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Review article

Physical activity – a neat solution to an impending crisis

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Abstract
Childhood obesity is arguably the most significant global public health threat, yet effective strategies to contain or prevent the disease are not available. This review examines the physical activity patterns of children and the role physical activity plays in daily energy expenditure. The prevailing focus on moderate to vigorous activity in childhood means there is limited objective information on either sedentary behaviour or non-exercise activity thermogenesis (NEAT), the energy expended during the activities of daily living. Most strategies targeting the prevention of childhood obesity have focused upon adding moderate to vigorous activity and have not been particularly successful. The low efficacy of more purposeful activity is perhaps not surprising because of the small variance in children's physical activity levels explained by moderate to vigorous activity. Subtle changes in NEAT have in contrast been shown to account for differences in fat-mass gain or resistance in adults. Theoretically, manipulating a child's living environment to enhance NEAT would create a positive gain in TDEE, a gain that could lead to the prevention of excess fat-mass. More careful consideration of the specific aspects of physical activity that are most influential in the maintenance of body weight in childhood is a priority. Appreciating the role NEAT may play in the variation of total daily energy expenditure in children is a future challenge for physical activity research.

Key words: Physical activity, energy expenditure, obesity, children.

Introduction

The Year of the Pig brought with it something of a baby boom in China, as tradition expounds that the 'xiao zhu' or little pigs born this year are blessed with the fat and prosperous image of the pig. Overweight has long been regarded as a symbol of wealth in traditional Chinese culture. Unfortunately, the excessive accumulation of fat now apparent in many Chinese youngsters has well-established adverse consequences, with the most apparent being the increase in lifestyle disease risk in Chinese children, including a clustering of cardiovascular risk factors in those found above the 85th percentile for BMI and waist circumference (Sung et al., 2007).

Population surveys now indicate that over the last decade the prevalence of overweight and obesity in Chinese children has increased by 180 % (Ji et al., 2004). Obesity is particularly pronounced in boys, with 24 % of 6-12 year old Hong Kong boys and 27 % of 6 to 12 year old Beijing boys reported to be obese (Hong Kong Department of Health, Personal Communication April 2006; Mi et al., 2006). It is estimated that nearly one quarter of China's total population will become overweight or obese, with this estimate projected to double if the urbanization of China continues at its current pace (Wu et al., 2005). Importantly, 50 to 80 % of obese children become obese adults, further increasing adult obesity and related co-morbidities (Styne, 2001). Unchecked, the economic consequences of this epidemic are predicted to be grim (Popkin et al., 2006). Prevention is urgently needed.

Overweight and obesity are the result of chronic energy imbalance. Increases in caloric intake, reductions in energy expenditure, or both, result in excess energy being stored and excessive weight being gained. A theoretical quantification of the imbalance was proposed by Hill and colleagues (Hill et al., 2003). Using NHANES data, the accumulated energy in adults necessary for excessive weight gain was estimated to be in the magnitude of 100 kcal per day. This excess was termed the energy gap, a gap which widens as one progresses from lean to overweight and from overweight to obese. Recent analyses of NHANES data for children estimated that the average energy gap was 110 to 165 kcal per day (Wang et al., 2006). These data have important implications for the future development of obesity-prevention strategies. They suggest that small changes to daily living, changes which result in an approximately 150 kcal per day difference, could impart energetic changes associated with the gain of initial excess weight.

There is substantial evidence to suggest that changes to daily living have resulted in a chronic depletion in total daily energy expenditure, specifically physical activity thermogenesis (Cavadini et al., 2000; Durnin, 1992; Hill et al., 1999). The decline in active transport, minimal manual household tasks and advances in electronic play have all been implicated in excessive accumulation of energy and the escalation of overweight and obesity (Bell et al., 2002; Lanningham-Foster et al., 2003; Robinson, 1999). The worldwide pandemic of overweight and obesity has led to a renewed interest in physical activity energy expenditure, but it is imperative that the precise aspects of physical activity that are important for weight maintenance are identified before it can be confidently promoted as the focus for prevention.

