'Too Much Sitting' and Metabolic Risk—Has Modern Technology Caught Up with Us?

David W Dunstan, PhD,[1,2,3,4,5] Genevieve N Healy, PhD,[1,3] Takemi Sugiyama, PhD[3] and Neville Owen, PhD[3]

1. Baker IDI Heart and Diabetes Institute, Melbourne; 2. Department of Epidemiology and Preventive Medicine, Monash University, Melbourne; 3. Cancer Prevention Research Centre, School of Population Health, The University of Queensland; 4. School of Exercise and Nutrition Sciences, Deakin University, Melbourne; 5. Vario Health Institute, Edith Cowan University, Perth

DOI: 10.17925/USE.2009.05.1.29

Abstract

Recent epidemiological evidence suggests that prolonged sitting (sedentary behavior: time spent in behaviors that have very low energy expenditure, such as television viewing and desk-bound work) has deleterious cardiovascular and metabolic correlates, which are present even among adults who meet physical activity and health guidelines. Further advances in communication technology and other labor-saving innovations make it likely that the ubiquitous opportunities for sedentary behavior that currently exist will become even more prevalent in the future. We present evidence that sedentary behavior (too much sitting) is an important stand-alone component of the physical activity and health equation, particularly in relation to cardio-metabolic risk, and discuss whether it is now time to consider public health and clinical guidelines on reducing prolonged sitting time that are in addition to those promoting regular participation in physical activity.

Keywords

Sedentary behavior, sitting time, physical inactivity, cardio-metabolic risk

Disclosure: The authors have no conflicts of interest to declare.
Acknowledgments: We wish to express our thanks to Associate Professor Jo Salmon, Deakin University for her assistance in the conceptualization and production of *Figure 3*.
Received: May 21, 2009 **Accepted:** September 7, 2009
Correspondence: David W Dunstan, PhD, Baker IDI Heart and Diabetes Institute, 250 Kooyong Road, Caulfield, Victoria, Australia, 3162. E: david.dunstan@bakeridi.edu.au

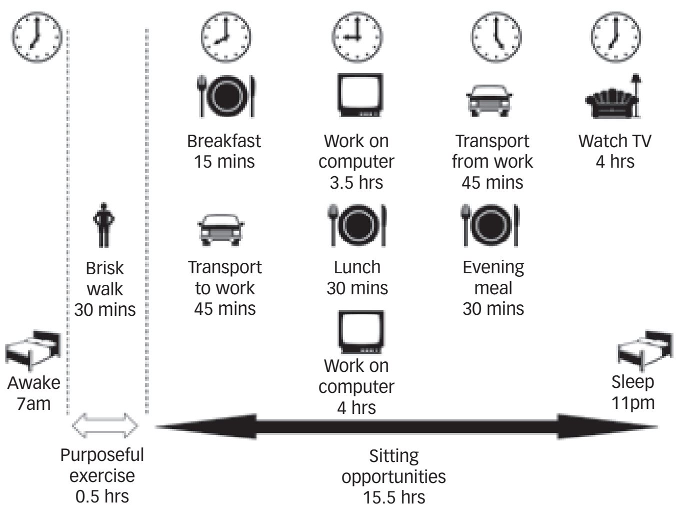
There is general recognition among physicians and other health professionals that regular participation in moderate- to vigorous-intensity physical activity (i.e. brisk walking, jogging, lap-swimming) is one of the cornerstones of chronic disease prevention and management. In addition to the physical and psychological benefits, there is considerable evidence that moderate- to vigorous-intensity activity has a positive influence on cardio-metabolic risk factors.[1] As a consequence, public health campaigns and recommendations regarding advice that may be provided by health professionals have typically focused on this intensity of physical activity, with current recommendations supporting the accumulation of at least 30 minutes of moderate to vigorous activity on at least five days of the week.[1]

While there has been some success with these public health campaigns, evident through the population-wide increases in leisure-time physical activity being observed in some countries over the past 10 years, this success has also coincided with a rapid rise in the prevalence of overweight and obesity in several countries over the same period.[2] Several factors may explain this apparent paradox. The most plausible explanation is the sole focus on an important, but limited, element of the overall physical activity spectrum: moderate- to vigorous-intensity activities. Focusing on this single component does not address the health consequences of participation in the plethora of sedentary behaviors that occupy the waking hours of most adults.

