MAYO CLINIC

REVIEW

Nonexercise Activity Thermogenesis in Obesity Management

Pedro A. Villablanca, MD, MSc; Jorge R. Alegria, MD; Farouk Mookadam, MBChB, MSc; David R. Holmes Jr, MD; R. Scott Wright, MD; and James A. Levine, MD, PhD

Abstract

Obesity is linked to cardiovascular disease. The global increase in sedentary lifestyle is an important factor contributing to the rising prevalence of the obesity epidemic. Traditionally, counseling has focused on moderate- to vigorous-intensity exercise, with disappointing results. Nonexercise activity thermogenesis (NEAT) is an important component of daily energy expenditure. It represents the common daily activities, such as fidgeting, walking, and standing. These high-effect NEAT movements could result in up to an extra 2000 kcal of expenditure per day beyond the basal metabolic rate, depending on body weight and level of activity. Implementing NEAT during leisure-time and occupational activities could be essential to maintaining a negative energy balance. NEAT can be applied by being upright, ambulating, and redesigning workplace and leisure-time environments to promote NEAT. The benefits of NEAT include not only the extra calories expended but also the reduced occurrence of the metabolic syndrome, cardiovascular events, and all-cause mortality. We believe that to overcome the obesity epidemic and its adverse cardiovascular consequences, NEAT should be part of the current medical recommendations. The content of this review is based on a literature search of PubMed and the Google search engine between January 1, 1960, and October 1, 2014, using the search terms *physical activity, obesity, energy expenditure, nonexercise activity thermogenesis,* and *NEAT*.

 ■ Mayo Clin Proc. 2015;90(4):509-519

"Life is like riding a bicycle. To keep your balance, you must keep moving."
— Albert Einstein (1879-1955)

OBESITY PANDEMIC AND PHYSICAL INACTIVITY

Obesity is a global pandemic; at least 78 million American adults are affected, as are almost 17% of children and adolescents.[1] Obesity is defined as a body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) of at least 30.[2] Several studies have established the relationship between visceral adiposity and subsequent adverse health conditions,[3] with 1 in 5 deaths worldwide attributed to obesity.[4] Also, obesity is associated with high social economic costs.[5] Although caloric excess is a substantial component of half of the obesity paradigm, physical inactivity (PI) significantly contributes to the other half of that paradigm. Adult PI worldwide is estimated to be 31%, and in the United States, this number is up to 50%.[6] In the past 50 years there has been an important decline in energy expenditure in occupation-related[7] and household management[8] physical activity (PA), which also plays a fundamental role in body weight and overall adiposity. Decreasing PI is one of the main foci for preventing and treating obesity and the deleterious health consequences associated with obesity.[9] Furthermore, PI is associated with an elevated risk of death from cardiovascular disease (CVD). A dose-response association exists between sitting time and cardiovascular mortality.[10]

Nonexercise activity thermogenesis (NEAT) is one of the components of total energy expenditure (TEE). Increasing NEAT is one potential intervention against adiposity and inactivity. The aim of this article is to promote awareness of the concepts of NEAT and to facilitate its incorporation by health care providers as an additional strategy in the management of obesity.

A computerized search was conducted in PubMed and the Google search engine between January 1, 1960, and October 1, 2014, using the search terms *physical activity, obesity, energy expenditure, nonexercise activity thermogenesis,*

From the Division of Cardiovascular Diseases, Montefiore Medical Center/Albert Einstein College of Medicine, New York, NY (P.A.V.); Sanger Heart and Vascular Institute, Charlotte, NC (J.R.A.); Division of Cardiovascular Diseases (F.M.) and Division of Endocrinology (J.A.L.), Mayo Clinic, Scottsdale, AZ; and Division of Cardiovascular Diseases, Mayo Clinic, Rochester, MN (D.R.H., R.S.W.).

ARTICLE HIGHLIGHTS

- A significant decrease in physical activity has contributed to the obesity pandemic. Complemented with moderate- to vigorous-intensity exercise activity, nonexercise activity thermogenesis (NEAT) seems to have a fundamental role in preventing and reducing the obesity pandemic.
- NEAT includes a series of continuous and vital movements that do not involve moderate- to vigorous-intensity exercise. These additive activities account for significant thermogenesis and energy consumption.
- NEAT variability can explain the caloric expenditure differences in individuals with similar phenotypes. Variances in work and leisure-time activities in individuals play a fundamental role in NEAT differences.
- By just doing simple daily manual task activities, NEAT can be enhanced throughout the workday and at home. These activities should be encouraged in childhood and continued during adulthood.
- NEAT decreases cardiovascular disease mortality and improves metabolic parameters. NEAT has good long-term adherence, with positive impact.

and *NEAT* to identify relevant articles. Articles were also identified through searches of reference lists and the authors' files. Both original and review articles published in English were reviewed.

NEAT: AN EMERGING STRATEGY AGAINST PI

Interventions to overcome the net positive excessive energy balance have traditionally been focused on encouraging moderate- to vigorous-intensity PA during discretionary time combined with caloric restriction[11]; however, this strategy has met with limited success in long-term randomized clinical trials, with no reduction in the rate of cardiovascular events.[12] Hence, a third strategy has emerged that focuses on reducing the total time spent in sedentary pursuits. This strategy includes the addition of short repetitive bouts of nonexercise PA and standing rather than sitting during prolonged periods of inactivity.[13]

WHAT IS NEAT?

NEAT encompasses the expenditure of energy that is secondary to movement beyond purposeful exercise and resistance training activities. Activities that promote NEAT include a series of continuous and vital movements with postural changes that do not involve moderate- to vigorous-intensity exercise and occur at a trivial or low energy workload on a daily basis for minutes to hours.[14,15] These activities involve walking, climbing stairs at work or any recreational community place, fidgeting, singing, laughing, cleaning, and standing, among others. These additive activities are associated with energy expenditure beyond the basal metabolic activity and account for significant thermogenesis and energy consumption.[16,17]

TOTAL DAILY ENERGY EXPENDITURE AND NEAT

NEAT has significant interindividual variation. To understand this variation, the 3 components of TEE must be explained: (1) basal metabolic rate (BMR), (2) thermic effect of food (TEF), and (3) PA (Figure 1).[18] The BMR represents approximately 60% of TEE. The TEF also contributes to TEE, and by some estimates composes as much as 10% of TEE. The mechanism by which energy is expended with food ingestion and digestion, including mastication, digestion, absorption, and transportation of nutrients, constitutes the TEF. The interindividual variability of the TEF is not reviewed herein, but note that compared with lean individuals, the TEF in obese people is reduced, with studies suggesting a lower level of sympathetic nervous system activation[19] and a diminished thermogenic response to the high-carbohydrate meal.[20]

The remainder of TEE involves PA. On average, PA accounts for 15% to 30% of TEE. Physical activity can be further divided into purposeful-voluntary exercise activity thermogenesis and NEAT (the movements associated with nonexercise activities).[21] Erroneously, purposeful-voluntary PA has been considered as the only major modifiable component of daily TEE.[22] Most overweight individuals, particularly the obese, have negligible PA, and NEAT could, therefore, be an important tool against the obesity pandemic.

