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A hitchhiker's guide to assessing sedentary behaviour among young people: Deciding what method to use

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Abstract
To provide a user's guide for selecting an appropriate method to assess sedentary behaviours among children and adolescents. While recommendations regarding specific instruments are not provided, the guide offers information about key attributes and considerations for objective (accelerometry; inclinometers; direct observation; screen monitoring devices) and subjective (self-report; parent report; and time use diaries/logs) approaches to assess sedentary behaviour Attributes of instruments and other factors to be considered in the selection of assessment instruments include: population (age); sample size; respondent burden; method/delivery mode; assessment time frame; physical activity information required (data output); data management; measurement error; cost (instrument and administration) and other limitations. Expert consensus among members of the Australasian Child and Adolescent Obesity Research Network's (ACAORN) Physical Activity and Sedentary Behaviour Special Interest Group. We developed decision flow charts to assist researchers and practitioners select an appropriate method of assessing sedentary behaviour, identified attributes of each method and described five real-life scenarios to illustrate considerations associated with the selection of each method of measurement. It is important that researchers, practitioners and policy makers understand the strengths and limitations of different methods of assessing sedentary behaviour among youth, and are guided on selection of the most appropriate instrument/s to suit their needs.

Keywords
among, method, young, deciding, people, hitchhiker, guide, assessing, sedentary, behaviour

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A hitchhiker's guide to assessing sedentary behavior among young people: Deciding what method to use

Running title: Assessing sedentary behavior among young people

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Abstract

Objective To provide a user's guide for selecting an appropriate method to assess sedentary behaviors among children and adolescents

Design While recommendations regarding specific instruments are not provided, the guide offers information about key attributes and considerations for objective (accelerometry; inclinometers; direct observation; screen monitoring devices) and subjective (self-report; parent report; and time use diaries/logs) approaches to assess sedentary behaviour Attributes of instruments and other factors to be considered in the selection of assessment instruments include: population (age); sample size; respondent burden; method/delivery mode; assessment time frame; physical activity information required (data output); data management; measurement error; cost (instrument and administration) and other limitations.

Methods Expert consensus among members of the Australasian Child and Adolescent Obesity Research Network's (ACAORN) Physical Activity and Sedentary Behavior Special Interest Group.

Results We developed decision flow charts to assist researchers and practitioners select an appropriate method of assessing sedentary behavior, identified attributes of each method and described five real-life scenarios to illustrate considerations associated with the selection of each method of measurement.

Conclusions It is important that researchers, practitioners and policy makers understand the strengths and limitations of different methods of assessing sedentary behaviour among youth, and are guided on selection of the most appropriate instrument/s to suit their needs.

Keywords: sitting, screen time, measurement, methodology, children,

Introduction

In recent decades, significant societal changes have created a reduced demand for physical activity with a profound resultant impact on the behavior of children and youth.[1] Physical inactivity has been described as the biggest public health problem of our time.[2;3] There is strong evidence that physical activity is associated with numerous health benefits in youth[4] and, similarly, that excessive sedentary behavior is likely to be independently related to a number of health-related conditions.[5;6] However, considerably more research is required to assess the benefits of reducing sedentary behavior, for example sitting less and standing more,[7] and the nature of sedentary behaviors tracking across the life course.[8]

Despite the apparent simplicity of the term, sedentary behavior is complex and not limited to a single behavior.[9;10] Time spent in sedentary behavior is distinct from lack of physical activity and, sedentary behaviors have unique behavioral constructs that have independent relationships to various health outcomes.[11;12] The importance of defining sedentary behavior and using the term consistently is illustrated by the fact that many studies which purport to address 'sedentary' behavior incorrectly assume individuals who are less active or do not meet recommended physical activity guidelines are sedentary. Rather, these individuals are 'insufficiently active', or 'inactive' if no physical activity is reported.