For instance, for a person who typically sleeps eight hours per day, meeting the minimum public health physical activity levels of 30 minutes of moderate- to vigorous-intensity activity each day constitutes only a small proportion of the remaining 16 hours in his or her day (see *Figure 1*). Indeed, recent studies that have used accelerometers to objectively measure daily physical activity among Australian adults have identified that, on average, the majority of adults' non-sleeping hours (up to 60%) is spent in sedentary time, with the remainder being disproportionally distributed to light-intensity (incidental movement) (35%), and only a small fraction of time to moderate to vigorous physical activities (usually less than 5%; see *Figure 2*).[3]

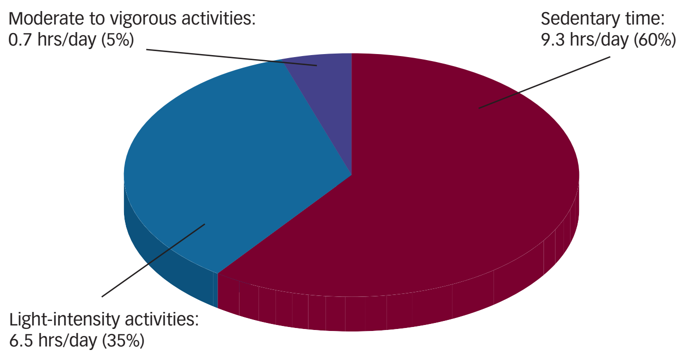
Sedentary time, derived from the Latin word 'sedere' meaning 'to sit', represents the time that individuals spend in various behaviors that require low energy expenditure such as working on the computer, watching television, or driving a car. Sedentary behavior, often used interchangeably with sedentary time, is the term now used to collectively characterise those behaviors that people encounter at home, at work, and during leisure and transportation that involve prolonged sitting rather than ambulatory movement.[4–6]

Figure 1: For an Individual Who Sleeps Eight Hours Each Night, the Remaining 16 Hours of the Day Are Typically Filled with Domestic and Work Duties



For this hypothetical 'physically active' adult who rises from the bed at 7am, a 30-minute brisk walk prior to breakfast ensures that the minimum level of 'purposeful exercise' is achieved early in the day. However, this person then sits for 15 minutes to eat breakfast followed by a car trip to work that takes 45 minutes. At work, this person spends the next 3.5 hours of the morning sitting at the office desk while working on the computer. At lunchtime this person sits in the lunchroom to consume lunch during the 30-minute lunch break. This is followed by another four hours sitting at the office desk while working on the computer. At the end of the work day, the person travels in the car for another 45 minutes before sitting down at the dining table to consume the evening meal. The day concludes with watching the favorite television shows with the family for the next four hours while seated on the sofa. Overall, in percentage terms, for this hypothetical person, up to 97% of waking hours may be spent in sitting activities. Yet, by undertaking 30 minutes of brisk walking, according to current public health guidelines, this person is 'physically active.' The new term 'active couch potato' is probably more appropriate. Source: Hamilton et al., 2008.[4]

Figure 2: Objectively Measured (Accelerometer) Distributions of Sedentary Time, Light-intensity Physical Activity, and Moderate- to Vigorous-intensity Physical Activity During Waking Hours in Australian Adults



Source: Heaky et al., 2008.[27]

Recent evidence indicates that time spent in sedentary behaviors, independent of time spent in moderate- to vigorous-intensity activity, is related to health outcomes and cardio-metabolic biomarkers of chronic disease risk among adults.[4] The independence of these two behaviors is further reinforced in studies that have demonstrated detrimental cardio-metabolic health outcomes for 'active couch potatoes' (i.e. those individuals who meet the physical activity guidelines but also have high sedentary time; see *Figure 3*).[7–9] These findings have led to the emergence of a strong scientific interest in understanding and influencing sedentary behavior.

