Karunamuni N, Lubans DR. Social cognitive theories used to explain physical activity behavior in adolescents: a systematic review and meta-analysis. *Prev Med* 2013;**56**:245–53.
47. Prestwich A, Sniehotta FF, Whittington C, Dombrowski SU, Rogers L, Michie S. Does theory influence the effectiveness of health behavior interventions? Meta-analysis. *Health Psychol* 2014;**33**:465–74.
48. Dishman RK, Dowda M, McIver KL, Saunders RP, Pate RR. Naturally-occurring changes in social-cognitive factors modify change in physical activity during early adolescence. *PLoS One* 2017;**12**: e0172040. doi:10.1371/journal.pone.0172040.
49. Owen KB, Smith J, Lubans DR, Ng JY, Lonsdale C. Self-determined motivation and physical activity in children and adolescents: a systematic review and meta-analysis. *Prev Med* 2014;**67**:270–9.
50. Mellecker R, Lyons EJ, Baranowski T. Disentangling fun and enjoyment in exergames using an expanded design, play, experience framework: a narrative review. *Games Health J* 2013;**2**:142–9.
51. Baranowski T, Abdelsamad D, Baranowski J, O'Connor TM, Thompson D, Barnett A, et al. Impact of an active video game on healthy children's physical activity. *Pediatrics* 2012;**129**:e636–42. doi:10.1542/peds.2011-2050.
52. Norris E, Hamer M, Stamatakis E. Active video games in schools and effects on physical activity and health: a systematic review. *J Pediatr* 2016;**172**:40–6.
53. Fu Y, Burns RD. Effect of an active video gaming classroom curriculum on health-related fitness, school day step counts, and motivation in sixth graders. *J Phys Act Health* 2018;**15**:644–50.
54. Lu AS, Baranowski T, Thompson D, Buday R. Story immersion of videogames for youth health promotion: a review of literature. *Games Health J* 2012;**1**:199–204.
55. Burgermaster M, Contento I, Koch P, Mamykina L. Behavior change is not one size fits all: psychosocial phenotypes of childhood obesity prevention intervention participants. *Transl Behav Med* 2018;**8**:799–807.
56. Lawler M, Heary C, Nixon E. Variations in adolescents' motivational characteristics across gender and physical activity patterns: a latent class analysis approach. *BMC Public Health* 2017;**17**:661. doi:10.1186/s12889-017-4677-x.
57. Oishi S, Gilbert EA. Current and future directions in culture and happiness research. *Curr Opin Psychol* 2016;**8**:54–8.
58. Baranowski T. Pokemon Go, go, go, gone? *Games Health J* 2016;**5**:293–4.
59. Ni MY, Hui RWH, Li TK, Tam AHM, Choy LLY, Ma KKW, et al. Augmented reality games as a new class of physical activity interventions? The impact of Pokemon Go use and gaming intensity on physical activity. *Games Health J* 2018. doi:10.1089/g4h.2017.0181. [Epub ahead of print].
60. Koh HE, Oh J, Mackert M. Predictors of playing augmented reality mobile games while walking based on the theory of planned behavior: web-based survey. *JMIR Mhealth Uhealth* 2017;**5**:e191. doi:10.2196/mhealth.8470.
61. Lalot F, Zerhouni O, Pinelli M. "I wanna be the very best!" Agreeableness and perseverance predict sustained playing to Pokemon Go: a longitudinal study. *Games Health J* 2017;**6**:271–8.
62. Silva AM, Judice PB, Carraca EV, King N, Teixeira PJ, Sardinha LB. What is the effect of diet and/or exercise interventions on behavioural compensation in non-exercise physical activity and related energy expenditure of free-living adults? A systematic review. *Br J Nutr* 2018;**119**:1327–45.
63. Nooijen CFJ, Del Pozo-Cruz B, Nyberg G, Sanders T, Galanti MR, Forsell Y. Are changes in occupational physical activity level compensated by changes in exercise behavior? *Eur J Public Health* 2018;**28**:940–3.
64. Sampson DL, Broadbent JA, Parker AW, Upton Z, Parker TJ. Urinary biomarkers of physical activity: candidates and clinical utility. *Expert Rev Proteomics* 2014;**11**:91–106.
65. Pechlivanis A, Kostidis S, Saraslanidis P, Petridou A, Tsalis G, Mougios V, et al. H NMR-based metabonomic investigation of the effect of two different exercise sessions on the metabolic fingerprint of human urine. *J Proteome Res* 2010;**9**:6405–16.
66. Pechlivanis A, Kostidis S, Saraslanidis P, Petridou A, Tsalis G, Veselkov K, et al. 1H NMR study on the short- and long-term impact of two training programs of sprint running on the metabolic fingerprint of human serum. *J Proteome Res* 2013;**12**:470–80.
67. Klesges LM, Baranowski T, Beech BM, Cullen K, Murray D, Rochon J, et al. Social desirability bias in self-reported dietary, physical activity and weight concerns measures in 8-10 year old African-American girls: results from the Girls Health Enrichment Multi-site Studies (GEMS). *Prev Med* 2004;**38**(Suppl. 1):S78–87.
68. Baranowski T, O'Connor T, Johnston C, Hughes S, Moreno J, Chen TA, et al. School year versus summer differences in child weight gain: a narrative review. *Child Obes* 2014;**10**:18–24.