Total daily energy expenditure, activity thermogenesis and the prevention of excessive weight gain

There are three primary components that constitute total daily energy expenditure: resting metabolic rate, the thermic effect of food and physical activity thermogenesis. Resting metabolic rate accounts for approximately 50 to 60 % of TDEE. Variation between individuals is small

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and is essentially a function of body size. The thermic effect of food accounts for only 10 to 15 % of TDEE, whilst the contribution made by physical activity thermogenesis can vary enormously from a meagre 15 % in the sedentary to 50 % in the active (Donahoo et al., 2004; Levine, 2004b). There is more limited data on the components of TDEE in children under 12 years of age children, however, the relative contribution of the three components would appear similar (DeLany et al., 2006; Montgomery et al., 2004).

Levine and colleagues (Levine, 2004a; Levine et al., 2006) have shown that the variation in physical activity thermogenesis is better understood when it is subdivided into exercise activity thermogenesis and non-exercise activity thermogenesis (NEAT). NEAT is unstructured activity and constitutes all the lifestyle movement patterns and postural adjustments engaged in as a matter of course, rather than the energy expended through more purposeful or structured exercise activity thermogenesis (EAT). NEAT comprises three sub-components. These include body posture, ambulation, and all other movements, essentially fidgeting (Levine et al., 2001b). In comparison to the 1-2 % variation in TDEE contributed by EAT, NEAT varies enormously between individuals and has been shown to play an important role in the maintenance of body weight (Levine et al., 2005). This is best illustrated by Levine's observation that it is not EAT that delineates the lean adult from the obese; rather it is sub-components of NEAT. Their discovery that obese adults sit for 164 minutes per day more than lean adults, whilst the lean stand and ambulate for 152 minutes per day more than the obese, led to the conclusion that the variation in NEAT in adults was primarily related to ambulation and body posture (Levine et al., 2005). The energetic benefit of standing and ambling ranged from 269 to 477 kcal per day. Levine et al. (2005) suggest that if the obese adult adopted the postural and ambulatory patterns of the lean, they would expend an average 350 kcal per day more, and assuming energy intake remained constant, resist further weight gain.

The role of NEAT in paediatric obesity has yet not been evaluated, but may prove to play a key role in modulating weight gain in children. Variation in body posture and ambulation may also distinguish the lean from the obese child. Theoretically, manipulating a child's living environment to enhance NEAT, and create a positive gain in TDEE, could lead to the prevention of excess fat-mass. These concepts have not yet been tested.

The complexity of assessing NEAT and its sub-components has been highlighted by Levine and colleagues in their development and validation of the Physical Activity Monitoring System (PAMS) for this purpose (Levine et al., 2001a; 2001b; 2003). Recently Lanningham-Foster and colleagues (2005) validated the PAMS for use in children, which promises future evidence of the primary predictors of NEAT in children, as well as an understanding of the role NEAT may play in the variation in TDEE in youngsters.

Advances in the objective assessment of physical activity have meant we have amassed a sizable literature on childhood physical activity patterns over the last two decades. Whilst there is minimal evidence of the degree to which specific aspects of activity account for variance in TDEE, there is evidence of the predominant pattern and intensity of activity in children. This information can help build a better understanding of the relative contribution activity of differing intensities makes to the variation in total physical activity.

The pattern and intensity of physical activity in children

There is an abundance of data which shows sustained periods of physical activity are rarely apparent during the daily movement repertoire of children (Armstrong et al., 1991; 2006; McManus et al., 1995; Welsman et al., 1997). Through a comprehensive series of studies, Armstrong and colleagues have provided probably the largest heart rate derived activity data set for children (Armstrong et al., 2006). Moderate intensity physical activity has been defined as activity, which elicits a cardiovascular response between 140 to 159 beats·min^{-1}. This threshold has been found to correspond to walking at 4 km·hr^{-1} in both Caucasian and Chinese children (Armstrong, 1998; McManus et al., 2004), and has largely been adopted as an appropriate marker of moderate intensity activity (Livingstone et al., 2003). Likewise, a threshold of >159 beats·min^{-1} has generally been accepted as an appropriate marker of vigorous intensity. Very few children sustain 20-minute periods of at least moderate activity (Armstrong et al., 1991; Gilbey et al., 1995; McManus, 2006; McManus et al., 1995). Even a single 10-minute period of sustained moderate intensity activity was absent in at least one quarter of 7 to 12 year olds (Armstrong et al., 1991; Gilbey et al., 1995; McManus, 2006; McManus et al., 1995).

