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A systematic review of the validity and reliability of sedentary behaviour measures used with children and adolescents

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Abstract

The aim of this review was to evaluate the reliability and validity of methods used to assess the multiple components of sedentary behaviour (i.e. screen time, sitting, not moving and existing at low energy expenditure) in children and adolescents. Twenty-six studies met our inclusion criteria and were reviewed. Thirteen studies reported the reliability of self- and proxy-report measures of sedentary behaviour and seven of these were found to have acceptable test-retest reliability. Evidence for the criterion validity of self- and proxy-report measures was examined in three studies with mixed results. Seven studies examined the reliability and/or validity of direct observation and the findings were generally positive. Five studies demonstrated the utility of accelerometers to accurately classify sedentary behaviour. Self-report measures provide reliable estimates of screen-time, yet their validity remains largely untested. While accelerometers can accurately classify participants' behaviour as sedentary, they do not provide information about type of sedentary behaviour or context. Studies utilising measures of sedentary behaviour need to more adequately report on the validity and reliability of the measures used. We recommend the use of objective measures of sedentary behaviour such as accelerometers, in conjunction with subjective measures (e.g. self-report) to assess type and context of behaviour.

Introduction

The prevalence of paediatric obesity has become a major public health issue (1). In addition to poor dietary patterns, reductions in physical activity and increased time spent sedentary have been highlighted as the major contributors to the epidemic (2). While much of the focus of obesity prevention and treatment has centred on the promotion of physical activity, interventions targeting time spent in sedentary behaviour, screen time in particular have demonstrated promise (3-5). The term sedentary behaviour may be defined as minimal energy expenditure (1 to 1.5 metabolic equivalent multiples of rest) that typically involves sitting or lying down (6). Time spent in sedentary behaviour is distinct from lack of physical activity as these are considered unique behavioural constructs that have independent relationships to various health outcomes (7). Although time spent watching television has typically been the focus of sedentary behaviour studies (8), other domain-specific sitting behaviours such as using the computer, playing electronic games, reading, talking on the telephone and travelling by bus, car, or train also contribute to young people's sedentary time. Notably, national guidelines in many countries have included recommendations to minimise sedentary behaviour including limiting the amount of time spent using screen-based recreation pursuits to less than two hours per day (9, 10).

Time spent in sedentary behaviour among children and adolescents has been linked positively to overweight and obesity and other adverse health outcomes in both cross-sectional (11-13) and longitudinal studies (14, 15). In a recent large-scale 4-year longitudinal study, higher levels of baseline self-reported TV viewing were positively associated with a steeper body mass index (BMI) trajectory among U.S. adolescent girls

(15). A cross-sectional study of Portuguese children who participated in the European Youth Heart Study found even after adjusting for sex, birth weight, pubertal status, and total or central fat mass, there were positive associations between objectively-assessed time spent sedentary (defined as <500 accelerometer counts per minute) and insulin resistance (16). A further cross-sectional study that included more than 5,000 12-year old children in the UK used accelerometers to assess sedentary time (defined as <200 counts per minute) and found that for every hour spent sedentary per day, after adjusting for sex, social factors, sleep, television viewing time and pubertal status, children were 32% more likely to be obese (17). However, this association was attenuated when physical activity was included in the model. Inconsistencies in study findings may be attributed to varying definitions of sedentary time from accelerometry data. Given the increasing evidence base on the adverse health consequences of time spent in sedentary behaviour, the valid and reliable assessment of sedentary behaviour is an important public health priority and a key issue for future research. Quality instruments for assessing sedentary behaviour with known measurement psychometric properties are vital for understanding dose-response relationships between sedentary behaviour and health and developmental outcomes, for population health monitoring, for determining the correlates and predictors of sedentary behaviour, and for determining the impact of health interventions targeting reductions in sedentary time. While methodological issues relating to the assessment of physical activity among children and adolescents have been explored in numerous reviews (18-21), issues pertaining to the assessment of sedentary behaviour have received little attention. Bryant and colleagues (22) published a systematic review of studies that had included a measure of television exposure in children and adolescents. The authors

found a large number of studies that had used self-report measures and noted that the validity and reliability of commonly used measures were rarely provided. While their review provided important recommendations for assessing television viewing exposure in youth, it did not explore the multiple components of sedentary behaviour (e.g. time spent playing electronic games and computers, sitting time) and it did not include objective measures of sedentary behaviour (e.g. accelerometers and direct observation). The importance of assessing the multiple components of sedentary behaviour has been highlighted in the literature (8). No previous review has evaluated the reliability and validity of objective and subjective methods used to assess the multiple components of sedentary behaviour. The primary aim of this review was to evaluate the reliability and validity of methods used to assess the multiple components of sedentary behaviour in children and adolescents (i.e. screen time, sitting, not moving and existing at low energy expenditure) by systematically reviewing the existing literature.

Methods

Identification of studies

A systematic review of studies reporting validity and/or reliability of methods used to assess the multiple components of sedentary behaviour (i.e. screen time, sitting, not moving and existing at low energy expenditure) in youth was guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (23) and was conducted in four phases. Firstly, we conducted a systematic search of published literature using electronic databases (described in detail below). In the second phase we conducted an internet-based search and search of authors' personal collections for published literature examining measures of sedentary behaviour among children and

adolescents (aged 3-18 years). Articles were then hand-searched to identify key researchers and programs of work examining sedentary behaviour in the target age group. The third phase involved contacting key authors or research groups to identify measures of sedentary behaviour they had used, or were aware of, with this age group. The fourth phase was to identify any further articles from reference lists of retrieved articles.