Sitting is the predominant sedentary behavior, but the term 'sedentary' has typically referred to any activity which does not increase resting energy expenditure appreciably above the resting metabolic rate (i.e., 1.0-1.5 metabolic equivalent units (METs)).[13] It is also important to distinguish sedentary behavior from the energy expenditure of light-intensity physical activity (1.5-2.9 METs)[10]. The most common sedentary activities include watching television (TV), playing video/computer games, surfing the Internet, reading, and playing a musical instrument.[14]

Measurement of sedentary behavior is notoriously challenging as it requires an understanding of which behaviors are being undertaken, along with the context and the duration. In young people, a substantial amount of time is spent watching TV, however, this alone fails to capture the diversity of sedentary behaviors.[9] A wide range of measures have been used to quantify TV viewing, including direct observation, self/proxy and real-time data capture,[9] but considerable work is needed in this area.[15] Recent systematic reviews of sedentary behavior measures highlighted the poor validity and reliability of many of the existing measures.[6;16] Further, the health consequences of sedentariness among youth have also been reported,[6;16] and linked to weight status and adverse metabolic profiles cross-sectionally[17-19] and prospectively.[20;21]

Sedentary behavior is a relatively new area in health behavior research and there is a need to expand the evidence-base to better understand the epidemiology and health consequences, and determine effective intervention strategies.[22;23] The evidence must come from accurate measurement, and while there is scope for the improvement of measures of sedentary behavior in children and adolescents, there is currently a wide variety of approaches being utilized.[15;16] There is currently no guide detailing the characteristics and discussing the suitability of common measures to assist researchers and practitioners interested in measuring this behavior. The purpose of this paper is to provide a user's guide for selecting methods to assess sedentary behavior among children and adolescents.

Methods

In 2011, members of the Australasian Child and Adolescent Obesity Research Network's (ACAORN) Measurement of Physical Activity and Sedentary Behaviors Special Interest Group met to discuss how best to assist other stakeholders in child health who may be interested in measuring sedentary behavior among children and adolescents. The first step of this process was to undertake a systematic review to identify the validity and reliability of common methods used to measure sedentary behavior in young people.[16] The second step

was to highlight the decision making process that researchers and practitioners need to consider when measuring sedentary behavior in young people, such as deciding on the type of measurement instrument, the purpose of the assessment, and the practical considerations.

Figure 1 about here

Figure 1 illustrates the two methods (i.e., objective and subjective) used to assess sedentary behavior in young people and the potential cost and sample size associated with each measurement method. Each method comprises different instruments, and the key attributes and the limitations and practical considerations of each instrument are listed in Tables 1 and 2, respectively.

Objective measures of sedentary time may include motion devices (inclinometer, accelerometer), observation (direct, video) and other electronic devices specifically designed to measure electronic media use or screen time (ST). The primary reason for selecting objective measures is to minimise measurement error, however objective measures are typically more costly and therefore more likely to be used when assessing smaller numbers of children, although large funded trials may also consider objective measures.

The limitation of motion devices is their inability to provide contextual information (i.e., setting and type of activity). Accelerometers have traditionally been used to measure physical activities rather than measuring sedentary time. There is, however, some evidence that information on sedentariness (includes standing) can be reasonably determined from accelerometers (i.e., cut point < 100 cpm).[24;25] More recently inclinometers, which assess anatomical position in three planes (lying, sitting, standing) and postural changes (sitting/standing) are being explored as a method to measure sedentary time in children. A

limitation is that inclinometers, which are taped or strapped to the thigh, maybe uncomfortable to wear for prolonged periods.

An additional consideration regarding motion devices is individual compliance; typically, these small devices are worn for approximately one week, and can pose a degree of participant burden, which may result in missing data when the device is not worn. Further, there are times when these devices may malfunction, leading to a loss of data. While there has been an increase in use of motion devices to measure sedentary time, a significant research gap is the lack of standardised monitoring protocols (e.g., wear time) and data reduction strategies (e.g., which algorithm).

Observation methods entail an observer recording participants' activities while watching the subject. This may be completed by a trained individual directly observing the child or indirectly by videoing the child. The benefit of using video recording is that multiple views potentially improve objectivity and aspects of behavior can be reviewed. Irrespective, both observation methods require systematic recording of observations. This may be achieved using a simple observation method where the observer has a list to record the child's posture, the domain (or setting) and the activity. It is worth noting that in some jurisdictions, employing observation methods may be prohibited by institutional ethics committees.