Children's preference for intermittent short-duration movement has long been recognized (Astrand, 1952) and is best illustrated by the work of (Bailey et al., 1995). Through two separate analyses (Bailey et al., 1995; Berman et al., 1998), bouts of activity in children were found to be frequent (83 and 89 bouts per hour in boys and girls respectively), with a mean duration of 20s. The majority of activity bouts were of low-to-moderate intensity, interspersed with very occasional bursts of vigorous intensity movement (median duration 3s). As such there has been a shift away from an emphasis on encouraging sustained periods of physical activity (Sallis et al., 1994), toward accumulating moderate to vigorous physical activity throughout the day (Cavill et al., 2001; Strong et al., 2005).

Figure 1 provides a summary of the time spent being moderately (A) and vigorously (B) physically active per day in 4 to 12 year old boys and girls. These data are drawn from a range of European and Asian studies using heart rate monitoring (Armstrong et al., 1991; Falgairette et al., 1996; Gilbey et al., 1995; Harro, 1997; McManus, 2006; McManus et al., 1995; Sleap et al., 2000; Welsman et al., 1997). Many of the European children attain or are close to attaining the recommended 1 hour per day of moderate intensity activity (Strong et al., 2005). In stark contrast, the Hong Kong Chinese boys and girls accumulated on average 37 minutes per day less moderate intensity activity than the European children. A similar pattern