Databases were searched from 1985 until the most recent published articles (including in-press articles) as at May 2010. The databases searched included: Academic Search Premier; CINAHL; Cochrane Central Register of Controlled Trials; Cochrane Database of Systematic Reviews; Global Health; Health Source: Nursing / Academic; MedLINE (PubMed); Psycharticles; Psychology and Behavioural Sciences Collection; PsychInfo; SportsDiscus. Individualised search strategies for the different databases focused on 1) behaviours, including combinations of the following key words: 'sedentar*, 'sitting', *screen', 'television', 'computer', 'electronic games', 'video', 'DVD', 'video games' and 'electronic media', in conjunction with 2) measurement related words including: 'instrument', 'survey', 'log', 'diary', 'questionnaire', 'self-report', 'proxy report', 'accelerom*', 'inclinom*' 'actigraph', 'motion sensor', 'heart rate', measure* or assess* or observ*. When the database did not allow age limiters to be set, words related to childhood and adolescence (i.e. 'child*', 'adolescent', 'young people', 'youth') were also included. The keyword search was limited to words appearing in the title and abstract.

Criteria for inclusion/exclusion

Two of the authors (JD and AH) independently assessed the eligibility of the studies for inclusion according to the following criteria: i) child and adolescent

participants (aged 3-18 years); ii) direct observation (including video); self- or proxy-report, or objective measure of sedentary behaviour; iii) validity and/or reliability of a sedentary behaviour measurement tool reported; iv) published or in-press in a peer-reviewed journal; and vi) published in English. Articles were only included if the reliability and/or validity of the instruments' sedentary behaviour component were analysed and reported separately. Reviews, positions statements, case studies, abstracts and editorials were not included in the review. Articles that only included children or adolescents with disabilities or developmental delays that may impact their ability to accurately recall sedentary behaviour were excluded.

Reliability of sedentary behaviour measures

Reliability refers to the consistency of a response either across multiple tests within a single assessment, generally called internal consistency, or across multiple assessments, known as test-retest or stability reliability (18). In addition, inter-rater reliability refers to the stability of observations between two or more testers measuring the same behaviour (agreement between raters), while intra-rater reliability refers to the consistency of observations made by the same observer on different days. Two authors (LB and DRL) independently assessed the reported reliability of the sedentary behaviour measures using a modified version of the checklist developed for assessing the qualitative attributes and measurement properties of physical activity questionnaires (QAPAQ) (21, 24). Reliability was rated as acceptable, borderline, unacceptable, or indeterminate if it was not possible to assess using the criteria provided. Intraclass correlation coefficient (ICC) is the preferred method for estimating test-retest reliability (19) or Kappa for dichotomous data or weighted Kappa for ordinal data (24). An ICC or Kappa of above

0.70 is considered acceptable (Pearson's correlation or Spearman's rank of > 0.80 was also considered to be acceptable) (25). Borderline was reserved for an ICC or Kappa between .60 -.69 (Pearson correlation or Spearman's rank > 0.70 was also considered to be borderline). Intra-rater and inter-rater reliability of direct observation can be assessed using ICC or Kappa and values above 0.70 were considered acceptable.

Validity of sedentary behaviour measures

Validity is the extent to which a method measures what it claims to measure (21). There are numerous types of validity (i.e., criterion, concurrent, and content) relevant to sedentary behaviour measurement. Criterion validity refers to the relationship between results of the measure being assessed and the recognised measure or 'gold standard'(21). Studies assessing the validity of physical activity questionnaires often use accelerometers and direct observation as their criterion measures. Similarly, for the current review, accelerometers and direct observation were considered to provide evidence of criterion validity. Concurrent validity is the extent to which results are associated with those of other existing measures (e.g. comparing results from a new sedentary behaviour questionnaire to those from an existing measure). While comparing one method of unknown validity against another method of unknown validity does not provide evidence of criterion validity, agreement between measures indicates concurrent validity. Content validity refers to the degree to which the content of an instrument adequately reflects all aspects of the outcome of interest. As there is a lack of consensus on how high correlations should be to demonstrate adequate criterion or concurrent validity (26), classifications for direct observation, self- and proxy-report measures were not provided.

As reported in the Introduction section, accelerometry has been used to

objectively assess free-living sedentary behaviour among children and adolescents. To utilise accelerometry for this purpose requires consistent cut-point definitions to be applied to the data to categorise the counts accumulated by the device each epoch into either sedentary behaviour or physical activity. Validity data for published cut-points corresponding to different accelerometer models were reviewed. Results for sensitivity (true positive rate), specificity (false positive rate), and area under the receiver operating characteristic (ROC) curve (false-positive rate (1 – specificity) versus true-positive rate) were extracted and reported. For area under the ROC curve analysis, an area of 1 indicates perfect classification accuracy, while an area of 0.5 represents a complete absence of classification accuracy. Values of > 0.90 were rated as excellent, 0.80–0.90 good, 0.70–0.80 fair, and < 0.70 poor (27).

Results

Study selection

The initial search of 11 databases located 2862 potential articles. Of these studies 2813 were excluded based on titles and abstracts and 49 full-text articles were retrieved. Further studies were located in the reference lists of these articles and additional studies known to the authors were considered for inclusion. A review of the full content of the papers reduced the number of studies to 26 that met the inclusion criteria (Figure 1).

Sedentary behaviour measures and method of measurement

Thirteen studies reported the reliability of self-report or proxy-report measures of sedentary behaviour in children and adolescents (28-40). Time spent watching TV was the most frequently measured sedentary behaviour. However, more recent self-report measures of sedentary behaviour often included computer use and time playing electronic

games. Proxy-report measures of sedentary behaviour were used in four studies with younger children (29, 30, 33, 36), while self-report measures were used in all of the adolescent studies (> 12 years). Of both the proxy- and self-report measures, three (28, 35, 41) required participants to report their time in sedentary behaviour from the previous week, but the majority of measures required participants or parents to report usual weekday and weekend sedentary behaviour .