PURPORTED NEAT MEDIATORS AND BRAIN SITES OF ACTION

Emerging evidence suggests that exercise activity may be partly genetically influenced. This is

Mayo Clin Proc. ■ April 2015;90(4):509-519 ■ http://dx.doi.org/10.1016/j.mayocp.2015.02.001
www.mayoclinicproceedings.org

not unexpected because previous work has demonstrated that the variation in body weight and body fat distribution is genetically determined to a certain extent.[23] Recent information suggests that the nuclei possibly involved in the regulation of NEAT are located in the hypothalamus and extrahypothalamic nuclei[24] in a complex network that determines the level of spontaneous PA. Multiple potential neuromediators are implicated in this process,[25-28] including orexin, neuromedin U, ghrelin, and the agouti gene–related protein. These neuroendocrine modulators likely represent only a partial list of modulators that recognize internal and external signals and activate descending and ascending projections through limbic pathways that are incorporated into different areas of the brain. This complex neural network influences the quantity and quality of the energy efficiency of PA and NEAT and, thus, affects energy balance and promotes energy homeostasis.[29] Orexin is the most well-established neuromodulator of NEAT. Animal studies have shown that the ablation of orexin neurons causes narcolepsy and obesity[30] and that the use of orexin antagonists decreases spontaneous movements.[31] Conversely, increased orexin levels stimulate more unintentional movements.[32] These molecular findings have been correlated with low levels of orexin and with depressed responses to orexin in the brains of obese animals, which suggests some resistance to NEAT stimuli.[33-35] The Supplemental Figure (available online at http://www.mayoclinicproceedings.org) illustrates the potential neuromediators of NEAT.

By means of the potential NEAT mediators studied in animal models, Levine[36] termed 2 groups of animals that would explain leanness and obesity: NEAT activators are those animals with a copious and robust NEAT signal, and NEAT conservers have a blunted response to NEAT signals and expend lower levels of energy, resulting in obesity.[36]

NEAT MECHANISM

Inadequate energy expenditure results in the excess energy being stored as fat. Levine et al[37] demonstrated the relationship between fat gain and NEAT in obese and lean individuals exposed to similar environments. Twenty healthy volunteers (10 lean and 10 obese) were examined for 10 days by comparing body posture and motion to assess NEAT. Volunteers were instructed to continue with their usual daily activities without adopting new exercise practices. The results showed that the obese individuals were seated for longer periods compared with their leaner counterparts and suggested that if obese individuals were to adopt the same NEAT activities as the leaner counterparts, an extra 350 calories per day of energy expenditure would be achieved.

Given that BMR and TEF are relatively constant, PA has the greatest variability. Therefore, it also primarily influences fat deposition during excess food intake and, in part, explains how 2 individuals of similar body size can expend different caloric amounts. Studies on overfeeding indicate that people with the highest variation in activity energy expenditure have the lowest rate of weight gain compared with those with low activity, who show an increased rate of weight gain.[38] This interindividual variability of NEAT illustrates how 2 people with similar physical characteristics and caloric intake can have different body morphometrics.

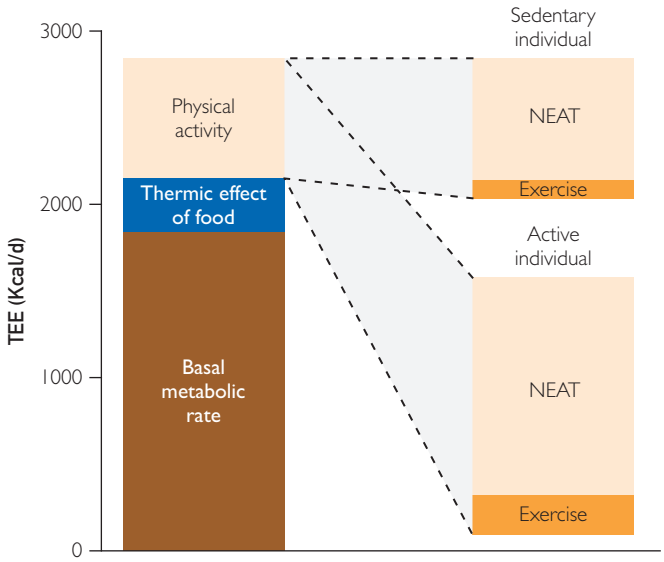

FIGURE 1. Components of total energy expenditure (TEE). The left column shows the 3 components of TEE: basal metabolic rate, thermic effect of food, and extent of physical activity.[18] In the right column, physical activity is further divided into nonexercise activity thermogenesis (NEAT) and exercise activity thermogenesis.[21] The right column also illustrates the theoretical difference in NEAT between sedentary and active individuals and the significant amount of extra calories that could be expended.

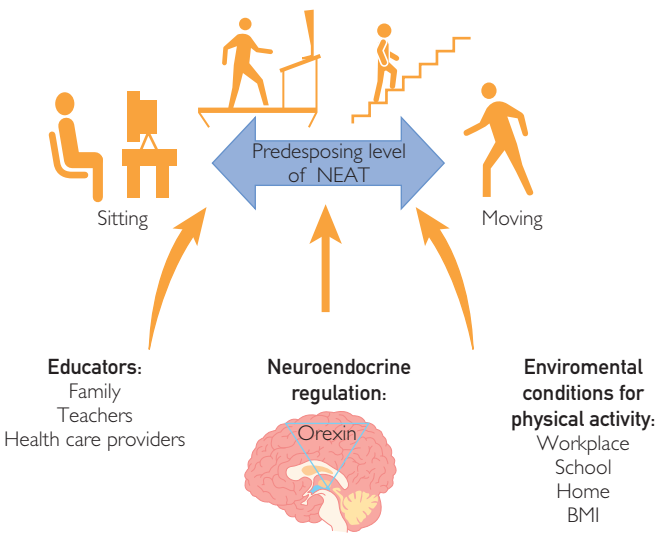

FIGURE 2. Factors involved in the level of nonexercise activity thermogenesis (NEAT). The interindividual variability predisposing to a higher or lower level of NEAT is driven by genetic and acquired factors. The genetic regulation of NEAT is possibly influenced by multiple neuromediators located in the hypothalamus, including orexin, neuromedin U, ghrelin, and the agouti gene—related protein. This, plus the conditioning of the environment to different levels of physical activity and the behavioral factors that we learned from our main educators, will determine an individual to be a NEAT activator or a NEAT conserver, predisposing us to spend more time either sitting or moving. Educators at all levels (family, teachers, and health care providers) should encourage NEAT in multiple settings, ie, the workplace, health care facilities, schools, or any institutions in the community where we spend considerable time. NEAT implementation strategies are particularly critical for overweight and obesity to prevent the health consequences associated with this epidemic. Patients should stand up from their desktops, work in a standing position, climb the stairs, and keep moving to increase the level of NEAT. BMI = body mass index.