In this article, we posit that sedentary behavior (too much sitting) may be at least as important a public health problem as the lack of moderate- to vigorous-intensity physical activity (too little exercise). We put forward an argument for an expanded perspective on physical activity and health where behavior (both sedentary and physical activity) across the day and at all intensities should be considered. We present a brief overview of recent evidence that identifies too much sitting as an important ingredient of the physical activity and health equation, particularly in relation to cardio-metabolic risk. We emphasise that the impacts of too much sitting need to be considered as influences that are additional to the still very important clinical and public health concerns about too little exercise.

Sedentary Behavior—The Downside of Modern Technology

If one were able to travel back in time to any period prior to the 1970s and experience (or re-experience) the lifestyle that existed at that time, it would be readily apparent that one would be exposed to a remarkably different environment than exists today. In particular, the rapidly evolving innovations that have taken place over the past few decades have led to an ever-increasing reliance on information and communication technologies and other labor-saving devices, with associated decreases in energy expenditure.[10]

Effectively, in today's modern society, prolonged sitting has been engineered into our lives across many settings, including transportation, the workplace, and the home.[11] This is reflected in time-use surveys that have shown a progressive rise in the time spent in sedentary behaviors such as television (TV) viewing, computer game use, and 'surfing the net,' and also the rapid rise in car ownership and usage patterns.[12]

Sedentary behavior has also been embedded into many workplaces: computers and labor-saving devices have replaced much of the need to stand up and move about at work, as well as the physical activity involved in manual handling tasks. For example, prior to the introduction of emails it was common practice to walk and talk to a colleague about work issues, or to send a letter in the post that invariably required a short walk to a centralised mail room for the letter to be distributed. Another pertinent example for clinicians and physicians is the reliance on electronic records of a patient's medical history, contrasting with previous eras whereby obtaining such information required a short walk to the medical records office. Unfortunately, the continued interest and pursuit of labor-saving devices across various settings does not show any signs of slowing down. Therefore, it is possible that we have not yet reached the full potential for prolonged, ubiquitous sitting, nor have we fully uncovered what the health consequences are likely to be.[13]

Sedentary Behavior and Cardio-metabolic Health

In contrast to the decades of research pertaining to the cardio-metabolic benefits of moderate to vigorous physical activity, the scientific interest in understanding the influence of prolonged sitting on cardio-metabolic risk is in its relative infancy, with most of the evidence being centered on epidemiological associations. In particular, most of this work has focused on the associations between a specific, yet very common, leisure-time sedentary behavior: TV viewing time. In cross-sectional studies, prolonged TV viewing time has been shown to be deleteriously associated with several cardio-metabolic outcomes, including overweight/obesity, metabolic syndrome, abnormal glucose metabolism, and other biomarkers of chronic disease risk.[7,8,14–18]

In longitudinal studies, prolonged TV viewing time has been shown to be associated with an increased incidence of type 2 diabetes, cancer, and weight gain.[19–23] Importantly, many studies have reported such associations with TV viewing time to be independent of leisure-time physical activity. Indeed, there is evidence that even among adults who are meeting the current public health guidelines on physical activity, those who watch high amounts of TV have a less favorable health profile than do those watching lesser amounts.[8,9]

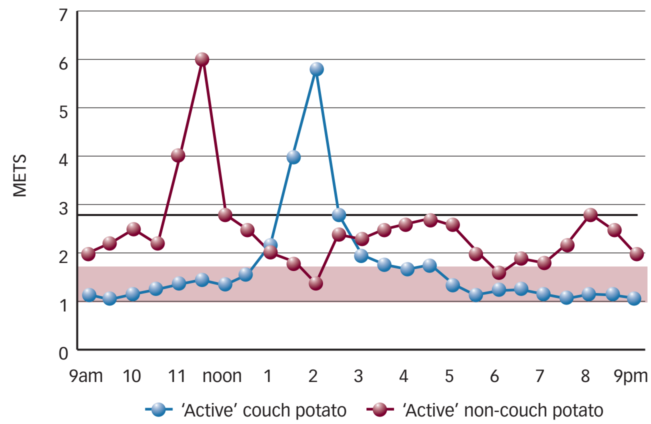
Accelerometers—Using Technology to More Accurately Capture Sedentary Time