Three (29, 42, 43) and five (43-47) studies reported the inter-observer reliability and concurrent validity of direct observation techniques, respectively. Five measures of direct observation were designed to provide an assessment of time in physical activity, but also reported the validity or reliability for time in sedentary behaviour (42, 44-46, 48). One study reported the inter-observer reliability for home observations using time-lapse cameras (29). Five studies examined the validity of accelerometers for measuring sedentary behaviour (49-53).

Reliability of self- and proxy-report measures

The reliability of self- and proxy-report measures of sedentary behaviour are outlined in Table 1. Reliability was assessed using ICCs (28, 33, 34, 36-39) in most studies, but bivariate correlation (29, 30), Kappa (31, 32), percent agreement (32) and Spearman rank order correlations (32, 34, 40) were also used. Periods between test and retest were generally one to two weeks. However, Anderson and colleagues evaluated the 1-month test-retest reliability for a 10-day TV viewing diary. Seven measures were found to have acceptable test-retest reliability for specific components of sedentary behaviour (28, 30, 34, 36, 37, 39, 40) and two measures were classified as borderline (29, 33). In general, reliability was better for TV viewing than it was for computer use and playing

electronic games. The reliability of weekday sedentary behaviour was generally higher than weekend sedentary behaviour. There were no obvious differences in the reliability of sedentary behaviour measures for boys and girls.

Criterion validity of self- and proxy-report measures

Three studies examined the criterion validity of a self- or proxy-report measure of sedentary behaviour by comparing the results to direct observation (29) or accelerometry (41, 54) (Table 2). Hardy et al. (41), reported the mean weekly difference between self-reported sedentary behaviour using the Adolescent Sedentary Activity Questionnaire (ASAQ) and accelerometer estimates of sedentary behaviour. While this method of assessing validity was not addressed in our predetermined criteria, the results indicate that this measure has acceptable validity (less than 5% of data outside the limits of agreement). Similarly, Wen and colleagues (54) examined the relationship between sedentary behaviour using an accelerometer and proxy-reported sedentary behaviour and found a positive correlation.

Concurrent validity of self- and proxy-report measures

Three studies compared the results from self-report measures with diary entries in children and adolescents (28, 32, 34). One study examined the relationship between child- and parent-reported sedentary behaviour (33) and another study reported a content validity index. Four self-report measures were found to have correlation coefficients ≥ 0.30 (28, 32-34). Liou and colleagues (38) reported a content validity index of 0.99, but did not explain how this score was achieved and we were therefore, unable to classify the validity of their self-report measure. Salmon and colleagues examined the concurrent

validity of self-report and proxy-report sedentary behaviour in youth (33) and found the strongest association for TV viewing.

Reliability and validity of direct observation

Seven studies examined the psychometric properties of direct observation tools for assessing sedentary behaviour at home (29, 42), in community settings (43, 44), during physical education lessons (45, 48), or during breaks at school (46). Six studies reported reliability results (29, 43, 45, 46, 48) and four studies provided validity data (43-45, 48) (Table 4). Anderson and colleagues (29) used video-recordings to observe children's time spent in the room with TV and their time spent directing their visual attention towards the TV. Inter-observer reliabilities between ratings by two assessors were 0.98 and 0.90 for presence in the viewing room and visual attention towards the TV, respectively. DuRant et al.(42), used direct observation to assess children's time spent television viewing by coding each minute throughout the day and also reported high inter-observer reliability (96% agreement). The validity and inter-observer reliability of the Children's Activity Rating Scale (CARS) was examined among young children (43) . Percent VO_2 max and heart rate were found to differ between CARS category 1, representing sedentary behaviour (stationary – no movement, e.g. lying and sitting), and category 2 (stationary – with movement, e.g., standing and colouring). Inter-observer agreement from 389 paired observation periods by 11 observers over 12 months was 84.1%. McKenzie et al (44) tested the validity of the Behaviours of Eating and Activity for Children's Health Evaluation Systems (BEACHES) instrument using heart rate monitoring. The authors found a linear relationship between heart rate and intensity of

activity, with the lowest average heart rate associated with lying down (99 beats/minute) and the highest heart rate associated with 'very active' time (153 beats/minute).

Rowe and colleagues (45) tested the validity and reliability of the System for Observing Fitness Instruction Time (SOFIT) categories (lying, sitting, standing, walking, running) among students in 1st through to 8th grade during a structured activity protocol in their physical education classes using heart rate monitoring. Heart rates during sedentary behaviours (sitting and lying) differed from standing and walking, and heart rates during sedentary behaviours had high internal consistency reliabilities ($r > 0.99$). Among 9th to 12th grade students, Rowe et al. (47), tested the validity and reliability of the SOFIT categories against both heart rate and energy expenditure measured by indirect calorimetry. Although heart rates differed for sedentary behaviours (sitting and lying) compared with standing and walking, energy expenditure did not differ between lying, sitting and standing, but did differ between those categories and walking. Internal consistency reliabilities for sedentary categories were higher for heart rate ($r \geq 0.98$) compared with energy expenditure ($r = 0.78$-0.82).

