

Sedentary Behaviour and Biomarkers of Cardiometabolic Health Risk in Adolescents: An Emerging Scientific and Public Health Issue

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A highlight of this issue of *Revista Española de Cardiología* is the report of original research by Martínez-Gómez et al,¹ in which they examine the associations of objectively assessed sedentary time (too much sitting, as distinct from too little exercise) and body fatness with cardiovascular risk factors in a subsample of 201 adolescent participants of the Madrid AFINOS study. The key scientific features of their investigation are the objective measurement of ambulatory movement (and non-movement) using accelerometers, from which they derive the amount of time spent sedentary. In their study, they conducted careful anthropometric measurements to determine central and overall adiposity, and measured a range of biomarkers of cardiovascular risk. They report significant associations of time spent sedentary and body fatness with biomarkers of cardiovascular risk in this group of young people aged 13 to 16 years.

What is Sedentary Behaviour, as Distinct From the Lack of Physical Activity?

Sedentary behaviours are those pursuits which generate very low energy expenditures.² They include behaviours that involve sitting or reclining (but not standing), and occur across the domains of work (including paid and unpaid), travel, and leisure-time. Time spent in these behaviours is regarded as sedentary time. Common sedentary

behaviours, such as television (TV) viewing time, sitting at school, and computer use have metabolic equivalent (MET) values in the range of 1-1.5.² In contrast, moderate-to-brisk-paced walking involves an energy expenditure of some 3-5 METs; running and vigorous sports can involve energy expenditures of 8 METs or more.²

Research on physical activity and health has in the main concentrated on quantifying the amount of time spent in activities involving these higher levels of energy expenditure (>3 METs), labeling those with no participation as “sedentary.”³ However, this definition ignored the substantial contribution that light-intensity (1.6-2.9 METs) activities make to overall daily energy expenditure,⁴ as well as the potential health benefits of participating in these light intensity activities, rather than being sedentary (which from our perspective is prolonged sitting time, as distinct from not engaging in physical activity).^{5,6} Furthermore, although individuals can be both sedentary and inactive, there is also the potential for high sedentary time and high exercise time to co-exist, for example among athletes in training who must spend significant amounts of time in rest and recovery from intense physical efforts. Physiologically, distinct effects are observed between prolonged sedentary time and too little exercise.⁷ These findings have been supported by population-based epidemiological research, which has generally reported the associations of sedentary time with health outcomes to be independent of physical activity (exercise) levels. Indeed, detrimental associations of TV viewing time with cardiometabolic biomarkers have been observed even in those that meet the public health guidelines for physical activity (and would thus be considered “active”).⁸

Increasingly, sedentary behaviours are ubiquitous and environmentally-driven.⁹ The economic, social, and physical environments in which modern humans now move very little and sit a great deal within the contexts of their daily lives have been evolving rapidly, and particularly so since the

SEE ARTICLE ON PAGES 277-85

Funding source: G. N. Healy is supported by a NHMRC (#569861) / National Heart Foundation of Australia (PH 08B 3905) Postdoctoral Fellowship. N. Owen is supported by a Queensland Health Core Research Infrastructure grant and by NHMRC Program Grant funding (#301200).

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middle of the last century. These changes in personal transportation, communication, workplace and domestic entertainment technologies have been associated with significantly-reduced demands for human energy expenditure, because they all require prolonged sitting. Such environmental and social changes have been identified as the cause of the low levels of physical activity that characterise people's usual ways of life in urban, suburban, and rural environments.

Adolescents as a Key Target Group

In the 2003-2004 US National Health and Nutrition Examination Survey (NHANES), older adolescents (16-19 years) were the second most sedentary group on average, after older adults (≥ 60 years).¹⁰ As young people begin to approach their adult physical stature and move into adult-like daily occupations (including long school hours) and social roles, they become increasingly susceptible to these pervasive influences to spend their time in sedentary behaviours: or, too much sitting.

The study by Martínez-Gómez et al focuses on this important socio-demographic group.¹ Their findings raise significant concerns about the early development of behaviour patterns and body habitus attributes that may significantly increase the risk of major chronic diseases (particularly type 2 diabetes, cardiovascular disease, and breast and colon cancer). While these diseases may not manifest themselves until later in adult life, it seems that not only the behavioural basis, but also the biological precursors for these chronic diseases may be established during adolescence.