ENVIRONMENTAL CONDITIONS FOR PI

The wide variability in work practices and leisure-time activities between individuals plays a fundamental role in NEAT differences.[39] An example illustrating the magnitude of this variability in TEE would be to consider changing the occupation of an individual who works in a chair-bound job to a more active job, such as in an agricultural field. Based on data measuring the energy expenditure of different lifestyles and activity patterns,[40] this type of occupational change could theoretically increase TEE of the same individual up to an extra 2000 kcal/d, primarily through NEAT-related activities.[41]

Social and economic advancement has promoted easy access to hypercaloric foods and overfeeding. This advancement has also made it harder to get enough PA because of easy access to motorized transportation, sedentary jobs, and labor-saving devices, among others.[42] Despite some evidence of obesity-promoting genes,[43] genetic changes alone are unlikely to explain the rapid growth in obesity. It is more likely that a combination of genetic factors and the consequences of an environment that promotes a sedentary lifestyle and easy access to unhealthy food is responsible for the obesity pandemic. A Danish study conducted in 17,058 patients found no difference in BMIs in physically active people with a genetic predisposition to obesity compared with those who did not have the obesity gene.[44]

Leisure-time activity is increasing,[45] and energy is spent more on household activities, transportation, and occupational activity than in sport or recreational activity.[46] Spending 10 inactive hours at work and 8 hours during leisure time[47] affords an opportunity for health care professionals to suggest changes in the work structure that may increase NEAT. Figure 2 summarizes the factors involved in various levels of NEAT.

Ultimately, obesity treatment should emphasize behavioral methods to foster and maintain decreased energy intake with low-calorie diets in addition to behavioral and environmental interventions to facilitate long-term PA adherence.

PI TRANSLATION OF NEAT DEFICIT

Sitting time is independently associated with an increased risk of diabetes[48] and total mortality, regardless of PA level.[49,50] A Canadian study showed a dose-response relationship between sitting time and mortality from all causes and CVD, independent of leisure-time PA.[10] This prospective cohort study followed more than 17,000 patients for an average of 12 years (204,732 person-years of follow-up.) for the ascertainment of mortality status. After adjusting for cofounders, they found a progressively higher risk of all-cause mortality and CVD mortality across higher levels of sitting time (hazard ratio, 1.54; $P<.001$). Therefore, PA does not counteract the negative effects of prolonged sitting. Although seemingly subtle, this distinction is key to our understanding of sedentary behavior.

EVIDENCE BEHIND NEAT BENEFITS

Metabolic Benefits

The importance of the NEAT approach to weight control has already been tested, and benefits have

Mayo Clin Proc. ■ April 2015;90(4):509-519 ■ http://dx.doi.org/10.1016/j.mayocp.2015.02.001
www.mayoclinicproceedings.org

been demonstrated at the metabolic level. Lipoprotein lipase (LPL), an enzyme that plays a central role in the pathogenesis of atherosclerosis and obesity,[51] was measured in rats with different levels of PA. The results show that persistently low- to moderate-intensity activities show higher LPL activity levels compared with nonsustained intense exercises,[52] thus demonstrating the effect of NEAT at modulating LPL and the potential for altering the risk of atherosclerosis. The biochemical benefit of NEAT has also been shown in humans with type 2 diabetes, particularly improving metabolic parameters such as insulin sensitivity, high-density lipoprotein cholesterol level, and blood pressure.[53] In a randomized crossover design study, 18 healthy individuals followed 3 different PA regimens that included sitting for prolonged hours, vigorous exercise for 1 hour, and minimal-intensity PA that consisted of 6 hours of sitting with 4 hours of walking at a leisurely pace and 2 hours of standing. The exercise and minimal-intensity PA regimens differed largely in time spent sitting or lying but were designed to have comparable energy expenditure. Insulin sensitivity and circulating lipid levels were measured in the fasting state the morning after each posture allocation. Triglyceride, non—high-density lipoprotein cholesterol, apolipoprotein B, and insulin plasma levels improved significantly in the minimal-intensity PA regimen compared with sitting and showed nonsignificant trends for improvement compared with exercise.[54]

Cardiovascular Benefits

NEAT not only reduces the occurrence of the metabolic syndrome but also lowers the long-term risk of CVD events and all-cause mortality. A long-term follow-up prospective Swedish study followed a population of 3839 patients, men and women, for 12.5 years, with results showing that patients with higher levels of NEAT, regardless of regular moderate-intensity exercise PA, reduced the risk of CVD events by 27% and all-cause mortality by 30%.[55] These benefits were also shown in another large prospective cohort of 14,345 men followed up for 11.4 years. Participants who maintained or improved NEAT had a lower risk of all-cause mortality and CVD mortality by 15% and 19%, respectively. Change in BMI was not associated with all-cause and CVD mortality after adjusting for possible confounders and changes in fitness.[56]

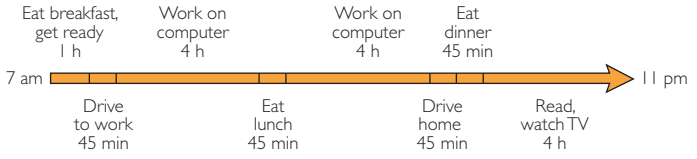

FIGURE 3. Nonexercise activity thermogenesis (NEAT) opportunities to intervene. From awakening to bedtime, most persons have numerous opportunities to increase their NEAT.

NEAT should be considered a primary tool in the management of obesity and PI in patients with CVD. Evidence from a prospective cohort study of 1038 patients with stable coronary heart disease showed that those who practice daily strenuous PA have increased CVD mortality.[57] The study showed a reverse J-shaped association of PA level with CVD mortality, with the most frequently active patients also having increased hazard (2.36; 95% CI, 1.05-5.34).