Objective measures of sedentary behaviours

Five studies examined the criterion validity of accelerometers for measuring sedentary behaviour in youth by comparing accelerometer cut-points with direct observation (49, 52), metabolic units (50, 53), calorimeter and heart rate telemetry (51). Of the four studies examining cut-points for the Actigraph, three reported excellent validity (50, 52, 53). Reilly and colleagues (49) developed and validated a sedentary behaviour cut-point for the Actigraph against direct observation among 3- to 4-year-olds. They found that a definition of <1100 counts/min provided optimal sensitivity (83%) and

specificity (82%) for young children's sedentary time. Similarly, Sirard et al. (52), developed age-specific sedentary behaviour cut-points for the Actigraph using direct observation. Sensitivity and specificity were high for all ages (92%-100%) and optimised at <1204, <1452, and <1592 counts/min for 3-, 4-, and 5-year-olds, respectively. Treuth and colleagues (50) developed cut-point definitions for the Actigraph among 13- to 14-year-old adolescent girls using VO^2 measured by a portable indirect calorimetry system. For sedentary behaviour (<1.5 METs), sensitivity (100%) and specificity (100%) were optimised at <100 counts/min. Evenson and colleagues (53) also found that this cut-point optimised sensitivity (95%) and specificity (93%) among 5- to 8-year-olds, where portable indirect calorimetry was used to measure oxygen consumption.

Sedentary behaviour cut-points for the Actical and Actiwatch accelerometers have been validated among children and adolescents, with one study reporting excellent classification accuracy among children (53) and another reporting good classification accuracy among children and adolescents (51). Evenson and colleagues (53) found that sensitivity (97%) and specificity (98%) were optimised at < 44 counts/min for the Actical among 5- to 8-year-olds. Puyau and colleagues (51) used calorimetry to determine cut-points for sedentary behaviour (activity energy expenditure <0.01 kcal/kg/min), and found that <100 and <50 counts/min provided good classification accuracy among 7- to 18-year-olds for the Actical and Actiwatch, respectively (area under ROC curve: Actical = 0.85, Actiwatch = 0.85).

Discussion

This systematic review identified studies that reported on the reliability and/or validity of measures of sedentary behaviour used in children and adolescents 0-18 years

of age. Despite the wide use of sedentary behaviour measurement tools in studies involving children and adolescents, few studies report the reliability and validity of the measures used. Further, the methods of assessing reliability and validity varied between studies, making cross-study comparisons difficult. It is of additional concern that many studies compared one method of unknown validity against another measure of unknown validity to establish concurrent validity. While the varying utility of the measures prohibits blanket recommendations for all study types, the results presented here provide useful comparisons for researchers designing new studies and selecting measurement tools.

Despite only being assessed in five studies, accelerometers appear to provide a valid measure of sedentary behaviour. When assessed against direct observation, metabolic monitoring and energy expenditure via calorimetry, accelerometers achieved greater than 80% sensitivity and specificity. In two of the four studies, perfect (100%) sensitivity and specificity were reported. Given the objective nature of accelerometry measurement, it is perhaps not surprising that this method achieved such high validity results. Where feasible, use of objective measures of sedentary behaviour is desirable to provide accurate assessment of children and adolescents' sedentary behaviour that is not marred by human error or bias. Accelerometers have the benefit of being able to assess sedentary behaviour in free-living conditions, unlike other objective measures such as calorimetry. However, the cost associated with the purchase of accelerometers, the technical expertise required to transform the raw data into useable data and the additional costs associated with retrieving the monitors from study participants may prohibit use of accelerometers in many studies. In addition, accelerometers cannot differentiate sitting

from standing upright with minimal movement, nor can they provide information on the type of sedentary behaviours children are engaging in and therefore would not be appropriate for use in studies interested in investigating specific types of sedentary behaviour. Despite the positive findings in this review, there is considerable variation in the Actigraph cut-points used for sedentary behaviours especially among preschoolers. This difference is possibly due to use of different criterion methods (direct observation vs indirect calorimetry). There is a need for the cross-validation of cut-points in a single study.

Seven studies reported reliability or validity of direct observation measures of sedentary behaviour. This semi-objective measure performed well with inter-observer reliability exceeding 90% (29, 42, 55) and validity assessed against heart rate monitoring (44, 45, 47) and energy expenditure (indirect calorimetry) (47) was also high. Such methods may provide a useful alternative to objective measurement, with less potential for bias than self- or proxy-report measures. Direct observation has the added benefit of allowing more comprehensive assessment including type and duration of sedentary behaviour, as well as contextual factors associated with engagement in sedentary behaviour (e.g. presence of other people). However, use of such measures can be costly as it involves a large investment of time by research staff to collect and analyse the observational data, which may be prohibitive for studies with large sample sizes. Because of the time required to train observers, the length of the observation period, and the tedious data-coding requirements, it is highly labour intensive and expensive (56). Subject reactivity to observers is also a legitimate concern, but this problem can be minimized by performing repeat observations. Another limitation of direct observation is

that it cannot feasibly be used to assess total habitual sedentary time, and it can only assess sedentary behaviour in specific predefined settings such as the home, school class, playground, parks, etc.

The reliability and validity of self- and proxy-report measures of children's and adolescents' sedentary behaviour were most commonly reported. This is likely to be a reflection of the popularity of these types of measures. Thirteen studies reported on the reliability and/or validity of such measures but there was much less consistency in the findings than for accelerometry or direct observation. A number of studies attempted to establish the concurrent validity of self- and proxy-report measures by comparing the results to other forms of self- or proxy-report (e.g. log book or activity diary). However, this is problematic as it involves comparing one method of unknown validity against another measure of unknown validity. The two studies (41, 54) which used an objective criterion measure, accelerometry, reported lower levels of validity. Due to the lack of a 'gold standard', future studies examining the validity of sedentary behaviour measures should consider adjusting correlation coefficients upward to attenuate for the weakening effect of measurement error.

Reliability results for self- and proxy-report measures of children's and adolescents' sedentary behaviour were mixed. It is difficult to draw conclusions from these results as the measures varied substantially; in the type and aspect of sedentary behaviour they assessed, the period of recall required, the method of administration, the time lapse between assessments, and method of analyses. So while the inconsistent results suggest that self- and proxy-report measures are less reliable than other methods of assessing sedentary behaviour in children and adolescents, it is likely that some of

these measures are of higher quality and more comprehensive than others. While much more susceptible to recall and reporting biases than more objective measures, self- and proxy-report measures of sedentary behaviour have the advantage that they are relatively low cost, easy to administer and thus can be easily applied in large scale studies. They are also able to assess all aspects of sedentary behaviour including type, duration and context.