As Martínez-Gómez and colleagues highlight,¹ the majority of studies that have examined the relationship of sedentary time with cardiometabolic health in children and adolescents have been conducted under the framework of the European Youth Heart Study (EYHS): a cross-sectional population study investigating the personal, environmental and lifestyle factors that may influence cardiovascular disease risk factors in children aged 9 and 15 years. The findings from the current study build on those from the EYHS, and extend them to examining significant health risks among adolescents 13 to 16 years, as well as additional biomarkers, such as apolipoprotein. It is important now to broaden these findings beyond the highly-informative cross-sectional findings that are now reported, by following-up and reassessing these young people as they transition through the various stages of adolescence and beyond. Additionally, it is important to further examine how the relationships may vary by gender, by age, and by race/ethnicity, and to examine how the relevant health behaviours

(such as diet, exercise, and sedentary time) may interact.

Building the Evidence Base: Extending Beyond the Cross-Sectional Study

Sedentary behavior research is in its early stages, and is probably 20 years behind physical activity research in terms of valid and reliable measurement, and, understanding the behavioural determinants and the efficacy and effectiveness of interventions. Thus, it is important to build a solid base for this new area of research through developing a more-extensive body of epidemiological findings on how sedentary behavior findings may be linked to a range of health outcomes, within different population groups for whom genetic, cultural, social, and environmental exposures will be different in scientifically-important ways.

However, it is also imperative that this new field of research moves quickly to go beyond the inherent logical limitations of cross-sectional studies: to prospective study designs to examine the long-term effects of sedentary behavior on health; to experimental studies to further understand the physiological mechanisms that may underpin the findings; and, to intervention studies examining the feasibility of changing sedentary behaviors, and the associated health outcomes of any change.

Two recent, longitudinal studies have highlighted the potential importance of sedentary behaviours on health. In a follow-up of Australian Diabetes, Obesity and Lifestyle Study (AusDiab) participants over 6.5 years, high levels of television viewing time were significantly associated with increased all-cause and cardiovascular disease mortality.¹¹ The adverse consequences of prolonged sitting time have been reinforced by follow-up findings on participants in the Canada Fitness Surveys that have been carried out since 1980s.¹² Those who initially reported that they spent the majority of their day sitting had significantly poorer long-term mortality outcomes; importantly, the sitting time-mortality relationships were apparent even among those who were physically active, and were stronger among those who were overweight or obese.¹²

As Martínez-Gómez et al argue, it seems likely that there is a unique physiology of sedentary time, within which biological processes that are distinct from traditionally-understood exercise physiology may be operating.¹ The groundbreaking laboratory studies of Hamilton et al, provide important insights into the possible mechanisms that may underlie the associations observed.⁷ In their series of studies, lipoprotein lipase (LPL) regulation was identified as a key pathway through which sedentary time (involving prolonged postural unloading of large

skeletal muscles) may impact on cardiometabolic health. These studies also found that the cellular processes initiated from sedentary time were unique and qualitatively different from exercise-related biological responses.⁷ Mechanistic studies such as these, identifying potential underlying mechanisms, are a crucial element to the sedentary behavior and health research field.

Intervention studies specifically targeting reductions in sedentary time are primarily limited to children, and often target specific sedentary behaviours, such as television viewing time and computer and electronic game use (for example, the “switch-play” intervention by Salmon et al¹³). Examining what changes are feasible, what are the correlates of such changes, and the sustainability of these changes, are important next steps in sedentary behaviour research with adolescents, as well as with children and adults.

The Importance of Breaking-up Sedentary Time

In addition to examining the aggregate or average sedentary time (either across the day, or in specific domains such as the school or travel, or for particular behaviours such as television viewing time, computer use or study), there is also the potential to further extend the scientific focus, by examining how the sedentary time is accrued. In a study of 169 Australian adults, we demonstrated that breaks in sedentary time (as distinct from the total volume of time spent being sedentary) were shown to have beneficial associations with metabolic biomarkers.¹⁴

Sedentary time may be considered to be interrupted or broken if accelerometer counts rose up to or above 100 counts per minute. Breaks from sedentary time can involve activities such as standing from a sitting position, or walking a step. A higher number of breaks in sedentary time were beneficially associated with waist circumference, body mass index, triglycerides, and 2-hour plasma glucose; these relationships were independent of total sedentary time, moderate-to-vigorous intensity activity time, and the average intensity of physical activity.¹⁴ Interestingly, patterns of sedentary time accumulation (but not total sedentary time) were shown to differ among 4 groups of adults with various activity patterns (healthy group with active occupation; healthy group with sedentary occupation; group with chronic back pain; group with chronic fatigue syndrome).¹⁵

These two findings suggest some interesting directions for further studies with adolescents. Examining, for example (as we have done with adults), the associations of breaks in sedentary time with biomarkers of cardiometabolic health

in adolescents would potentially be an important contribution with significant implications for public health, educational and urban-transport policies. Based on the findings of our studies with Australian adults, we would predict that among adolescents with fewer breaks in their sedentary time, significantly more-deleterious patterns of cardiovascular risk would be observed.