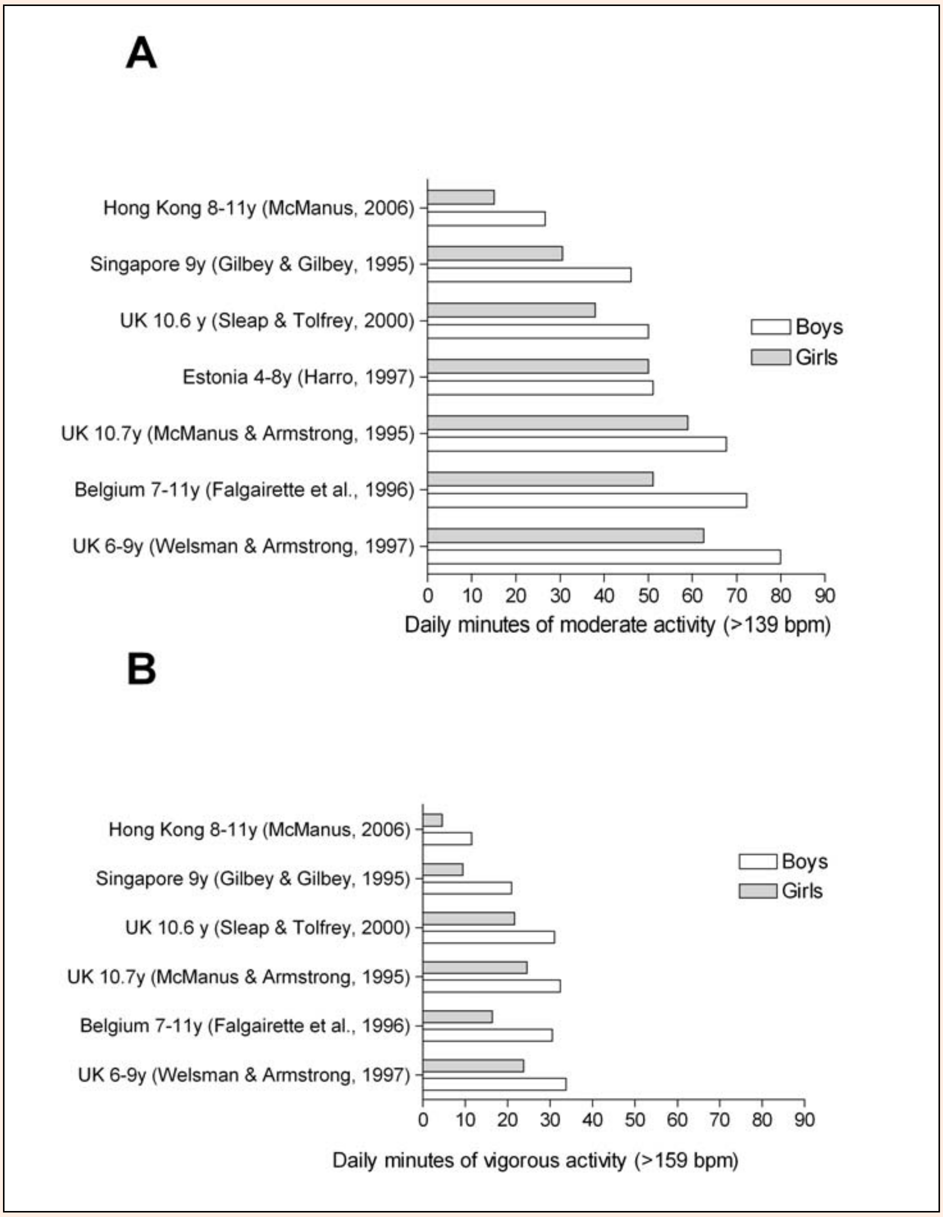

Figure 1. Levels of moderate (A) and vigorous (B) physical activity in children, measured using heart rate monitoring.

is apparent for the vigorous intensity activity, with Hong Kong Chinese children accumulating far less vigorous activity than either the European or Singaporean children.

Distinguishing between sedentary and low intensity activity is problematic with heart rate monitoring because of extraneous influences upon low level heart rates such as emotions and fitness. A threshold of > 120 beats.min^{-1} has been used to quantify lower intensity activity and these data are available for Singaporean and British children (Gilbey et al., 1995; Sleap et al., 2000). Singaporean boys accumulated 167 minutes per day of light intensity activity, whilst their British counterparts accumulated 118 minutes per day. The Singaporean girls spent 116 minutes of the day in light intensity activity, in comparison to 105 minutes per day in the British girls. If these values are considered relative to the total physical activity level (low, moderate and vigorous activity combined), light intensity activity accounts for between 71 % and 74 % of total physical activity level in the Singaporean boys and girls respectively. In the British boys and girls, light intensity activity accounts for 59% and 64% of total physical activity respectively. Moderate to vigorous activity comprised only 29% of the total active time for Singaporean boys and 26% of total active time for Singaporean girls. Whilst 41% of total active time was spent in moderate to vigorous activity in the British boys, and 36 % in the British girls (Gilbey et al., 1995; Sleap et al., 2000).

Accelerometry studies are more difficult to interpret because of variation in devices used, as well as inconsistent definitions and thresholds for intensity (Freedson et al., 2005). Accelerometers are however, easy to use and affordable and a number of large-scale studies have provided extensive information on the physical activity levels of European children. Dencker and colleagues reported that 9 to 10 yr old Swedish boys and girls accumulated 210 and 190 minutes of moderate intensity activity per day respectively (Dencker et al., 2005). Boys accumulated forty-six minutes of vigorous activity, whilst girls accumulated thirty-five minutes per day. Similarly aged boys and girls from Sweden and Estonia (from the European Youth Heart Study) accumulated 182 and 161 minutes of moderate activity respectively (Ruiz et al., 2006). The boys accumulated 31 minutes of vigorous activity per day, whilst the girls accumulated 22 minutes per day. Further data from over 1000 participants of the European Youth Heart (Ekelund et al., 2004) found boys spent 12 % of their day engaged in activity of at least moderate intensity, whilst girls accumulated somewhat less (8.7 %). This translates to an average of 86 minutes for the boys and 63 minutes for the girls, and is quite similar to heart rate estimates from Armstrong and colleagues (Armstrong et al., 1991; Welsman et al., 1997). Interestingly both data sets are interpreted using a threshold equivalent to walking at 4 $km.hr^{-1}$. What is clear from this large scale data set is that most of a European child's day is spent being sedentary or engaged in light intensity movement. This is true of both boys and girls who were shown to spend similar amounts of time being sedentary (61.8 and 65.3 % respectively) or engaged in light intensity movement (26 % for both).