While there are clear advantages and disadvantages to the use of the different types of measures of sedentary behaviour in children and adolescents, it appears that objective measures provide the most valid and reliable assessment. Decisions on the choice of measures to use in a study will undoubtedly be largely driven by the study type and resources available. Nonetheless, where possible we recommend the use of objective measures of sedentary behaviour such as accelerometers, in conjunction with more subjective measures (direct observation or self- or proxy-report) to assess aspects of sedentary behaviour that are not captured by accelerometry such as type and context of behaviour. In choosing self- or proxy-report instruments, we recommend researchers select those instruments which have previously been shown to have acceptable reliability and validity. We strongly recommend that studies utilising measures of sedentary behaviour report on the validity and reliability of the measures used, particularly where they have modified existing instruments.

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Table 1: Reliability of self- and proxy-report measures of sedentary behaviour in children and adolescents

Study	Study sample	Behaviour assessed	Methods	Results	Rating
Anderson et al. (29)	N = 334 families with 5 year old children United States	*Proxy-report home TV viewing 10-day diary*- parents reported the time the TV was turned on and whether or not child was in the room.	1-month test-retest for 10-day viewing diary using bivariate correlation.	$r = 0.72$	Borderline
Taras et al. (30)	N = 66 mothers of children aged 3-8 years United States	*Interviewer administered proxy-report of TV viewing*- parents reported their children's time spent watching TV during and between meals for a typical weekday, a typical Saturday and a typical Sunday.	14-21 day test-retest reliability using PC.	$r = 0.80$	Acceptable
Brener et al (31)	N = 4619 children 13-18 years United States	*Self-report measure of TV viewing*- as part of the Youth Risk Behavior Survey Questionnaire participants report <= 2 hours watching TV on an average school day.	2-week test-retest reliability using Kappa.	$k = 0.47\%$	Unacceptable
Schmitz et al. (32)	N = 245 children 11-15 years United States	*Self-report measure of TV viewing and computer use*- participants report their weekday and weekend time watching TV and using the computer.	1-week test-retest reliability. Reliability assessments included % agreement, Kappa and SROC.	% agreement ranged from 35% (weekend TV Summer) to 50% (computer use).	Unacceptable
		Self-report measure of TV viewing- the TV viewing question from the 1999 Youth Risk Behaviour Questionnaire (YRBS).		SROC for TV viewing and computer use ranged from $\rho = 0.55$ (weekend TV summer) to $\rho = 0.68$ (weekday TV school year).	Unacceptable
				Kappa ranged from 0.42 (weekend TV Summer) to 0.55 (weekday school year)	Unacceptable
				YRBS weekday TV item % agreement (48%), SROC (ρ	Unacceptable

				= 0.68) and Kappa (0.55).	
Salmon et al. (33)	N = 156 parents 40.0 ± 5.2 years N = 147 children 10-12 years Australia	*Proxy-report sedentary behaviour measure*- parents reported time their child usually spent watching TV, playing electronic games and using the computer in a typical week and on a typical weekend. *Self-report sedentary behaviour measure*- children reported time their child usually spent watching TV, playing electronic games and using the computer in a typical weekday and on a typical weekend.	2-week test-retest reliability using ICC 1-week test-retest reliability using ICC.	Proxy-report ICC (based on mean minutes per day) ranged from 0.6 to 0.8. Self-report ICC not reported.	Borderline Indeterminate
Vereecken et al. (34)	N = 112 children 11-15 years Germany	*Self-report measure of TV viewing*- participants reported their usual hours of TV viewing (including videos) in free time on weekdays and weekend days.	7-day test -retest reliability using ICC.	ICC (average TV viewing per day) for boys = 0.76 ICC for girls = 0.81	Acceptable
Koezuka et al. (35)	N = 7982 children 12-19 years Canada	*Self-report measure of sedentary behaviour* - participants reported the number of hours per week (categorical) spent during leisure time using computers, playing video games, watching TV and reading.	Internal consistency of the measure assessed using SROC among the 4 sedentary behaviours.	SROC among the 4 sedentary behaviours ranged from ρ= 0.04 to ρ = 0.13.	Indeterminate
Salmon et al. (36)	N = 133 parents of children aged 5-12 Australia	*Proxy-report of TV viewing*- parents reported TV viewing by children on a usual weekday and weekend day.	7-14 day test-retest reliability using ICC.	ICC of usual daily TV = 0.78	Acceptable
Hardy et al. (37)	N = 250 11-15 years Australia	*Self-report measure of sedentary behaviour* - participants completed the Adolescent Sedentary Activity Questionnaire (ASAQ) which requires participants to report their time spent using small screen recreation devices	2-week test-retest reliability using ICC.	ICC for total time spent in sedentary behaviour was ≥ 0.70 (except for Grade 6 boys = 0.57). ICC values were high for all	Acceptable