Tables 1 & 2 about here

Subjective measures rely on self-report, or in the case of children aged <12 years, proxy reporting by a third party (usually a parent). Subjective measures are generally cheaper so are therefore often used in the assessment of larger groups, but may also be selected for smaller groups when budgetary constraints prevail. A significant benefit of self/proxy report methods is that contextual information can be collected which allows the researcher to examine a broad range of sedentary behaviors, or specific sedentary activities such as ST

passive transport. It is worth noting that while self-report measures may provide reliable estimates of sedentary behavior or ST, their validity remains largely untested[16]. The major limitation of self/proxy report is the potential for significant measurement error. Logs/diaries, where the participant prospectively records the main activity undertaken during a specified time interval (e.g., 30 minute blocks) have the potential to reduce measurement error, but this method carries considerable respondent burden and is not appropriate for younger age groups. Furthermore, because all activities are recorded, this method requires the extraction of sedentary activities.

Scenarios The following scenarios have been selected to represent a range of circumstances and should be read in conjunction with Figure 1 and Tables 1 and 2 which provide greater detail to help guide the most appropriate choice of instrument(s).

Scenario A: Screen time intervention among preschoolers; Researchers plan to design and evaluate the potential efficacy of a 12-week intervention to reduce ST in children aged 2-3 years in the home setting. Children will be randomised as a family unit to either an intervention or control group. ST will be assessed among approximately 80 children (40 in each group) at baseline and at 3-month post-intervention time points. The aims of this research are to (i) determine if the intervention results in reduced total ST at home and, (ii) determine duration by each screen type.

In this scenario, the researchers are assessing changes in children's ST using a randomised controlled trial (RCT) design. Key outcomes of interest are the duration and context of the ST participation at home. The sample comprises children who are too young to self-report, and the study requires details of types of ST behavior. Objective measurement using inclinometers or accelerometers are not appropriate as these methods will not provide the context of the behavior or whether the sedentary time was ST or other sedentary behaviours.

An appropriate approach is a parent proxy questionnaire using recall over a certain number of days.

The number of days that represent an accurate estimate of habitual ST behaviors in this age group and in this setting is unknown, and will depend on day-to-day variations in the home context. Ideally, weekday and weekend day ST should be captured. However, despite recognised limitations, parent proxy self-report recall instruments can be used to provide an estimate of minutes spent in ST and assess compliance with guidelines and determine the types of ST in which children engage.

Scenario B School-based RCT to reduce sitting during school class-time; Traditional classroom teaching techniques predominantly involve children being seated for sustained periods. Evidence among adults suggests that sustained sitting may be detrimental to health and that interrupting sitting time may reduce such risks.[26] Researchers have planned a 6-month RCT to test strategies to reduce classroom sitting in primary school children through alternative teaching practices. The RCT involves two classes within each year level at six schools (three control and three intervention schools), and approximately 300 students.

To determine the effectiveness of the intervention, researchers must detect changes in time spent 'sitting' during class time between baseline and post-intervention. Key considerations in the selection of appropriate measurement instruments include: the age of the participants, the need to detect behavior within particular periods, the need to differentiate sitting from other postures, potential burden to participants and minimisation of class disruption. In this scenario, self-report measures may be inappropriate due to participant age (cognitive limitations). Proxy-reports by teachers may also be inappropriate as they would only provide group-level information rather than data about individuals. The use of self-report logs/diaries may be burdensome during class-time, may disrupt class activities and could result in reactivity. Accelerometry may also be inappropriate because they quantify 'movement' and

do not provide any postural information. Low movement counts are indicative of limited movement and not necessarily 'sitting'.

In this scenario, inclinometers and direct observation may be the most appropriate measurement tools. Inclinometers enable researchers to determine time spent sitting or lying (based on postural information), can be worn over long periods (e.g., one week) and allow researchers to extract data from specific periods of interest (e.g., class times). Direct observation would provide the same 'information' with the additional opportunity to value-add by documenting specific behaviors undertaken in each posture (e.g., reading, writing, art, craft, etc). However, direct observation may result in reactivity as participants know they are being observed, and may be costly given the number of observations that would be required (each period across the school day for each class at each school) on multiple school days. Further, the number of days of observations required is not established.