NEAT IMPLEMENTATION: FROM HOME TO WORKPLACE TO SCHOOL

Household Activities

The promotion of activities with higher NEAT and the numerous opportunities to implement it may be another tool in the armamentarium against the obesity epidemic (Figure 3). Lanningham-Foster et al[58] systematically examined the energetics of mechanization on daily tasks such as manual washing of clothes or dishes, walking to work, and climbing stairs. Performing such NEAT activities instead of using labor-saving equipment could expend considerable energy. For example, performing yard work (100-150 kcal/h) or home cleaning and maintenance (500-600 kcal per night) can expend 10 to 50 times more energy than sitting in front of the television (9 kcal/h).[41]

Initiatives comprising NEAT activities that are beneficial and their calorie expenditure are shown in the Table.[59] The first column includes sedentary activities, such as watching television (TV) and surfing the Internet; these activities burn 0 to 50 kcal/h and should be minimized. Column 2 entails more energetic activities that require standing around the house, such as cooking and ironing, which burn 50 to 100 kcal/h. The last column illustrates activities that maximize NEAT, activities that keep you moving and can burn up to 100

TABLE. Daily Activities According to the Amount of Nonexercise Activity Thermogenesis (NEAT)

Activity	Calories Burned per Hour		
	0-50	>50-100	>100-200
NEAT home activity			
Barbecuing/grilling		X	
Cleaning			X
Clearing out storage space/garage			X
Cooking dinner		X	
Grocery shopping			X
Hanging pictures			X
Ironing		X	
Laundry			X
Organizing closets			X
Painting walls			X
Redecorating			X
Sweeping			X
Vacuuming			X
General NEAT movements			
Climbing stairs			X
Pacing			X
Pushing a stroller			X
Riding in an automobile	X		
Standing		X	
Stretch band exercises		X	
Stretching		X	
Walking (strolling pace)			X
Walking and talking (briskly)			X
Walking around the home/office			X
Walking the dog			X
Walking to work			X
NEAT yard activity			
Playing fetch with dog			X
Gardening			X
Mowing lawn			X
Planting flowers			X
Pruning shrubs			X
Raking leaves			X
Shoveling snow			X
Trimming hedges			X
Washing automobile			X
Watering plants			X
Weeding			X
Hobbies and other recreational NEAT activity			
Baking		X	
Bicycling			X
Bird watching			X
Playing board/card games		X	
Bowling			X
Dancing			X
Fishing			X
Playing Frisbee or other outdoor games			X
Hiking			X
Journaling (while strolling)			X
Knitting/sewing		X	
Kayaking			X
Playing the piano or another musical instrument		X	

Continued on next page

to 200 kcal/h above the BMR, such as sweeping or gardening for 1 hour. Once an individual learns how many calories can be expended, it becomes easier to achieve NEAT caloric goals. Patients should consider changing sedentary habits and seated time into NEAT activities, such as taking the stairs instead of the elevator, reading the newspaper, or watching TV on a stationary bike. Essentially, activities that create movement will enhance caloric expenditure.

A randomized controlled pilot trial studied the feasibility and efficacy of NEAT during leisure-time activities.[60] The trial examined the benefits of stepping in place during TV commercials in an inactive population of adults to increase PA and simultaneously combat the negative effects of sedentary TV viewing. The results showed favorable outcomes ($P<.05$) not only augmenting the number of daily steps but also decreasing the TV viewing time and improving anthropometrics.

Workplace Activities

The workplace can also facilitate NEAT activities. Individuals spend more than half the day seated at work,[61] and this affords an opportunity for promoting PA and reducing sedentary time.[62] With current technology, a NEAT-promoting workstation is now feasible.[63] Researchers have demonstrated that people will use a walking workstation while performing traditional office functions. Other modalities with the same technology, such as a workstation stepping device, have shown an increase in PA while at work.[64] In addition, simple interventions that have been validated in the laboratory and assessed for safety and utility for use by obese individuals include a lanyard with the tag "Walk-and-Talk Meeting in Progress"[63] and the placement of printers and trash cans farther away from workstations and break areas. Figure 4 shows a theoretical example of how an individual could increase the energy expended with NEAT at work and during leisure time, and the potential effect on weight loss. The Supplemental Table (available online at http://www.mayoclinicproceedings.org) illustrates solutions related to NEAT in the work environment.

Conception to Childhood

Empirical evidence hypothesized a novel intergenerational theory of the etiology of the childhood obesity epidemic in which nongenetic

Mayo Clin Proc. ■ April 2015;90(4):509-519 ■ http://dx.doi.org/10.1016/j.mayocp.2015.02.001
www.mayoclinicproceedings.org

vectors of evolution, such as maternal deficit of NEAT and PI during pregnancy, among other socioenvironmental factors, are the predominant causal elements in the recent rise in the prevalence of childhood obesity.[65] Once established, childhood obesity is an important predictor of adult obesity, and it may be amenable to intervention.[66] The most successful intervention will be that which prevents the development of obesity before the reproductive years. An exciting possibility is that NEAT-promoting activities could be applied and encouraged in a similar form to pregnant women and during childhood to prevent onset of the obesity pandemic and related complications. A pilot program tested the hypothesis that elementary school–aged children would be more physically active while attending school in a novel, activity-permissive environment compared with a traditional school. Compared with children in the traditional school, children in the activity-permissive school were found to move almost twice as much,[67] thereby increasing NEAT energy expenditure. Furthermore, educational attainment improved.[68] With this evidence and public health policy statements emphasizing the limitation of PI,[69,70] NEAT may afford an opportunity to reduce obesity in childhood.

NEAT FEASIBILITY IN THE COMMUNITY

An example of the effectiveness of NEAT in a community setting where the prevalence of obesity is low is the Amish communities. NEAT is applied and accumulated throughout the day during occupational requirements, chores, errands, and transportation. Only 4% of Amish adults are obese. They walk an average of 18,000 steps per day, perhaps the highest mean value reported for a sample at this time,[71] compared with non-Amish US adults, who average approximately 5100 steps per day.[72]

NEAT QUANTIFICATION

One of the challenges faced by researchers trying to promote PA is having access to accurate and practical instruments to measure, monitor, and increase the efficiency of measuring PA in a continuous and unobtrusive manner.[73] In the past decade, technologies using low-power and low-cost electronic sensors have emerged. These devices can assess PA and its determinants. Instruments such as accelerometers provide new ways to collect and estimate the intensity, duration, and frequency of PA, mitigating the recall bias of self-report instruments. Given the rapid growth of mobile phone technology, stand-alone devices with consumer applications have been validated. Accelerometers in mobile phones enable precise and accurate measurement of daily PA,[74] and wireless technology makes them even friendlier to users.