		(e.g. watching TV/DVDs), doing homework (with/without computer and tutoring), traveling (motorized), in cultural activities (e.g. hobbies, playing a musical instrument), and socializing (e.g. sitting with friends, using the telephone) and travel.		students for small screen recreation, education and cultural sedentary behaviour with only one or two borderline exceptions. In addition, ICC was unacceptable for 'education' weekdays for Grade 6 boys and girls, ICC was also unacceptable for 'cultural' weekend for Grade 8 boys, There were a range of ICC unacceptable values for 'social' and travel. ICC values for weekend days were lower than for weekdays.	
He et al. (28)	Sample not reported Canada	*Self-report measure of sedentary behaviour* - participants completed a modified version of the Child Sedentary Activity Questionnaire (CSAQ). The CSAQ requires participants to recall the hours spent each day of the previous week watching TV/videos and playing computer and video games outside school hours.	2-week test-retest reliability using ICC	ICC = 0.98	Acceptable
Liou et al. (38)	Sample not reported China	*Self-report measure of sedentary behaviour* - participants report average number of hours weekend and weekday spent watching TV, using computers (not for school), reading, traveling in a vehicle and studying/completing homework.	ICC used for test-retest reliability but period between assessments is not described.	ICC = 0.84.	Indeterminate

Liu et al. (39)	N = 95 11-15 years China	*Self-report measure of sedentary behaviour* - participants completed 8 items related to sedentary behaviour from the Health Behaviour in School-aged Children survey translated into Chinese. Items related to time spent on weekdays and weekend days for the following items: time watching TV/DVDs, using the computer, playing computer and console games, and doing homework.	3-week test-retest reliability using ICC.	ICC for TV and Homework (both weekday and weekend) were acceptable ICC for PC and console games was borderline for weekend and unacceptable for weekdays ICC for using computer was unacceptable	Acceptable Unacceptable Unacceptable
Rey-Lopez et al. (40)	N = 183 13-18 years Europe	*Self-report measure of sedentary behaviour* - participants reported the hours TV watching (categorical), playing computer games and console games, surfing the internet for non-study reasons, surfing the internet for study reasons and studying both on weekends and weekdays.	1-week test-retest reliability using Kappa.	Weekday TV viewing $k = 0.71$ Computer games $k = 0.82$ Console games $k = 0.82$ Internet no study $k = 0.86$ Internet study $k = 0.46$ Studying $k = 0.73$ Weekend TV viewing $k = 0.68$ Computer games $k = 0.79$ Console games $k = 0.81$ Internet no study $k = 0.71$ Internet study $k = 0.33$ Studying $k = 0.82$	 Acceptable Acceptable Acceptable Acceptable Unacceptable Acceptable Acceptable Acceptable Acceptable Acceptable Unacceptable Acceptable

Note. The studies are provided in chronological order, then alphabetical order. PA = physical activity; ICC = intraclass correlation, SROC = Spearman rank order correlation; ρ = Spearman coefficient; *k* = Kappa coefficient, *r* = Pearson correlation coefficient, PC = Pearson correlation, NR = not reported; PAL = physical activity level.

Table 2: Criterion validity of self-report and proxy-report measures of sedentary behaviour in children and adolescents

Study	Study sample	Description of measure	Methods	Criterion	Results
Anderson et al. (29)	334 families with 5 year old children United States	*Proxy-report questionnaire*- parents reported child's number of hours of TV viewing time each day of the week during the morning, afternoon and evening. Parents also completed a daily activity chart in which the parents indicated child's daily schedule including TV viewing. *Home TV viewing diary*- parents reported the time the TV was turned on and whether or not child was in the room. *Home-observations*- Using time-lapse video cameras placed in the homes of children which filmed TV and room area. Video equipment began recording when the TV was turned on and stopped recording when the TV was turned off.	The study involved 4 phases: 1. Home visit by researcher to observe child's TV viewing and parents completed TV questionnaire 2. Parents provided with 10-day viewing diary 3. 1 month later, a second 10-day viewing diary was issued with experimental group having recording equipment installed 4. Post-test and debrief Bivariate correlation used to examine the relationship between proxy-report estimates and actual TV viewing time.	Video observation of actual behaviour	Correlation between proxy-report of TV viewing and home TV viewing diary was $r = 0.62$ Correlation between time lapse videos and diary estimates was $r = 0.84$ when any uncertainty was treated as the child not present Correlation between diary 1 and daily activity chart was $r = 0.48$ Correlation between diary 1 and direct estimate of hours watching TV $r = 0.60$
Hardy et al. (41)	N = 172 girls 12-15 years Australia	*Self-report measure of sedentary behaviour* - Participants report time in the following sedentary behaviour before and after school, on a weekend or weekday: watching TV or videos, playing video games, using a	Construct validity of the sedentary behaviour measure self – report questionnaire was determined by accelerometry. At each data collection subjects wore an MTI accelerometer for 7	Accelerometer	Mean weekly difference between self report and accelerometer based measures was -3.2 hours/week. Less than 5% of data points were outside the limits of agreement (±2SD) -26.5 to 20.1

		computer for fun or study, doing homework / study, reading, talking on the phone, sitting with friends, doing hobbies or crafts, music/practice, traveling in a car, bus, ferry or train and going to the cinema.	consecutive days (except whilst sleeping or in water). The mean weekly difference between self-report and accelerometer-based sedentary behaviour and limits of agreement were calculated.		h/week).
Wen et al. (54)	N = 34 parents and their children 3-5 years Australia	*Proxy-report of child's physical activity and sedentary behaviour* - parents reported their child's behaviour in terms of number of times, hrs and mins. in a 7-day diary. A number of items were used to assess the amount of time in sedentary behaviour including watching TV, videos, DVD, computer or computer games inc. Playstation, playing indoors in a stationary way, reading, napping /sleeping, eating and sitting in a pram.	Children wore accelerometers for 7-days. SROC was used to examine the relationship between the diary entries and accelerometer activity counts.	Accelerometer	Time spent in sedentary behaviour recorded by the diary was positively correlated with sedentary behaviour time assessed by the accelerometer ($\rho = 0.24$). Time in screen time was ($\rho = 0.08$).

Note. PA = physical activity; ICC = intraclass correlation, SROC = Spearman rank order correlation; ρ = Spearman coefficient*; k* = Kappa coefficient, *r* = Pearson correlation coefficient, PC = Pearson correlation, NR = not reported; PAL = physical activity level.