Scenario C: Treatment program for overweight/obese primary school children; A researcher is seeking to evaluate the effects of a 10-week family-centred sedentary behavior reduction intervention on adiposity in overweight/obese 8- to 12-year-old children. The feasibility study is a single-arm experiment involving 30 overweight/obese children with assessments of sedentary behavior taken pre- and post-intervention, and the researcher wants to determine if the intervention reduced children's sedentary time (i) overall daily and (ii) outside of school hours.

For this intervention, the researcher needs to selects an instrument that is both accurate and objective, and sensitive enough to detect the hypothesised changes in sedentary time. Although the sample size is relatively small, direct observation would not be feasible because it is likely that the children attend different schools, and because the researcher is also interested in understanding the effects of the intervention on sedentary time outside of school hours. Self-report questionnaires offer a cost-effective option, but the assessments would be

vulnerable to recall-bias because of the age of the participants. Parent-proxy reports would also not be recommended because their estimates might be influenced by social desirability bias and this could result in under-reporting of the behavior, or parents' understanding of the desired effects of the intervention might result in under-reporting at post-test. It would also be difficult to accurately assess children's total sedentary time, which occurs in many settings and contexts and not always in the presence of parents.

An objective measure is recommended and monitoring devices worn on the body, such as inclinometers or accelerometers, would be most suitable. The use of an inclinometer would allow the researcher to examine time spent in different postures, and from this changes in sitting/lying time as a result of the intervention could be evaluated. If accelerometers are chosen, the researcher can apply age-appropriate cut-points to determine sedentary time. The real-time data acquisition from objective monitoring devices would allow the researcher to specifically examine sedentary time that occurs outside of school hours, in addition to children's overall or total sedentary time per day.

Scenario D: Primary prevention of adolescent screen time in clinical settings; A general practitioner (GP) is concerned about the metabolic profile of an obese adolescent patient presenting markedly overweight and with obvious signs of insulin resistance. During the consultation the GP ascertains from the adolescents' parents and the adolescent that the adolescent spends most of their time sitting on the couch playing e-games, watching TV/DVDs.

Access to adolescent obesity management clinics is limited, and because the GP has a small, busy practice is unable to provide on-going long consultations to the adolescent. The GP decides that the best management strategy will be based on regular brief counselling consultations that incorporate goal setting. The adolescent's parents are asked to help the

adolescent set realistic ST reduction goals and to help monitor progress towards reducing ST.

Objective measures are not suitable for several reasons. Firstly, motion sensors do not capture contextual information and, the cost of motion sensors is prohibitive to the practice budget. Furthermore, the GP does not have the time and expertise to interpret the data collected by objective instruments. Rather, the most feasible line of intervention is for the GP to ask the adolescent to complete a time use diary, or suitable structured questionnaire, about their ST.

This baseline information will identify the duration spent on ST and the time of day spent on ST. The GP can use this information to help the adolescent set realistic goals aimed at reducing ST. The GP can monitor the adolescent's progress towards reducing ST at on-going consultations for the monitoring the obese adolescents' progress.

Scenario E: Population prevalence of screen time among adolescents; Health and education professionals have concerns about non-school recreational ST among adolescents. In order to determine whether investments should be allocated to develop a school-based intervention to encourage adolescents to reduce their ST, the first step is to ascertain how prevalent ST is, and whether there are sociodemographic differences in teenagers' ST. To determine the population prevalence, a large sample of adolescents (i.e., several hundred) from a range of high school years, across different educational sectors, and geographical and socioeconomic areas is required to determine population estimates which are generalisable.

In this scenario, objective measures such as accelerometers and inclinometers are inappropriate for several reasons. First and foremost, objective measures do not provide contextual information, so will not discriminate between ST activities, or other sitting

behaviours, therefore self-report is the most desirable method of measurement. Unlike younger children, adolescents are capable of self-report, albeit recall can be affected by social desirability, and estimates of time are subject to large error. Questionnaires have the ability to discriminate between ST activities and to determine habitual non-school ST on week and weekend days. In school environments, questionnaires can be administered either as pen and paper, or via computers/smart boards.