The development of objective physical activity measurement technology has provided epidemiologists and other researchers with sophisticated tools to more accurately measure the entire range of activity, from sedentary through to very vigorous activities, in free-living subjects over a number of days. One of the key objective measurement tools is the accelerometer. Accelerometers are small electronic devices that are generally worn on the hip and that allow detailed data to be recorded on not only the amount of active (or sedentary) behavior an individual has undertaken, but also the intensity, duration, frequency, and patterns of these behaviors.[24] Given the inherent bias and difficulty associated with self-report measures, the incorporation of accelerometers into population-based public health research has been instrumental in advancing the field of research on physical activity as well as on sedentary behaviors.

Recent cross-sectional studies in adults that have used accelerometers show that objectively measured sedentary time is deleteriously associated with a number of cardio-metabolic biomarkers, including waist circumference, blood glucose, insulin, and triglycerides.[3,25–27] In general, these findings were independent of objectively measured moderate- to vigorous-intensity activity.[3,27]

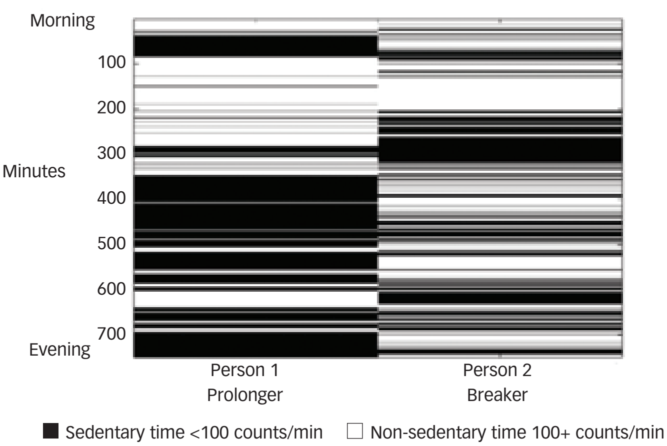
Furthermore, our recent work in Australian adults revealed that people who interrupted their sedentary time more frequently (for example, they might go to get a drink, or simply stand up to answer the telephone) had a better metabolic profile than those whose sitting time was mostly uninterrupted.[28] The relationship for these 'breakers' compared with 'prolongers' (see *Figure 4*) was independent of their total sedentary time and their time spent in moderate- to vigorous-intensity activity, further emphasizing the key message to 'move more, more often.'

Figure 3: A Hypothetical Representation of the Physical Activity and Sedentary Patterns and Energy Equivalent (METS) Over a 12-hour Day for Two Individuals, Both of Whom Participate in Equivalent Amounts of Health-enhancing Physical Activity*



**>3 metabolic equivalents (METS) for the purpose of this figure. The key distinction between these individuals is that the 'active couch potato' spends a considerable proportion of the remainder of the day in activities that have low energy expenditure (1.0–1.8 METS—sedentary time), whereas the 'active non-couch potato' spends the remainder of the day largely engaged in light-intensity activity (1.8–3.0 METS), with little time spent being sedentary. Both of these individuals would be seen as being physically active, yet the active couch potato clearly spends a substantially greater amount of time being sedentary than the non-couch potato.*

Figure 4: Objectively Measured (Accelerometer) Time Spent in Activities <100 Counts per Minute (Sedentary) and ≥100 Counts per Minute (Non-sedentary) in Two Australian Adults Who Shared Identical Total Time Spent Being Sedentary During a 14-hour Day



Sedentary time (dark area) in person 1 is accumulated over prolonged periods throughout the day ('prolonger'), while person 2 has a high frequency of transitions from sedentary to non-sedentary time (light area) during the day ('breaker').