Pedometers and step logs are relatively low-cost and attractive strategies for encouraging the measurement of PA.[75] With these technologies, it is easy to self-monitor and accomplish personal goals.[76] Evidence from studies showed a significant improvement not only in the average total steps but also in BMI and systolic and diastolic blood pressure. No changes were seen in energy intake.[77]

A limitation of tracking NEAT using these novel devices is assuming that all PAs have an energy cost equivalent while ignoring the intrinsic differences in fitness.[78] Accelerometers still have limitations regarding generalizability and validity, between-study comparability, and sustainability.[79] In addition, to implement and evaluate interventions designed to increase PA participation, it is essential to further our understanding of PA behaviors in the different

TABLE. Continued

Activity	Calories Burned per Hour		
	0-50	>50-100	>100-200
Hobbies and other recreational NEAT activity, continued			
Reading (lounging)	X		
Reading (standing)		X	
Skiing (water or snow)			X
Surfing the Web (sitting)	X		
Surfing the Web (standing)		X	
Swimming			X
Practicing Tai Chi			X
Playing tennis			X
Watching TV	X		
Watching TV on an elliptical trainer			X
Watching TV on a stationary bike			X
Watching TV on a treadmill			X
Playing video games (seated)	X		
Playing video games (while moving)			X
Doing volunteer work (setting up/serving meals)			X
Window shopping			X
Practicing yoga			X

TV = television.

Data from *Move a Little, Lose a Lot: New NEAT Science Reveals How to Be Thinner, Happier, and Smarter.*[59]

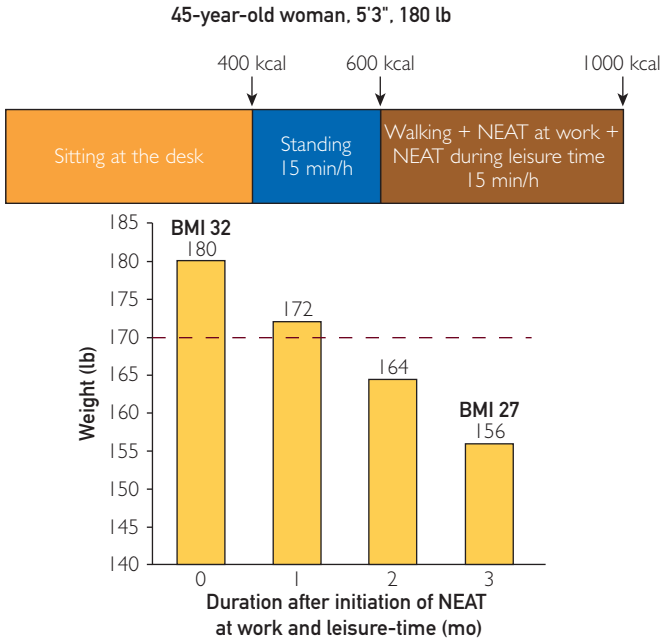

FIGURE 4. Implementing nonexercise activity thermogenesis (NEAT): a theoretical model. With increased NEAT at work and during leisure time, a 45-year-old female office worker who is 5 feet 3 inches tall, weighs 180 lb, and has a body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) of 32 could, in theory, reduce weight and BMI over 3 months to healthier levels. She expends 400 kcal while sitting for 8 hours. By progressively increasing standing and walking and adding other NEAT activities during work and leisure time, she can theoretically decrease her BMI from 32 to 27 in 3 months. The dotted line represents the obesity threshold.

stages of life, from childhood to early and late adulthood, as movement patterns during these unique periods differ; and PA recommendations are specific for each age group.[80]

NEAT AS A COMPLEMENT TO PURPOSEFUL PA

The health benefits to support purposeful aerobic exercise are well-known,[81] and NEAT should not be considered a substitute. There is broad agreement among clinicians and public health experts that moderate- to vigorous-intensity PA of at least 30 minutes 5 days per week for a total of 150 minutes is recommended by guidelines.[82] The benefits of moderate- to vigorous-intensity exercise in CVD are clear.[83,84] However, the long-term success from recent randomized studies has been disappointing,[12] especially in overweight and obese patients,[85] with poor compliance[86] despite the widespread promotion.[87] On average, 15% of individuals succeeded in maintaining their initial weight loss,[88] and in those who succeeded, the interventions resulted in modest weight loss, which was gradually regained over time.[89]

The average American sleeps 8.5 hours per day, allowing 15.5 hours in which exercise is not being practiced as recommended in the guidelines. The average exercise time in adults is 18 minutes, and more than half of all leisure time is spent watching TV and engaging in other sedentary activities.[90] The available information obtained from self-report questionnaires provides insight into the PA levels of the American population (considering the recall and response bias often involved with the use of this method).[91] NEAT may be considered as a substitute for the amount of time currently spent sitting to increase the low-grade energy expenditure that sitting offers.

Compliance with purposeful exercise is low. On the contrary, NEAT has a higher rate of adherence over time. This was observed in a Chinese study that compared the prevalence of purposeful exercise and NEAT in 32,005 adolescents; NEAT remained high over time and seemed easier to accumulate than exercise in adolescents regardless of age or sex.[92]

NEAT LIMITATIONS AND FUTURE ONGOING TRIALS

Although several clinical trials and cohort studies have assessed the benefit of NEAT body morphometrics, blood pressure, and lipid markers, there are no robust studies assessing long-term outcomes on cardiovascular events or cardiovascular mortality. The potential benefit of obesity reduction on the musculoskeletal system and related orthopedic conditions has yet to be elucidated as well. In the past decade, attention has shifted to implementing an intensive lifestyle intervention to reduce obesity. This effort includes moderate- to vigorous-intensity PA, although long-term results have been less than expected. For this reason, alternative well-designed strategies for weight management that incorporate a healthy diet, purposeful exercise activity, and interventions designed to decrease sedentary time and promote NEAT activities should be considered. A robust study using these strategies, with intermediary, biochemical, and cardiovascular outcomes and mortality, should be performed.

Mayo Clin Proc. ■ April 2015;90(4):509-519 ■ http://dx.doi.org/10.1016/j.mayocp.2015.02.001
www.mayoclinicproceedings.org

Several trials evaluating NEAT effectiveness on weight loss and PA promotion are currently ongoing or in the process of completion, with the results expected in 2015. The I-CAN trial (Intervention Composed of Aerobic Training and Non-Exercise Physical Activity) will determine the effects of aerobic exercise training and increasing the amount of NEAT outside of training on the fat around the abdomen, weight, fitness, and sensitivity to insulin. The RISE trial (Reducing Sedentary Behavior vs Increasing Physical Activity in Older Adults) is another randomized controlled trial comparing the effects of PA interventions in older adults who are able to walk for exercise. One intervention will target 150 min/wk of brisk walking, consistent with current recommendations, and the other intervention will target a decrease in time spent in sedentary behaviors (eg, sitting) of 60 min/d. In both interventions, enrollees will wear an activity armband that will allow self-monitoring of activity or sedentary behavior in real time using a smartphone. To investigate the effect of NEAT on baseline PA and sedentary behaviors in occupational activities, a Swedish randomized controlled trial is currently recruiting patients to implement active office workstations compared with conventional office spaces. Thus far, none of these studies a priori plan to look at cardiovascular outcomes, but that would be the next phase of study should these findings prove encouraging.