The most substantial evidence of the relative contribution activity of differing intensities makes to the variation in overall physical activity levels of children comes from a study of young Scottish children (Montgomery et al., 2004). Total daily energy expenditure was assessed using doubly-labelled water in 2 to 7 year olds, and activity thermongenesis and physical activity level calculated. Specific dimensions of physical activity were assessed using accelerometry, and the relative contribution sedentary, light, and moderate to vigorous intensity activity made to physical activity levels determined. It was found that moderate to vigorous activity explained only about 10 % of the total variance in physical activity level. Instead, the variation in physical activity level appeared to relate primarily to light intensity movement and sedentary behaviour. It was concluded that in children moderate to vigorous activity contributes little to overall physical activity levels. Parallel to Levine's work, these findings would suggest that the most promising approach to increasing TDEE in children would be the conversion of sedentary behaviour to low intensity activity, as opposed to focusing on moderate to vigorous intensity activity.

Future strategies

Strategies utilizing physical activity as the focus for the prevention of childhood obesity have predominantly used activity of at least a moderate intensity and have not been notably successful. When the effect of physical activity on weight or body composition was considered both from longer term and short term randomized controlled trials, these have largely failed to impact on the weight status of children (Doak et al., 2006; Lobstein et al., 2004; Reilly et al., 2003; Summerbell et al., 2005; Wareham et al., 2005). Perhaps because moderate to vigorous activity accounts for a relatively small amount of the variance in activity thermogenesis, then these findings are unsurprising and would suggest that more careful consideration of the specific aspects of physical activity that are most influential in the maintenance of body weight is warranted.

If preventing weight gain needs on average only 150 kcal per day, this could easily be accomplished by adding incidental movement or NEAT to a child's daily routine. For example, replacing rides on escalators with stair climbing, or walking rather than riding escalators. Alternatively nutritional modification as opposed to activity modification may be a more achievable way of closing the energy gap in children. Wang and colleagues have suggested that restricting caloric intake by, for instance, a can of coke per day was an easily achievable way of closing the energy gap, whilst asking a child to exchange 1.9 hours of sitting for 1.9 hours of walking was not (Wang et al., 2006). It is hard to argue with this logic. Technology is constantly evolving to provide the most visually stimulating, exhilarating and interactive play-forms for children. The long-term sustainability of an obesity prevention strategy that depends upon removal of a child's preferred entertainment form is doubtful. Perhaps however NEAT affords more imaginative intervention solutions. Consider screen time. Various reports suggest that children spend between 4 and 6 hours a day in front of a television, computer or gaming device screen (Vandewater et al., 2004; 2006). What if screen time involved incidental movement? Recent experimental investigations have shown that screen time can provide meaningful increases in energy expenditure if interactive (Lanningham-Foster et al., 2006). Interactive game technology (Sony EyeToy; Dance Dance Revolution Ultramix 2) resulted in energy expenditure increases between 108 to 172 % above rest. What if the majority of screen time took place while walking? Lanningham-Foster et al. (2006) has shown that watching the television whilst walking on a treadmill increased energy expenditure by 138 % above rest. These data provide support for the idea that converting the sedentary screen time enemy into a NEAT ally is a feasible, and likely appealing, way of adding activity back into the otherwise sedentary lives of children. Efforts need to be channelled into creating and testing the efficacy of innovative NEAT solutions such as these.

Conclusions

It is paradoxical that whilst childhood obesity is a public health priority we have yet to find effective strategies to prevent it. The available objective data on physical activity levels in children clearly show that low intensity activity dominates the daily activity pattern of a child. Physical activity research needs to build an objective base of information on the sedentary behaviour and light activity component of physical activity, as well as the subcomponents of non-exercise activity thermogenesis in children. Most importantly, the most modifiable of these components needs to be determined. Finding NEAT solutions to convert children's otherwise sedentary pursuits into active pursuits should be a priority in the fight to slow the obesity crisis.