These studies of objectively measured total sedentary time confirmed what was previously shown for self-reported TV viewing time: that is, sedentary time is a distinct risk behavior for cardio-metabolic health. These findings also reaffirm our earlier suggestion that public health strategies for chronic disease prevention and management need to concurrently address the two distinct, yet very common, behavioral entities of too much sitting and too little exercise.[29,30]

The Challenge and Complexities of Behavioral Change

A key next step in this research field is to assess the feasibility and sustainability of reducing sedentary behavior. Fortunately, valuable lessons can be taken from the established body of behavioral research on physical activity. Specifically, sedentary behavior may be viewed in much the same manner as physical activity behavior, which is now widely acknowledged as involving many different behavioral choices in many different contexts.[31] Furthermore, research on the determinants of physical activity has shown that several complex factors may act singly or in combination to promote or constrain people's ability to be physically active.[32,33]

Briefly, such behavioral determinants, as they might be applied to prolonged sitting in a range of contexts, may include:

- personal and demographic attributes (including gender, age, and educational attainment, which may affect the likelihood of discretionary and non-discretionary prolonged sitting);
- biological attributes (for example, overweight and obesity or other inherent attributes that may affect physical comfort or discomfort associated with prolonged sitting);
- the particular characteristics of the relevant behaviors, which may take different forms for different people in different settings (for example, sitting in conjunction with eating meals in front of television sets, sitting rather than standing on public transport, habitual email use rather than walking and talking to communicate with workplace colleagues);
- the psychological, cognitive, and emotional attributes of individuals, which may provide a basis for enjoyment of sitting in different contexts (for example screen-based entertainment or recreational automobile use);
- knowledge of health risks associated with prolonged sitting time;
- the social and cultural factors that act to make some sedentary choices easy and some more difficult for different individuals (for example, the expectations of others, or social norms that make walking to destinations or standing within the workplace an inappropriate or awkward choice; also the generally limited opportunities that exist for eating and drinking or sport-spectatorship while standing);
- physical environment factors, particularly those aspects of the built environment that may make active transport choices more difficult and driving a car an easier and more realistic option; and
- policies, rules, and regulations in many settings that may mandate being seated and not moving around (for example fire-safety regulations preventing standing in many entertainment/conference venues; workplace regulations that require fixed time at desks and other workstations).

Over the past three decades, research on physical activity and other health behaviors has highlighted the challenges of promoting persistence with changes in socially, environmentally, and personally ingrained patterns of behavior. As we have illustrated above, the determinants of these behaviors operate on multiple levels, and single changes within any of these domains are unlikely to have a sustainable impact in changing habitual behaviors.[34] Use of public health policy initiatives, environmental changes, well-designed public education campaigns and, most importantly, reinforcement and endorsement in clinical settings, is crucial in order to modify the patterns of a behavior that are ubiquitous in the population and that are persistent and highly resistant to change for individuals.

Too Little Exercise, Too Much Sitting, and Cardio-metabolic Health—Where to From Here?

The research agenda on too much sitting includes developing a broader understanding of the health consequences of prolonged sitting time and examining what follows from changes in these behaviors. This will require implementing and evaluating innovative interventions to change sedentary behaviors in transport, domestic, community, and occupational settings. Such studies will include controlled intervention trials to better understand the acute and chronic cardio-metabolic consequences of sitting for prolonged periods. This evidence will greatly assist in understanding the causal nature of how too much sitting affects health and will be necessary to inform potential new public health and clinical guidelines in relation to sitting time.

Additionally, there is now consideration being given to environmental, policy, regulatory, and educational interventions to reduce prolonged periods of sitting time in workplaces. Policy and regulatory approaches will require the relevant workplace consultation approaches, and educational interventions will most likely involve innovative uses of information technology, particularly email and websites, to inform and motivate individuals. Such initiatives will need to be carefully evaluated to determine whether they have the expected benefits, or whether there might be harm associated with them. Such interventions and careful evaluations will be required to further build on the evidence base now available on the cardio-metabolic correlates of sedentary behavior.