CONCLUSION

Physical inactivity may be one of the factors contributing to the global obesity pandemic. Reducing and breaking up the time spent in sedentary behaviors and preserving PA is extremely important to ameliorate obesity. Besides recommending practicing moderate- to vigorous-intensity PA, counseling and promotion of NEAT should be considered by health care providers to help control obesity. Encouragement and assistance in promoting personal and environmental behaviors of the NEAT concept should be encouraged in a manner similar to guideline-recommended physical exercise for obese patients. By avoiding sitting, promoting motion, and engaging in simple, repetitive, and creative activities, a significant amount of extra calories may be expended that can reduce weight and perhaps prevent the cardiovascular and metabolic complications associated with obesity.

ACKNOWLEDGMENTS

We thank Dr. Eric H. Yang for the creation of Figure 4.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mayoclinicproceedings.org.

Abbreviations and Acronyms: **BMI** = body mass index; **BMR** = basal metabolic rate; **CVD** = cardiovascular disease; **LPL** = lipoprotein lipase; **NEAT** = nonexercise activity thermogenesis; **PA** = physical activity; **PI** = physical inactivity; **TEE** = total energy expenditure; **TEF** = thermic effect of food; **TV** = television

Correspondence: Address to Pedro A. Villablanca, MD, MSc, Division of Cardiovascular Diseases, Montefiore Medical Center/Albert Einstein College of Medicine, 111 E 210th St, Bronx, NY 10467 (pvillabl@montefiore.org).

REFERENCES

1. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity in the United States, 2009-2010. *NCHS Data Brief*. 2012;82:1-8.
2. National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res*. 1998;6(suppl 2):51S-209S.
3. Poirier P, Giles TD, Bray GA, et al. Obesity and cardiovascular disease: pathophysiology, evaluation, and effect of weight loss: an update of the 1997 American Heart Association Scientific Statement on Obesity and Heart Disease from the Obesity Committee of the Council on Nutrition, Physical Activity, and Metabolism. *Circulation*. 2006;113(6):898-918.
4. Masters RK, Reither EN, Powers DA, Yang YC, Burger AE, Link BG. The impact of obesity on US mortality levels: the importance of age and cohort factors in population estimates. *Am J Public Health*. 2013;103(10):1895-1901.
5. Finkelstein EA, Trogdon JG, Cohen JW, Dietz W. Annual medical spending attributable to obesity: payer-and service-specific estimates. *Health Aff (Millwood)*. 2009;28(5):w822-w831.
6. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*. 2012;380(9838):247-257.
7. Church TS, Thomas DM, Tudor-Locke C, et al. Trends over 5 decades in U.S. occupation-related physical activity and their associations with obesity. *PLoS One*. 2011;6(5):e19657.
8. Archer E, Shook RP, Thomas DM, et al. 45-Year trends in women's use of time and household management energy expenditure. *PLoS One*. 2013;8(2):e56620.
9. Flegal KM, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. *JAMA*. 2013;309(1):71-82.
10. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc*. 2009;41(5):998-1005.
11. Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *J Am Coll Cardiol*. 2014;63(25, pt B):2985-3023.