Table 3: Concurrent validity of self-report and proxy-report measures of sedentary behaviour in children and adolescents

Study	Study sample	Description of measure	Methods	Criterion	Results
Schmitz et al. (32)	N = 245 children 11-15 years United States	*Self-report measure of TV viewing and computer use*- participants report their weekday and weekend time watching TV and using the computer in a diary.	To assess concurrent validity, participants completed TV and computer logs for 7 days. Validity assessments included SROC and mean difference using t-tests.	Self-reported TV and computer diary.	SROC ranged from 0.37 (weekend TV) to 0.47 (average week TV) Mean difference in hours ranged from -0.09 (average week TY) to 0.68 (computer only). SROC for YRBS item (weekday TV) was ρ = 0.46. Mean difference in hours for YRBS item was -0.04 hours.
		Self-report measure of TV viewing- the TV viewing question from the 1999 Youth Risk Behaviour Questionnaire (YRBS).			
Salmon et al. (33)	N = 156 parents Mean age = 40.0 ± 5.2 years	*Proxy-report sedentary behaviour measure*- parents reported time their child usually spent watching TV, playing electronic games and using the computer in a typical week and on a typical weekend.	Convergent validity between parents' proxy-report data and children self-report was tested using correlation.	Parent report of child's TV viewing, electronic game and computer usage.	TV viewing (ρ = 0.61), computer use (ρ = 0.47) and playing electronic games (ρ = 0.44). NR
	N = 147 children Mean age = 11.8 ± 0.8 years Australia	*Self-report sedentary behaviour measure*- children reported time their child usually spent watching TV, playing electronic games and using the computer in a typical weekday and on a typical weekend.	NR		

Vereecken et al. (34)	N = 112 children 11-15 years Germany	*Self-report measure of TV viewing*- participants reported their usual hours of TV viewing (including videos) in free time on weekdays and weekend days.	ICC was used to assess convergent validity of the self-report questions and a 7-day TV diary completed by participants.	Self-reported TV diary.	Boys ICC = 0.36 Girls ICC = 0.54
He et al. (28)	Sample not reported Canada	*Self-report measure of sedentary behaviour* - participants completed a modified version of the Child Sedentary Activity Questionnaire (CSAQ). The CSAQ requires participants to recall the hours spent each day of the previous week watching TV/videos and playing computer and video games outside school hours.	Criterion for validity was assessed using an activity diary. ICC values provided.	Self-reported activity diary.	ICC ranged from 0.5-0.8.
Liou et al (38)	Sample not reported China	*Self-report measure of sedentary behaviour*- items related to time spent on weekdays and weekend days for the following items: time watching TV/DVDs, using the computer, playing computer and console games, and doing homework.	Methods for assessing validity are not described.	Not reported.	Content validity index = 0.99

Note. PA = physical activity; ICC = intraclass correlation, SROC = Spearman rank order correlation; ρ = Spearman coefficient*; k* = Kappa coefficient, *r* = Pearson correlation coefficient, PC = Pearson correlation, NR = not reported; PAL = physical activity level.

Table 4: Reliability and validity of direct observation of sedentary behaviour in children and adolescents

Study	Study sample	Description of measure	Methods	Criterion	Results
Anderson et al. (29)	N = 334 families with a 5 year old child United States	*Home-observations*- Using time-lapse video cameras placed in the homes of families.	TV viewing (time spent in the TV room and time spent directing visual attention towards the TV) was observed using video-taped recording equipment in the families' homes. Inter-observer reliability for presence in the viewing room and visual attention was tested using bivariate correlation. Reliability based on 14 viewers rated by 2 observers.	N/A	Inter-observer reliability for presence in the viewing room and visual attention were $r = 0.98$ and $r = 0.90$, respectively.
Puhl et al. (43)	Validation: N = 25 children 6 years Inter-observer Reliability: N = 192 children 3-4 years United States	Children's Activity Rating Scale (CARS)	CARS categories (1. stationary – no movement, 2. stationary – with movement, 3. translocation – slow/easy, 4. translocation – medium/moderate. 5. translocation - translocation – medium/moderate. 5. Translocation –fast, very fast/strenuous) were validated against HR monitoring and indirect calorimetry during a 50-minute protocol. HR and VO_2were collected continuously. Reliability based on 389 paired observation periods by 11 observers over 12 months.	HR monitoring and indirect calorimetry	Mean %Max VO_2 differed for Category 1 - lying (14.6) and sitting (14.5) vs Category 2 - standing/colouring (21.2) and standing/ball activity (23.0). Mean HR (bpm) differed for Category 1 vs Category 2. Mean HR (bpm) differed for lying (89) vs sitting vs standing/ colouring (116) vs standing/ball activity (112). Inter-observer percent agreement = 84.1%.
McKenzie et al. (44)	N = 19 children 4-9 years United States	*Direct observation of children's behaviour*— The Behaviours of Eating and Activity for Children's Health Evaluation Systems (BEACHES) is a direct observation of	HR was measured using a UNIQ Heart watch while children participated in specific activities	HR monitoring	HR increased across activities HR lying = 99 BPM HR sitting = 107 BPM HR standing = 130 BPM HR walking = 130 BPM HR very active = 153 BPM