Public Health Policy Implications

In public health, there is a long history of large-scale behavioral change initiatives that have had significant impacts on whole populations.[29] For example, since the publication of landmark documents on smoking and health in the 1960s, there have been remarkable reductions in smoking prevalence in developed countries. These have resulted from a plethora of inter-related social, environmental, and policy changes, all fundamentally based on knowledge about the health consequences of tobacco use.

For public health initiatives aimed at increasing physical activity and reducing sedentary behavior, there are many allies in sectors other than health. For example, transportation and urban planning experts are now proposing changes to transport systems and the physical and functional layout of urban areas, including higher street connectivity (allowing multiple walking or bicycle routes to destinations), more mixed land use (providing multiple local destinations such as retail, food outlets, and other services), and population density (with more people making local services and businesses more viable), as well as related public policy initiatives that will act to promote higher rates of walking and bicycle use as alternatives to the use of private motor vehicles.[35] Potentially, the accumulation of additional evidence on the health impacts of sedentary behaviors may help to persuade workplace health and safety bodies to seriously begin to address the potential implications of prolonged unbroken sitting time in the workplace.

Clinical Implications

In medical and broader healthcare practice, it may turn out to be a feasible option to advise patients on reducing their sitting time and increasing their routine light-intensity activities as an additional (and in some cases alternative) element to the accepted recommendations on increasing levels of moderate to vigorous physical activity. While regular participation in moderate- to vigorous-intensity physical activity can be a powerful and important positive biological stimulus, reducing sitting time and increasing levels of light-intensity activity now appear to be viable and worthwhile additional options.

Conclusions

Recent advances in exercise science and population health studies have begun to highlight the health-promoting potential for reducing sitting time in people’s daily lives. These new options for increasing adults’ daily energy expenditure and metabolic health must be seen as additional to, and not replacing, the need for all adults to have regular participation in various forms of moderate to vigorous physical activity. This might include more active transport to and from work or in other aspects of daily life through walking or bicycle use, which would simultaneously reduce time that would otherwise be spent sitting, as well as increasing moderate to vigorous physical activity. Overall, there are many benefits that might flow from a broader perspective on physical activity, sedentary behavior, and health. The bottom line is that we need to consider the two major variables of the physical activity and health equation: too little exercise and too much sitting. ■

David W Dunstan, PhD, is Head of the Physical Activity Laboratory at the Baker IDI Heart and Diabetes Institute in Melbourne. He holds adjunct positions with The University of Queensland, Deakin University, Edith Cowan University, and Monash University. His interventional and epidemiological research focuses on the role of physical activity and sedentary behavior in the prevention and management of type 2 diabetes, obesity, and cardiovascular disease.

Genevieve N Healy, PhD, is a Post-doctoral Research Fellow at the Cancer Prevention Research Centre in the School of Population Health at the University of Queensland, and an Adjunct Research Fellow at the Baker IDI Heart and Diabetes Institute. Her PhD work reported some of the first evidence on the relationship between objectively measured sedentary time and light-intensity exercise time with cardio-metabolic health.

Takemi Sugiyama, PhD, is a Senior Research Fellow at the Cancer Prevention Research Centre, University of Queensland. His current research program is concerned with examining built and natural environment attributes associated with physical activity and sedentary behavior. He has a background in architecture and environment–behaviour studies.

Neville Owen, PhD, is a Professor of Health Behaviour and Director of the Cancer Prevention Research Centre in the School of Population Health, University of Queensland. He was previously Foundation Professor of Human Movement Science, Head of the School of Human Movement, and Director of Research for the Faculty of Health & Behavioural Sciences at Deakin University. His publications are in tobacco control, physical activity, and behavioral building of the evidence base for chronic disease prevention.