12. Wing RR, Bolin P, Brancati FL, et al. Cardiovascular effects of intensive lifestyle intervention in type 2 diabetes. *N Engl J Med*. 2013;369(2):145-154.
13. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand: quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011; 43(7):1334-1359.
14. Levine J, Baukol P, Pavlidis I. The energy expended in chewing gum. *N Engl J Med*. 1999;341(27):2100.
15. Kumahara H, Tanaka H, Schutz Y. Daily physical activity assessment: what is the importance of upper limb movements vs whole body movements? *Int J Obes Relat Metab Disord*. 2004; 28(9):1105-1110.
16. Dauncey MJ. Activity and energy expenditure. *Can J Physiol Pharmacol*. 1990;68(1):17-27.
17. Levine JA, Schleusner SJ, Jensen MD. Energy expenditure of nonexercise activity. *Am J Clin Nutr*. 2000;72(6):1451-1454.
18. Ravussin E, Lillioja S, Anderson TE, Christin L, Bogardus C. Determinants of 24-hour energy expenditure in man: methods and results using a respiratory chamber. *J Clin Invest*. 1986; 78(6):1568-1578.
19. Tentolouris N, Tsigos C, Perea D, et al. Differential effects of high-fat and high-carbohydrate isoenergetic meals on cardiac autonomic nervous system activity in lean and obese women. *Metabolism*. 2003;52(11):1426-1432.
20. Nagai N, Sakane N, Hamada T, Kimura T, Moritani T. The effect of a high-carbohydrate meal on postprandial thermogenesis and sympathetic nervous system activity in boys with a recent onset of obesity. *Metabolism*. 2005;54(4):430-438.
21. Levine JA. Nonexercise activity thermogenesis (NEAT): environment and biology. *Am J Physiol Endocrinol Metab*. 2004; 286(5):E675-E685.
22. Lavie CJ, McAuley PA, Church TS, Milani RV, Blair SN. Obesity and cardiovascular diseases: implications regarding fitness, fatness, and severity in the obesity paradox. *J Am Coll Cardiol*. 2014;63(14):1345-1354.
23. Maes HH, Neale MC, Eaves LJ. Genetic and environmental factors in relative body weight and human adiposity. *Behav Genet*. 1997;27(4):325-351.
24. Kotz CM, Teske JA, Billington CJ. Neuroregulation of nonexercise activity thermogenesis and obesity resistance. *Am J Physiol Regul Integr Comp Physiol*. 2008;294(3):R699-R710.
25. Novak CM, Zhang M, Levine JA. Neuromedin U in the paraventricular and arcuate hypothalamic nuclei increases non-exercise activity thermogenesis. *J Neuroendocrinol*. 2006;18(8):594-601.
26. Castaneda TR, Jurgens H, Wiedmer P, et al. Obesity and the neuroendocrine control of energy homeostasis: the role of spontaneous locomotor activity. *J Nutr*. 2005;135(5):1314-1319.
27. Proulx K, Cota D, Castaneda TR, et al. Mechanisms of oleoylethanolamide-induced changes in feeding behavior and motor activity. *Am J Physiol Regul Integr Comp Physiol*. 2005; 289(3):R729-R737.
28. Trayhurn P, Bing C, Wood IS. Adipose tissue and adipokines: energy regulation from the human perspective. *J Nutr*. 2006; 136(7 suppl):1935S-1939S.
29. Novak CM, Levine JA. Central neural and endocrine mechanisms of non-exercise activity thermogenesis and their potential impact on obesity. *J Neuroendocrinol*. 2007;19(12):923-940.
30. Hara J, Beuckmann CT, Nambu T, et al. Genetic ablation of orexin neurons in mice results in narcolepsy, hypophagia, and obesity. *Neuron*. 2001;30(2):345-354.
31. Kiwaki K, Kotz CM, Wang C, Lanningham-Foster L, Levine JA. Orexin A (hypocretin 1) injected into hypothalamic paraventricular nucleus and spontaneous physical activity in rats. *Am J Physiol Endocrinol Metab*. 2004;286(4):E551-E559.
32. John J, Wu MF, Siegel JM. Systemic administration of hypocretin-1 reduces cataplexy and normalizes sleep and waking durations in narcoleptic dogs. *Sleep Res Online*. 2000;3(1):23-28.
33. Novak CM, Kotz CM, Levine JA. Central orexin sensitivity, physical activity, and obesity in diet-induced obese and diet-resistant rats. *Am J Physiol Endocrinol Metab*. 2006;290(2):E396-E403.
34. Teske JA, Levine AS, Kuskowski M, Levine JA, Kotz CM. Elevated hypothalamic orexin signaling, sensitivity to orexin A, and spontaneous physical activity in obesity-resistant rats. *Am J Physiol Regul Integr Comp Physiol*. 2006;291(4): R889-R899.
35. Kok SW, Overeem S, Visscher TL, et al. Hypocretin deficiency in narcoleptic humans is associated with abdominal obesity. *Obes Res*. 2003;11(9):1147-1154.
36. Levine JA. Nonexercise activity thermogenesis: liberating the life-force. *J Intern Med*. 2007;262(3):273-287.
37. Levine JA, Lanningham-Foster LM, McCrady SK, et al. Interindividual variation in posture allocation: possible role in human obesity. *Science*. 2005;307(5709):584-586.
38. Diaz EO, Prentice AM, Goldberg GR, Murgatroyd PR, Coward WA. Metabolic response to experimental overfeeding in lean and overweight healthy volunteers. *Am J Clin Nutr*. 1992; 56(4):641-655.
39. Kruger J, Yore MM, Kohl HW III. Leisure-time physical activity patterns by weight control status: 1999-2002 NHANES. *Med Sci Sports Exerc*. 2007;39(5):788-795.
40. Black AE, Coward WA, Cole TJ, Prentice AM. Human energy expenditure in affluent societies: an analysis of 574 doubly-labelled water measurements. *Eur J Clin Nutr*. 1996;50(2):72-92.
41. McCrady-Spitzer SK, Levine JA. Nonexercise activity thermogenesis: a way forward to treat the worldwide obesity epidemic. *Surg Obes Relat Dis*. 2012;8(5):501-506.
42. Qi L, Cho YA. Gene-environment interaction and obesity. *Nutr Rev*. 2008;66(12):684-694.
43. Speliotes EK, Willer CJ, Berndt SI, et al. Association analyses of 249,796 individuals reveal 18 new loci associated with body mass index. *Nat Genet*. 2010;42(11):937-948.
44. Andreasen CH, Stender-Petersen KL, Mogensen MS, et al. Low physical activity accentuates the effect of the FTO rs9939609 polymorphism on body fat accumulation. *Diabetes*. 2008; 57(1):95-101.
45. Steffen LM, Arnett DK, Blackburn H, et al. Population trends in leisure-time physical activity: Minnesota Heart Survey, 1980-2000. *Med Sci Sports Exerc*. 2006;38(10):1716-1723.
46. De Vera MA, Ratzlaff C, Doerfling P, Kopec J. Reliability and validity of an internet-based questionnaire measuring lifetime physical activity. *Am J Epidemiol*. 2010;172(10): 1190-1198.
47. McCrady SK, Levine JA. Sedentariness at work: how much do we really sit? *Obesity (Silver Spring)*. 2009;17(11):2103-2105.
48. Manini TM, Lamonte MJ, Seguin RA, et al. Modifying effect of obesity on the association between sitting and incident diabetes in post-menopausal women. *Obesity (Silver Spring)*. 2014;22(4): 1133-1141.
49. Patel AV, Bernstein L, Deka A, et al. Leisure time spent sitting in relation to total mortality in a prospective cohort of US adults. *Am J Epidemiol*. 2010;172(4):419-429.
50. Warren TY, Barry V, Hooker SP, Sui X, Church TS, Blair SN. Sedentary behaviors increase risk of cardiovascular disease mortality in men. *Med Sci Sports Exerc*. 2010;42(5):879-885.
51. Zechner R, Strauss J, Frank S, et al. The role of lipoprotein lipase in adipose tissue development and metabolism. *Int J Obes Relat Metab Disord*. 2000;24(suppl 4):S53-S56.
52. Bey L, Hamilton MT. Suppression of skeletal muscle lipoprotein lipase activity during physical inactivity: a molecular reason to maintain daily low-intensity activity. *J Physiol*. 2003;551(pt 2): 673-682.
53. Hamasaki H, Yanai H, Mishima S, et al. Correlations of non-exercise activity thermogenesis to metabolic parameters in Japanese patients with type 2 diabetes. *Diabetol Metab Syndr*. 2013; 5(1):26.
54. Duvivier BM, Schaper NC, Bremers MA, et al. Minimal intensity physical activity (standing and walking) of longer duration