References

Armstrong, N. (1998) Young people's physical activity patterns as assessed by heart rate monitoring. *Journal of Sports Science* **16 (Suppl.),** 9-16.

Armstrong, N. and Bray, S. (1991) Physical activity patterns defined by continuous heart rate monitoring. *Archives in Disease in Childhood* **66,** 245-247.

Armstrong, N. and Welsman, J. (2006) The physical activity patterns of European youth with reference to methods of assessment. *Sports Medicine* **36,** 1067-1086.

Astrand, P. (1952) *Experimental studies of physical working capacity in relation to sex and age*. Copenhagen: Munksgaard.

Bailey, R., Olson, J., Pepper, S., Porszasz, J., Barstow , T. and Cooper, D. (1995) The level and tempo of children's physical activities: an observation study. *Medicine and Science in Sports and Exercise* **27,** 1033-1041.

Bell, C., Ge, K. and Popkin, B. (2002) The road to obesity or the path to prevention: motorized transportation and obesity in China. *Obesity Research* **10,** 277-283.

Berman, N., Bailey, R., Barstow, T. and Cooper, D. (1998) Spectral and bout detection analysis of physical activity patterns in healthy, prepubertal boys and girls. *American Journal of Human Biology* **10,** 289-297.

Cavadini, C., Siega-Riz, A. and Popkin, B. (2000) US adolescent food intake trends from 1965 to 1996. *Archives of Disease in Childhood* **83,** 18-24.

Cavill, N., Biddle, S. and Sallis, J. (2001) Health enhancing physical activity for young people: statement of the United Kingdom expert consensus conference. *Pediatric Exercise Science* **13,** 12-25.

DeLany, J., Bray, G., Harsha, D. and Volaufova, J. (2006) Energy expenditure and substrate oxidation predicts changes in body fat in children. *American Journal of Clinical Nutrition* **84,** 862-870.

Dencker, M., Thorsson, O., Karlsson, M., Linden, C., Svensson, J., Wollmer, P. and Anderson, L. (2005) Daily physical activity in Swedish children aged 8-11 years. *Scandinavian Journal of Medicine and Science in Sports* **16,** 252-257.

Doak, C., Visscher, T., Renders, C. and Seidell, J. (2006). The prevention of overweight and obesity in children and adolescents: a review of interventions and programmes. *Obesity Reviews* **7,** 111-136.

Donahoo, W., Levine, J. and Melanson, E. (2004) Variability in energy expenditure and its components. *Current Opinion in Clinical Nutrition and Metabolism* **7,** 599-605.

Durnin, J. (1992) Physical activity levels – past and present. In: *Society for the Study of Human Biology Symposium 34*: *Physical activity and health.* Ed: Norgan. Cambridge: Cambridge University Press. 20-27.

Ekelund, U., Sardinha, L., Anderssen, S., Harro, M., Franks, P., Brage, S., Cooper, A., Anderson, L., Riddoch, C. and Froberg, K. (2004) Associations between objectively assessed physical activity and indicators of body fatness in 9- to 10-y-old European children: a population-based study from 4 distinct regions in Europe (the European Youth Heart Study). *American Journal of Clinical Nutrition* **80,** 584-590.

Falgairette, G., Gavarry, O., Bernard, T. and Hebbelinck, M. (1996) Evaluation of habitual physical activity from a week's heart rate monitoring in French school children. *European Journal of Applied Physiology* **74,** 153-161.

Freedson, P., Pober, D. and Janz, K. (2005) Calibration of accelerometer output for children. *Medicine and Science in Sports and Exercise* **37,** 523-530.

Gilbey, H. and Gilbey, M. (1995) The physical activity of Singapore primary school children as estimated by heart rate monitoring. *Pediatric Exercise Science* **7,** 26-35.

Harro, M. (1997) Validation of a questionnaire to assess physical activity of children ages 4-8 years. *Research Quarterly for Exercise and Science* **68,** 259-268.

Hill, J. and Melanson, E. (1999) Overview of the determinants of overweight and obesity: current evidence and research issues. *Medicine and Science in Sports and Exercise* **31(Suppl.),** 515-521.