1. Haskell WL, Lee IM, Pate RR, et al., *Circulation*, 2007;116(9):1081–93.
2. Bauman A, Allman-Farinelli M, Huxley R, James WP, *Obes Rev*, 2008;9(Suppl. 1):119–26.
3. Healy GN, Dunstan DW, Salmon J, et al., *Diabetes Care*, 2007;30(6):1384–9.
4. Hamilton MT, Healy GN, Dunstan DW, et al., *Curr Cardiovasc Risk Rep*, 2008;2:292–8.
5. Owen N, Leslie E, Salmon J, Fotheringham MJ, *Exerc Sport Sci Rev*, 2000;28(4):153–8.
6. Pate RR, O’Neill JR, Lobelo F, *Exerc Sport Sci Rev*, 2008;36(4):173–8.
7. Dunstan DW, Salmon J, Owen N, et al., *Diabetologia*, 2005;48(11):2254–61.
8. Healy GN, Dunstan DW, Salmon J, et al., *Med Sci Sports Exerc*, 2008;40(4):639–45.
9. Sugiyama T, Healy GN, Dunstan DW, et al., *Int J Behav Nutr Phys Act*, 2008;5:35.
10. Lanningham-Foster L, Nysse LJ, Levine JA, *Obes Res*, 2003;11(10):1178–81.
11. Brownson RC, Boehmer TK, Luke DA, *Annu Rev Public Health.*, 2005;26:421–43.
12. United States Department of Labor, American Time Use Survey – 2007 Results. Available at: www.bls.gov/tus/ (accessed March 4, 2009).
13. Hamilton MT, Hamilton DG, Zderic TW, *Diabetes*, 2007;56(11): 2655–67.
14. Bertrais S, Beyeme-Ondoua JP, Czernichow S, et al., *Obes Res*, 2005;13(5):936–44.
15. Cameron AJ, Welborn TA, Zimmet PZ, et al., *Med J Aust*, 2003;178(9):427–32.
16. Dunstan DW, Salmon J, Healy GN, et al., *Diabetes Care*, 2007;30(3):516–22.
17. Dunstan DW, Salmon J, Owen N, et al., *Diabetes Care*, 2004;27(11):2603–9.
18. Gao X, Nelson ME, Tucker KL, *Diabetes Care*, 2007;30(3):694–700.
19. Brown WJ, Williams L, Ford JH, et al., *Obes Res*, 2005;13(8):1431–41.
20. Hu FB, Leitzmann MF, Stampfer MJ, et al., *Arch Intern Med*, 2001;161(12):1542–8.
21. Hu FB, Li TY, Colditz GA, et al., *JAMA*, 2003;289(14):1785–91.
22. Howard RA, Freedman DM, Park Y, et al., *Cancer Causes Control*, 2008;19(9):939–53.
23. Blanck HM, McCullough ML, Patel AV, et al., *Obesity (Silver Spring)*, 2007;15(6):1578–88.
24. Bassett DR Jr, Mahar MT, Rowe DA, Morrow JR Jr, *Med Sci Sports Exerc*, 2008;40(7 Suppl.):S529–36.
25. Balkau B, Mhamdi L, Oppert JM, et al., *Diabetes*, 2008;57(10): 2613–18.
26. Ekelund U, Griffin SJ, Wareham NJ, *Diabetes Care*, 2007;30(2):337–42.
27. Healy GN, Wijndaele K, Dunstan DW, et al., *Diabetes Care*, 2008;31(2):369–71.
28. Healy GN, Dunstan DW, Salmon J, et al., *Diabetes Care*, 2008;31(4):661–6.
29. Hamilton MT, Healy GN, Dunstan DW, et al., *Curr Cardiovasc Risk Rep*, 2008;2(4):292–8.
30. Owen N, Bauman A, Brown W, *Br J Sports Med*, 2009;43(2):81–3.
31. Brown WJ, Bauman AE, Owen N, *Br J Sports Med*, 2009;43(2):86–8.
32. Sallis JF, Owen N, *Physical Activity and Behavioral Medicine*, Thousand Oaks, CA: Sage, 1999.
33. Trost SG, Owen N, Bauman AE, et al., *Med Sci Sports Exerc*, 2002;34(12):1996–2001.
34. Sallis JF, Owen N, Fisher EB. In: Glanz K, Rimer BK, Viswanath K, eds., *Health Behaviour and Health Education: Theory, Research and Practice*, 4th edn., San Francisco: Jossey-Bass, 2008:465–82.
35. Saelens BE, Sallis JF, Frank LD, *Ann Behav Med*, 2003;25(2): 80–91.