improves insulin action and plasma lipids more than shorter periods of moderate to vigorous exercise (cycling) in sedentary subjects when energy expenditure is comparable. *PLoS One*. 2013;8(2):e55542.
55. Ekblom-Bak E, Ekblom B, Vikstrom M, de Faire U, Hellenius ML. The importance of non-exercise physical activity for cardiovascular health and longevity. *Br J Sports Med*. 2014;48(3):233-238.
56. Lee DC, Sui X, Artero EG, et al. Long-term effects of changes in cardiorespiratory fitness and body mass index on all-cause and cardiovascular disease mortality in men: the Aerobics Center Longitudinal Study. *Circulation*. 2011;124(23):2483-2490.
57. Mons U, Hahmann H, Brenner H. A reverse J-shaped association of leisure time physical activity with prognosis in patients with stable coronary heart disease: evidence from a large cohort with repeated measurements. *Heart*. 2014;100(13):1043-1049.
58. Lanningham-Foster L, Nysse LJ, Levine JA. Labor saved, calories lost: the energetic impact of domestic labor-saving devices. *Obes Res*. 2003;11(10):1178-1181.
59. Levine J. Preparing for the NEAT life: losing weight is only half the fun. In: *Move a Little, Lose a Lot. New NEAT Science Reveals How to Be Thinner, Happier, and Smarter*. New York, NY: Crown Publishers; 2009:81-83.
60. Steeves JA, Bassett DR, Fitzhugh EC, Raynor HA, Thompson DL. Can sedentary behavior be made more active? a randomized pilot study of TV commercial stepping versus walking. *Int J Behav Nutr Phys Act*. 2012;9:95.
61. Marshall S, Gyi D. Evidence of health risks from occupational sitting: where do we stand? *Am J Prev Med*. 2010;39(4):389-391.
62. Pronk NP. Physical activity promotion in business and industry: evidence, context, and recommendations for a national plan. *J Phys Act Health*. 2009;6(suppl 2):S220-S235.
63. Levine JA, Miller JM. The energy expenditure of using a "walk-and-work" desk for office workers with obesity. *Br J Sports Med*. 2007;41(9):558-561.
64. McAlpine DA, Manohar CU, McCrady SK, Hensrud D, Levine JA. An office-place stepping device to promote workplace physical activity. *Br J Sports Med*. 2007;41(12):903-907.
65. Archer E. The childhood obesity epidemic as a result of nongenetic evolution: the maternal resources hypothesis. *Mayo Clin Proc*. 2015;90(1):77-92.
66. Eriksson J, Forsen T, Osmond C, Barker D. Obesity from cradle to grave. *Int J Obes Relat Metab Disord*. 2003;27(6):722-727.
67. Lanningham-Foster L, Foster RC, McCrady SK, et al. Changing the school environment to increase physical activity in children. *Obesity (Silver Spring)*. 2008;16(8):1849-1853.
68. Prince M. Does active learning work? a review of the research. *J Eng Educ*. 2004;93(3):223-231.
69. Krebs NF, Jacobson MS. Prevention of pediatric overweight and obesity. *Pediatrics*. 2003;112(2):424-430.
70. Vanhees L, De Sutter J, Gelada SN, et al. Importance of characteristics and modalities of physical activity and exercise in defining the benefits to cardiovascular health within the general population: recommendations from the EACPR (part I). *Eur J Prev Cardiol*. 2012;19(4):670-686.
71. Bassett DR, Schneider PL, Huntington GE. Physical activity in an Old Order Amish community. *Med Sci Sports Exerc*. 2004;36(1):79-85.
72. Bassett DR Jr, Wyatt HR, Thompson H, Peters JC, Hill JO. Pedometer-measured physical activity and health behaviors in U.S. adults. *Med Sci Sports Exerc*. 2010;42(10):1819-1825.
73. Reilly JJ, Penpraze V, Hislop J, Davies G, Grant S, Paton JY. Objective measurement of physical activity and sedentary behaviour: review with new data. *Arch Dis Child*. 2008;93(7):614-619.
74. Manohar CU, McCrady SK, Fujiki Y, Pavlidis IT, Levine JA. Evaluation of the accuracy of a triaxial accelerometer embedded into a cell phone platform for measuring physical activity. *J Obes Weight Loss Ther*. 2012;1(106):3309.
75. Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: a systematic review. *JAMA*. 2007;298(19):2296-2304.
76. Yamanouchi K, Shinozaki T, Chikada K, et al. Daily walking combined with diet therapy is a useful means for obese NIDDM patients not only to reduce body weight but also to improve insulin sensitivity. *Diabetes Care*. 1995;18(6):775-778.
77. Johnson ST, Bell GJ, McCargar LJ, Welsh RS, Bell RC. Improved cardiovascular health following a progressive walking and dietary intervention for type 2 diabetes. *Diabetes Obes Metab*. 2009;11(9):836-843.
78. Troiano RP, Freedson PS. Promises and pitfalls of emerging measures of physical activity and the environment. *Am J Prev Med*. 2010;38(6):682-683.
79. Pedisic Z, Bauman A. Accelerometer-based measures in physical activity surveillance: current practices and issues. *Br J Sports Med*. 2015;49(4):219-223.
80. World Health Organization. Global recommendations on physical activity for health. WHO website. http://www.who.int/dietphysicalactivity/factsheet_recommendations/en. Accessed December 4, 2014.
81. Warburton DE, Katzmarzyk PT, Rhodes RE, Shephard RJ. Evidence-informed physical activity guidelines for Canadian adults. *Can J Public Health*. 2007;98(suppl 2):S16-S68.
82. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116(9):1081-1093.
83. Taylor RS, Brown A, Ebrahim S, et al. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. *Am J Med*. 2004;116(10):682-692.
84. Haykowsky MJ, Timmons MP, Kruger C, McNeely M, Taylor DA, Clark AM. Meta-analysis of aerobic interval training on exercise capacity and systolic function in patients with heart failure and reduced ejection fractions. *Am J Cardiol*. 2013;111(10):1466-1469.
85. McTiernan A, Sorensen B, Irwin ML, et al. Exercise effect on weight and body fat in men and women. *Obesity (Silver Spring)*. 2007;15(6):1496-1512.
86. Dunton GF, Berrigan D, Ballard-Barbash R, Graubard BI, Atienza AA. Environmental influences on exercise intensity and duration in a U.S. time use study. *Med Sci Sports Exerc*. 2009;41(9):1698-1705.
87. Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion. Steps to wellness: a guide to implementing the 2008 Physical Activity Guidelines for Americans in the Workplace. CDC website. http://www.cdc.gov/nccdphp/dnpao/hwi/downloads/Steps2Wellness_BROCH14_508_Tag508.pdf. Accessed September 2, 2014.
88. Ayyad C, Andersen T. Long-term efficacy of dietary treatment of obesity: a systematic review of studies published between 1931 and 1999. *Obes Rev*. 2000;1(2):113-119.
89. Dansinger ML, Tatsioni A, Wong JB, Chung M, Balk EM. Meta-analysis: the effect of dietary counseling for weight loss. *Ann Intern Med*. 2007;147(1):41-50.
90. American time use survey—2013 results. US Bureau of Labor Statistics website. http://www.bls.gov. Accessed December 4, 2014.
91. Shephard RJ. Limits to the measurement of habitual physical activity by questionnaires. *Br J Sports Med*. 2003;37(3):197-206; discussion 206.
92. Mak KK, Ho SY, Lo WS, McManus AM, Lam TH. Prevalence of exercise and non-exercise physical activity in Chinese adolescents. *Int J Behav Nutr Phys Act*. 2011;8:3.