		children's physical activity and eating behaviours and related environmental events using momentary time sampling.			
DuRant et al. (42)	N = 191 children 3-4 years United States	*Direct observation of children's TV viewing*- The Children's Activity Rating Scale (CARS) was used to determine when a child was in the room with a TV on and attending to the program.	Children were observed using CARS from 6-12 hours across 4 days in one year. Every minute the child watched TV was recorded	N/A	TV viewing inter-observer agreement was 96%.
Rowe et al. (45)	N = 173 adolescents Mean age = 10.6 years United States	*Direct observation of children's activity levels in PE lessons*- System for Observing Fitness Instruction Time (SOFIT)	SOFIT categories (lying, sitting, standing, walking, running) were validated against HR monitoring collected at 5 sec intervals during a 36-minute protocol. Internal consistency reliability for HR during each category was examined. Test-retest reliability was examined among 47 students.	HR monitoring	Mean HR (BPM) differed for: i) lying (87) and sitting (91) vs ii) standing (103) vs iii) walking (121). Internal consistency reliabilities were – HR: lying = 0.99, sitting = 0.99. Intraclass correlations were – HR: lying = 0.88, sitting = 0.88.
McKenzie et al. (46)	N = 24 middle schools Children in grades 6-8 United States	*Direct observation of children's activity levels during breaks*- The System for Observing Play and Leisure Activity in Youth (SOPLAY) is based on momentary time sampling and is used to determine the number of participants and their physical	Independent inter-observer reliability on 14 observations using ICC.	N/A	ICC for sedentary time = 0.98

		activity levels during play.			
Rowe et al. (48)	N = 35 adolescents Mean age = 15.7 years United States	*Direct observation of children's activity levels in PE lessons*-System for Observing Fitness Instruction Time (SOFIT)	SOFIT categories (lying, sitting, standing, walking, running) were validated against HR monitoring and indirect calorimetry during a 42-minute protocol. HR and VO_2were collected at 5 sec and 20 sec intervals, respectively. Internal consistency reliability for HR and EE during each category was examined.	HR monitoring	Mean HR (BPM) differed for: i) lying (71.6) and sitting (77.1) vs ii) standing (85.7) vs iii) walking (106.3). Mean EE ($O^2/kg^1/min^1$ differed for: i) lying (3.9), sitting (4.2), and standing (4.2) vs ii) walking (15.2). Internal consistency reliabilities were – HR: lying = 0.98, sitting = 0.98; EE: lying = 0.82, sitting = 0.78.

Note. HE = heart rate, EE = energy expenditure, BPM = beats per minute.

Table 5: Validity of objective measures of sedentary behaviour in children and adolescents

Study	Study sample	Measure	Methods	Criterion	Equation/cut-points	Results	Rating*
Reilly et al. (49)	Development: N = 30 children, 3-4 years Cross-validation: N = 50 children, 3-4 years Scotland	Actigraph 7164 accelerometer	Activity monitors were compared against a validated direct observation technique.	Direct observation	Sedentary behaviour <1100 counts/min	Sensitivity: 83% Specificity: 82%	Good
Treuth et al. (50)	N = 24 adolescent girls 13-14 years United States	Actigraph 7164 accelerometer	Participants wore accelerometers and Cosmed metabolic units to determine oxygen consumption and heart rate. Participants completed a range of sedentary activities including lying on a bed, sitting in a chair watching a movie and sitting in a chair playing a computer game. Sedentary behaviour <1.5 METs.	Metabolic measurement system	METs = 2.01 + 0.000856 counts/min Sedentary behaviour <100 counts/min	Sensitivity: 100% Specificity: 100% Area under ROC curve: 1.00.	Excellent
Puyau et al. (51)	N = 32 7-18 years United States	Actical accelerometer Actiwatch accelerometer	Activity monitors were validated and calibrated against continuous 4-hour measurements of EE by respiration room calorimetry and heart rate by telemetry. While they were in the calorimeter, the children adhered to a structured protocol of physical activities. Sedentary activities included playing Nintendo, and working on a computer. Correlation used to compare accelerometer counts with EE. Sedentary behaviour- AEE <0.01 kcal·kg^{-1}·min^{-1}.	Calorimeter and heart rate telemetry	Actical AEE = 0.00423 + 0.00031 counts$^{0.653}$ Sedentary behaviour <100 counts/min Actiwatch AEE = 0.00441 + 0.00032 counts$^{0.724}$ Sedentary behaviour <50 counts/min	Actical Area under ROC curve: 0.85. Actiwatch Area under ROC curve: 0.85.	Good Good

Sirard et al. (52)	Development: N = 16 children, 3-5 years Validation: N = 269 children, 3-5 years United States	Actigraph 7164 accelerometer	Participants completed 5 structured activities while wearing the accelerometers. Sedentary activities included sitting and talking and sitting and playing. Activity monitors were compared against a validated direct observation technique.	Direct observation	3y: <1204 counts/min 4y: <1452 counts/min 5y: <1592 counts/min	3y Sensitivity: 100% Specificity: 100% Area under ROC curve: 1.00 4y Sensitivity: 100% Specificity: 100% Area under ROC curve: 1.00 5y Sensitivity: 94% Specificity: 92% Area under ROC curve: 0.97	Excellent Excellent Excellent	
Evenson et al. (53)	N = 33 children 5-8 years United States	Actical accelerometer Actigraph 7164 accelerometer	Participants wore accelerometers and Cosmed metabolic system to determine oxygen consumption. Sedentary activities included sitting in a chair watching a movie and sitting in a chair colouring.	Metabolic measurement system	Actical Sedentary behaviour <44 counts/min Actigraph Sedentary behaviour <100 counts/min	Actical Sensitivity: 97% Specificity: 98% Area under ROC curve: 0.99 Actigraph Sensitivity: 95% Specificity: 93% Area under ROC curve: 0.98	Excellent Excellent	

Note. AEE = activity energy expenditure; EE = energy expenditure; HR = heart rate; ROC = receiver operating characteristic
*According to area under ROC curve results: > 0.90 = excellent, 0.80–0.90 = good, 0.70–0.80 = fair, and < 0.70 = poor (27).