A significant issue to consider when asking students to report ST activities is the concept of multi-tasking. For example, an adolescent may play on their computer while watching TV – so during the administration of the questionnaire it is important to instruct respondents to allocate the time proportionally spent on each screen activity. An alternative method to measure ST behavior is with time use diaries/log, or ecological momentary assessment (EMA), where respondents report activities undertaken during a specified time interval. A limitation of this method is that all activities are reported, generating large volumes of data from which ST data are extracted.

Concluding remarks

Sedentariness is a multi-faceted construct and is not considered a single behavior or the opposite of physical activity. Given recent evidence highlighting the health-related consequences that are independently associated with time spent in sedentary behaviors, the accurate measurement of sedentary behavior is particularly important. However, measurement is complex and requires an understanding of context, duration and which behaviors are being undertaken. No single, currently available assessment tool captures and describes every aspect of sedentary behavior. Objective measures of sedentary time may include motion devices, observation and other electronic devices specifically designed to measure ST. Subjective measures rely on self-report, or proxy reporting by a third party (usually a parent). Researchers and practitioners need to consider the type of measurement

instrument, the purpose, the intended outcomes, and a host of practical considerations when selecting the instrument(s) which best suit their needs.

Practical implications

Accurate assessment of sedentary behavior in youth is necessary to:

- determine prevalence and trends
- examine associations with health outcomes
- identify correlates, determinants, potential mediators and
- evaluate the effectiveness of interventions.

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Table 1 Key attributes of common methods for measuring sedentary behavior among young people.

	Objective methods				Subjective methods		
Characteristic	Accelerometers	Inclinometers	Screen monitoring devices	Direct observation	Self-report	Parent report	Time use Diary/Log
Population age	1.5-18 years	3-18 years	3-18 years	3-18 years	≥12 years	1.5-12 years	?? 13-18 years
Sample size	Small to large	Small to large	Small	Small	Small to large	Small to large	Small to medium
Method	Prospective/current. Monitor usually worn on a belt over right hip.	Prospective/current. Monitor usually worn on right thigh using a strap or adhesive pads.	Prospective/current. Unit attached to each screen, e.g. TV, computer. Individuals need to log-in using unique codes	Prospective/current Naked eye or video/film observation. Electronic recording forms. Momentary time-sampling (e.g., multiple 3-15 sec observations).	Retrospective recall: yesterday, usual week, past week, etc	Retrospective recall: yesterday, usual week, past week, etc	Prospective/current
Assessment time	Typically 7-days to capture habitual behavior.	Typically 7-days to capture habitual behavior.	Variable (from one day to several weeks)	Variable (from one to multiple days)	One-off	One-off	Typically 7-days to capture habitual behavior.
Data output	Counts body movement (accelerations) in real time; algorithms used to convert to durations of less than a user-identified	Time spent in different postures, including sitting, in real time. Number of sit-to-stand transitions. Bouts of sitting	Total time spent viewing electronic screen for each individual code over monitoring period (e.g. 1 week).	Time spent in different postures/intensities, including sitting/sedentary.	Average frequency and/or duration of overall sitting, or of specific sedentary behaviours. Weekday and weekend days	Average frequency and/or duration of overall sitting, or of specific sedentary behaviours. Weekday and weekend days	Minutes spent in specific behaviours in ‘real-time’.