Hill, J., Wyatt, H., Reed, G. and Peters, J. (2003) Obesity and the environment: where do we go from here? *Science* **299,** 853-855.

Ji, C., Sun, J. and Chen, T. (2004) Dynamic analysis on the prevalence of obesity and overweight school-age children and adolescents in recent 15 years in China. *Zhonghua Liu Xing Bing Xue Za Zhi* **25,** 103-108. (In Chinese: English abstract).

Lanningham-Foster, L., Jensen, T., Foster, R., Redmond, A., Walker, B., Dieter-Heinz, D. and Levine, J. (2006). Energy expenditure of sedentary screen time compared with active screen time for children. *Pediatrics* **118,** e1831-1835.

Lanningham-Foster, L., Jensen, T., McCrady, S., Nysse, L., Foster, R. and Levine, J. (2005). Laboratory measurement of posture allocation and physical activity in children. *Medicine and Science in Sports and Exercise* **37,** 1800-1805.

Lanningham-Foster, L., Nysse, L. and Levine, J. (2003) Labor saved, calories lost: the energetic impact of domestic labor-saving devices. *Obesity Research* **11,** 1178-1181.

Levine, J. (2004a) Non-exercise activity thermogenesis (NEAT). *Nutrition Reviews* **62 (Suppl.),** 82-97.

Levine, J. (2004b) Nonexercise activity thermogenesis (NEAT): environment and biology. *American Journal of Physiology: Endocrinology and Metabolism* **286,** e675-685.

Levine, J., Baukol, P. and Westerterp, K. (2001a) Validation of the Tracmor triaxial accelerometer system for walking. *Medicine and Science in Sports and Exercise* **33,** 1593-1597.

Levine, J., Lanningham-Foster, L., McCrady, S., Krizan, A., Olson, L., Kane, P., Jensen, M. and Clark M. (2005) Inter-individual variation in Posture Allocation: Possible role in human obesity. *Science* **28,** 584-586.

Levine, J., Melanson, E., Westerterp, K. and Hill, J. (2001b) Measurement of the components of nonexercise activity thermogenesis. *American Journal of Physiology: Endocrinology and Metabolism* **281,** e670-675.

Levine, J., Melanson, E., Westerterp, K. and Hill, J. (2003) Tracmor system for measuring walking energy expenditure. *European Journal of Clinical Nutrition* **57,** 1176-1180.

Levine, J., Vander Weg, M., Hill, J. and Klesges, R. (2006) Non-exercise activity thermogenesis: the crouching tiger hidden dragon of societal weight gain. *Arteriosclerosis, Thrombosis, and Vascular Biology* **26,** 729-736.

Livingstone, M., Robson, P., Wallace, J. and McKinley, M. (2003) How active are we? Levels of routine physical activity in children and adults. *Proceedings of the Nutrition Society* **62,** 681-701.

Lobstein, T., Baur, L. and Uauy, R. (2004) IASO International Obesity Taskforce. Obesity in children and young people: a crisis in public health. *Obesity Reviews* **5 (Supp. 1),** 4-104.

McManus, A. (2006) The influence of vehicular traffic upon physical activity in children. *Human Ecology* **14,** 159-163.

McManus, A. and Armstrong, N. (1995) Patterns of physical activity among primary schoolchildren. In: *Children in Sport.* Ed: F. Ring. Bath: University Press. 17-23.

McManus, A., Yung, T. and Leung, M. (2004) Peak oxygen uptake in relation to age, sex and maturation in Hong Kong Chinese children. *American Journal of Human Biology* **16,** 602-605.

Mi, J., Cheng, H., Hou, D., Teng, H., Duan, J., Teng, H. and Wang, Y. (2006). Prevalence of overweight and obesity among children and adolescents in Beijing in 2004. *Zhonghua Liu Xing Bing Xue Za Zhi* **27,** 469-474. (In Chinese: English abstract).

Montgomery, C., Reilly, J., Jackson, D., Kelly, L., Slater, C., Paton, J. and Grant, S. (2004). Relation between physical activity and energy expenditure in a representative sample of young children. *American Journal of Clinical Nutrition* **80,** 591-596.