Future Directions: the Need for Accurate and Reliable Measurement

Accurate and reliable measurement of time spent in sedentary behaviours is another key area for further development. Although accelerometers provide information about the time, duration, and intensity of ambulatory movements (from which estimates of sedentary time can be derived) they do not provide detail on postural changes. Thus, sitting or lying is not differentiated from standing still. The introduction of free-living research inclinometers (such as the ActivPAL) enables closer examination of specific time spent in sitting and lying behaviours.¹⁵

An important next step in sedentary behavior measurement is the integration of multiple information sources, such as accelerometers, inclinometers, GPS technology, and behavior logs: preferably in a format that has a low participant and analytic burden. Furthermore, the development of valid and reliable questionnaires that measure across multiple domains is necessary for population surveillance of this ubiquitous behavior.

Conclusion

We congratulate Martínez-Gómez et al on their well-conducted and important study.¹ While there have been several studies that have set out to identify the health consequences of sedentary behaviour in adolescents, few have reported blood-derived biomarker outcomes. The combination of objectively-assessed sedentary time as the main exposure variable with an extensive set of biomarker outcomes provides findings that are of great scientific value.

These findings ought now to be replicated and extended, and longitudinal and intervention trial study designs need to be applied. As the science develops, there will be considerably greater potential for informing the public-health and other policy changes that will reduce sedentary time (for example mandatory breaks from sitting during school hours; stronger public health recommendations on avoiding prolonged sitting; traffic control in urban environments to encourage walking and cycling). In the current human environment of multiple and ubiquitous opportunities to sit, there is the crucial

need to develop a broader range of opportunities for children, adolescents and adults to be more physically active, and to have practical and realistic ways to spend less time sitting within the normal contexts of their daily lives.¹⁶

REFERENCES

1. Martínez-Gómez D, Eisenmann JC, Gómez-Martínez S, Veses A, Marcos A, Veiga OL. Sedentarismo, adiposidad y factores de riesgo cardiovascular en adolescentes. Estudio AFINOS. *Rev Esp Cardiol.* 2010;63:277-85.
2. Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc.* 2000;32 Suppl :S498-504.
3. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev.* 2008;36:173-8.
4. Donahoo WT, Levine JA, Melanson EL. Variability in energy expenditure and its components. *Curr Opin Clin Nutr Metab Care.* 2004;7:599-605.
5. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, et al. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes Care.* 2007;30:1384-9.
6. Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care.* 2008;31:369-71.
7. Hamilton MT, Hamilton DG, Zderic TW. The role of low energy expenditure and sitting on obesity, metabolic syndrome, type 2 diabetes, and cardiovascular disease. *Diabetes.* 2007;56:2655-67.
8. Healy GN, Dunstan DW, Salmon J, Shaw JE, Zimmet PZ, Owen N. Television time and continuous metabolic risk in physically active adults. *Med Sci Sports Exerc.* 2008;40:639-45.
9. Owen N, Leslie E, Salmon J, Fotheringham MJ. Environmental determinants of physical activity and sedentary behavior. *Exerc Sport Sci Rev.* 2000;28:153-8.
10. Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, et al. Amount of Time Spent in Sedentary Behaviors in the United States, 2003-2004. *Am J Epidemiol.* 2008;167:875-81.
11. Dunstan DW, Barr ELM, Healy GN, Salmon J, Shaw JE, Balkau B, et al. Television viewing time and mortality: The AusDiab study. *Circulation.* Jan 11, 2010 [Epub ahead of print]. doi: 10.1161/CIRCULATIONAHA.109.894824
12. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. *Med Sci Sports Exerc.* 2009;41:998-1005.
13. Salmon J, Ball K, Crawford D, Booth M, Telford A, Hume C, et al. Reducing sedentary behaviour and increasing physical activity among 10-year-old children: overview and process evaluation of the 'Switch-Play' intervention. *Health Promot Int.* 2005;20:7-17.
14. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, et al. Breaks in Sedentary Time: Beneficial Associations with Metabolic Risk. *Diabetes Care.* 2008;31:661-6.
15. Chastin SF, Granat MH. Methods for objective measure, quantification and analysis of sedentary behaviour and inactivity. *Gait Posture.* Oct 23, 2009 [Epub ahead of print].
16. Hamilton MT, Healy GN, Dunstan DW, Zderic TW, Owen N. Too little exercise and too much sitting: inactivity physiology and the need for new recommendations on sedentary behaviour. *Curr Cardio Risk Rep.* 2008;2:292-8.