Characteristic	Objective methods				Subjective methods		
	Accelerometers	Inclinometers	Screen monitoring devices	Direct observation	Self-report	Parent report	Time use Diary/Log
	cutpoint to indicate the upper limit of 'sedentary'	time.			usually asked separately. Can provide context specific information	usually asked separately. Can provide context specific information	
Data entry and data reduction complexity	High – data downloaded to computer and reduced using specialised software	High - data downloaded to computer and reduced using proprietary software	Low – Data recorded by device	Low – Manual data entry	Low – manual data entry or scanned entry	Low – manual data entry or scanned entry	High- substantial data entry and data reduction required

Table 2 Limitations and practical considerations associated with common methods of measuring sedentary behavior among young people

	Objective methods				Subjective methods		
Characteristic	**Accelerometers**	**Inclinometers**	**Screen monitoring devices**	**Direct observation**	**Self-report**	**Teacher/Carer proxy report**	**Diaries / Logs**
Cost	High	High	High	High	Low	Low	Low
Sources of error and limitations on dimensions of SB captured	Unable to distinguish between standing still and sitting. No standard protocol for data management or reduction. Some models not water-proof. No contextual information (e.g. type of behavior). Participants may need support to ensure compliance.	Unable to distinguish between lying and sitting. No contextual information (e.g. type of behavior). Not suitable for water activities.	Assumption that participant is sedentary while engaged in 'screen time'. Screen-based media does not entirely capture the variety of ways young people can be sedentary (e.g. talking on the phone, listening to music).	Potential for participant reactivity. Data collection method can be considered invasive.	Poor respondent memory and/or motivation. Susceptibility to socially desirable responses. Incomplete entries/missing data. Computer availability for electronic data entry varies among schools. Literacy levels among respondents can vary widely.	Potential for bias. Potential poor teacher/carer memory, judgment or motivation. Incomplete entries/ missing data. Possibility that respondent is unaware or was not present to observe behaviour of the child during all of the recall period.	Potential for participant reactivity. Poor respondent motivation. Susceptibility to socially desirable responses. Under-estimation of incidental activities. Under or over-estimation of time spent sedentary. Age limitation for memory.
Additional considerations	Must be individually programmed. May require log/diary to record times	Must be individually programmed. May require log/diary to record times	May require other methods to be used in conjunction to record type of behavior and	Obtaining ethics approval to observe children may be problematic. May require additional	Lists of SB cues need to be culturally appropriate. Caution should be taken when	Respondents and researchers must share common understanding	Poor compliance to monitoring protocols may limit amount of useful data

Characteristic	Objective methods				Subjective methods		
	Accelerometers	**Inclinometers**	**Screen monitoring devices**	**Direct observation**	**Self-report**	**Teacher/Carer proxy report**	**Diaries / Logs**
	when not worn. Compliance issues (especially among adolescents and obese participants) can substantially reduce final sample.	when not worn. Compliance issues (especially among adolescents and obese participants) can substantially reduce final sample.	posture. Researchers required to visit participants' homes to install and retrieve device. Each screen used by participant requires a separate device. Parents/child need to adhere to protocol of not sharing log-ins.	pre-monitoring period to reduce participant reactivity.	estimating total time spent in SB due to young people engaging in multiple SB's simultaneously.	of terms used (e.g. sedentary behavior)	and/or the sample size
Tips to improve compliance and/or data quality	Incentives for compliance. Daily text messages to parents to remind children, or (directly to adolescents) to wear device.	Incentives for compliance. Daily text messages to parents to remind children to wear device.		Conduct repeated observations where possible/relevant. Non-intrusive observation needed to reduce reactivity.	Shorten the recall period (although estimates may then not clearly represent habitual behavior) Interviewer administered self-report may improve quality of participants'	As per self-report. In addition, ensure recall period is during a time the respondent is likely to have been aware of the child's behaviour. Ensure appropriate	Ensure diary / log entry method is simple, visually appealing and clear for young to follow. 'Blocked time' diaries may be useful to reduce participant burden. Daily

Characteristic	Objective methods				Subjective methods		
	Accelerometers	Inclinometers	Screen monitoring devices	Direct observation	Self-report	Teacher/Carer proxy report	Diaries / Logs
					responses. Consider use of pictures / diagrams to assist.	respondent is selected (eg. the parent that is home immediately after school)	text messages to parents to remind children to complete diaries (or direct text messages to adolescents).

Figure Legends

Figure 1 Decision flow chart to select approaches to measuure sedentary behavior among young people

Figure 1 Decision flow chart to select approaches to measuure sedentary behavior among young people