Popkin, B., Kim, S., Rusev, E., Du, S. and Zizza, C. (2006). Measuring the full economic costs of diet, physical activity and obesity-related chronic diseases. *Obesity Research* **7,** 271-293.

Reilly, J. and McDowell, Z. (2003) Physical activity interventions in the prevention and treatment of paediatric obesity: systematic review and critical appraisal. *Proceedings of the Nutrition Society* **62,** 611-619.

Robinson, T. (1999) Reducing children’s television viewing to prevent obesity: a randomized controlled trial. *Journal of the American Medical Association* **282,** 1561-1567.

Ruiz, J., Rizzo, N., Hurtig-Wennlof, A., Ortega, F., Warnberg, J. and Sjostrom, M. (2006) Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. *American Journal of Clinical Nutrition* **84,** 299-303.

Sallis, J. and Patrick, K. (1994) Physical activity guidelines for adolescents: a consensus statement. *Pediatric Exercise Science* **6,** 302-314.

Sleap, M. and Tolfrey, K. (2000) Do 9- to 12-yr-old children meet existing physical activity recommendations for health? *Medicine and Science in Sports and Exercise* **33,** 591-596.
Strong, W., Malina, R., Blimkie, C., Daniels, S., Dishman, R., Gutin, B., Hergenroeder, A., Must, A., Nixon, P., Pivarnik, J., Rowland, T., Trost, S. and Trudeau, F. (2005) Physical activity recommendations for school-age youth. *Journal of Pediatrics* **146**, 732-737.
Styne, D. (2001) Childhood and adolescent obesity. Prevalence and significance. *Pediatric Clinics North America* **48,** 823-854.
Summerbell, C., Waters, E., Edmunds, L., Kelly, S., Brown, T. and Campbell, K. (2005) Interventions for preventing obesity in children. *The Cochrane Database of Systematics Reviews* **20,** CD001871.
Sung, R., Yu, C., Choi, k., McManus, A., Li, A., Xu, S., Chang, D., Lo, A., Chan, J. and Fok, T. (2007). Waist circumference and body mass index in Chinese children: cutoff values for predicting cardiovascular risk factors. *International Journal of Obesity,* **31,** 550-558.
Vandewater, E., Bickham, N. and Lee, J. (2004). Time well spent? Relating television use to children's free-time activities. *Pediatrics* **117,** e181-191.
Vandewater, E. and Huang, X. (2006) Parental weight status as a moderator of the relationship between television viewing and childhood overweight. *Archives in Pediatric and Adolescent Medicine* **160,** 425-431.
Wang, Y., Gortmaker, S., Sobol, A. and Kuntz, K. (2006). Estimating the energy gap among US children: a counterfactual approach. *Pediatrics* **118,** e1721-1733.
Wareham, N., van Sluijs, E. and Ekelund, U. (2005) Physical activity and obesity prevention: a review of the current evidence. *Proceedings of the Nutrition Society* **64,** 229-247.
Welsman, J. and Armstrong, N. (1997) Physical activity patterns of 5 to 11-year-old children. In: *Children and Exercise XIX: promoting health and well-being.* Eds: Armstrong, N., Kirby, B. and Welsman, J.London: E and FN Spon. 139-144.
Wu, Y., Ma, G., Hu, Y., Li, Y., Li, X., Cui, Z., Chen, C. and Kong, L. (2005) The current prevalence status of body overweight and obesity in China: data from the China National Nutrition and Health Survey. *Zhonghua Yu Fang Yi Xue Za Zhi* **39,** 316-320. (In Chinese: English abstract).

Key points

- Excessive weight gain affects children in both developed and developing countries alike, and results initially from small energy imbalances. Increasing the energy expended in daily living has the potential to re-adjust energy balance and prevent initial excess weight gain.
- Sedentary behaviour and light intensity movement, as opposed to moderate or vigorous movement, dominate a child's day. We need to understand more about which aspects of activity account for variance in total daily energy expenditure in children.
- Finding innovative and creative ways to increase the daily energy children expend should be a priority.

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