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REVIEW

Examining sedentary time as a risk factor for cardiometabolic diseases and their markers in South Asian adults: a systematic review

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Abstract
Objectives The objective was to systematically review the literature to determine whether sedentary time was associated with cardiometabolic diseases and their risk factors among South Asian adults.
Methods Six electronic databases were searched to identify all studies that examined the association between sedentary time and cardiometabolic diseases (e.g., diabetes, cardiovascular disease) and their risk factors [e.g., body mass index (BMI), waist circumference (WC), lipids, blood pressure (BP), glucose] among South Asian adults. Two independent reviewers performed abstract/full-text screening, data abstraction, and quality assessments.
Results Searching identified 1757 potential articles; 22 were used in the analysis. Greater sedentary time was associated with an increased likelihood of diabetes ($n=5$), higher BMI ($n=13$), WC ($n=3$), BP ($n=2$), and glucose ($n=4$). Thirteen out of 22 studies were of higher quality.
Conclusion Results identified a trend whereby greater sedentary time was associated with an increased risk for diabetes, and several other cardiometabolic risk factors among South Asian adults. High quality studies are needed to identify whether risk factors are independent of physical activity levels to inform culturally-specific interventions for South Asians.

Keywords South Asians · Sedentary behaviour · Cardiometabolic disease

Introduction

South Asia is the fastest growing region in the world (The World Bank 2016), and individuals of South Asian ethnic background are growing as one of the largest visible minority populations in other regions of the world (Government of Canada 2013; Hanif et al. 2014; United States Census Bureau 2012). South Asians have shown to be at greater risk for coronary heart disease compared to other ethnic groups (Williams et al. 2011). Numerous studies have reported a higher prevalence of cardiometabolic disease in South Asians and disproportionally poorer health outcomes overall when compared to other ethnic groups (Gupta and Brister 2006; Hanif et al. 2014; Leenen et al. 2008; Manuel and Schultz 2004; Rana et al. 2014; Shah 2008). The elevated risk for cardiometabolic disease among South Asians may arise from complex interactions between genetic and environmental factors (Rana et al. 2014). Among South Asians, the incidence of cardiometabolic disease is rising due to a marked shift in lifestyle as a result of economic growth, urbanization, sedentary lifestyle, and changes in dietary pattern (Ravikiran et al. 2010). This pattern is especially observed among individuals living in South Asian countries such as India. It is essential to determine the impact of ethno-specific behavioral patterns on the risk for cardiometabolic diseases to identify targets for

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public health interventions among this ethnic minority group (Chomitz et al. 2013; Yates et al. 2012a). Reducing sedentary time has been proposed as a novel public health approach to managing disease risk. Reducing time spent sitting during different times of the day may be more feasible than previous efforts to promote structured exercise programs (Dempsey et al. 2014). Further, contrary to previous assumptions, physical activity interventions do not necessarily result in meaningful reductions of sedentary time (Prince et al. 2014).

Sedentary behaviours refer to activities that do not require significant energy expenditure, including television (TV) viewing, computer use, driving, reading or playing video games while in a sitting or reclining position (Sedentary Behaviour Research Network 2012). High quality data have shown greater sedentary time is related to higher mortality, as well as a greater incidence of cardiovascular diseases, cancers, type 2 diabetes, and other risk factors (Biswas et al. 2015; Ford and Caspersen 2012; Grontved and Hu 2011; Proper et al. 2011; Rhodes et al. 2012; Saunders et al. 2012; Wilmot et al. 2012).

Sedentary behaviours are important determinants of metabolic dysfunction (Saunders et al. 2012). However, the magnitude of effect has the potential to be greater in some high-risk minority groups (Yates et al. 2012a). South Asians are described as having substantially lower levels of physical activity and higher sedentary time than the general population (Fischbacher et al. 2004). Differences exist when comparing the manner in which sedentary behaviours are performed irrespective of total sedentary time, highlighting the importance of analyzing domain-specific sedentary behaviours (Healy et al. 2008, 2011). There is currently no published synthesis looking at the relationship between sedentary time (across domains) and cardiometabolic risk factors and disease in South Asian adults. Additional research regarding sedentary behaviours would allow the development and dissemination of culturally appropriate interventions to reduce sedentary time in South Asians (Babakus and Thompson 2012; Ye et al. 2009). Such a synthesis provides evidence as to the need for the development of culturally appropriate interventions. Therefore, the objective of this study was to systematically review the literature to determine whether total sedentary time and domain-specific sedentary behaviours (e.g., TV viewing time, screen time, sitting time) are associated with cardiometabolic diseases/conditions (e.g., diabetes, cardiovascular disease, metabolic syndrome) and markers of disease (body mass index [BMI], waist circumference [WC], lipids, blood pressure [BP], glucose, insulin) among South Asian adults.

Methods

The available literature was systematically reviewed to examine sedentary time as an independent risk factor for cardiometabolic diseases and their markers in South Asian adults. The review sought to identify all studies that reported on the possible association between sedentary time and/or domain-specific sedentary behaviours (e.g., TV time, sitting time, etc.) with cardiometabolic diseases and their risk factors (primary and secondary outcomes) in South Asian adults. This systematic review adhered to the reporting guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement and met the criteria outlined in a measurement tool to assess systematic reviews (AMSTAR) checklist (Moher et al. 2009; Shea et al. 2007, 2009). The systematic review methodology was prospectively registered with PROSPERO (CRD42014012871; http://www.crd.york.ac.uk/PROSPERO).

Study inclusion criteria

Types of participants

Studies were included if the population was identified as being comprised of South Asian adults (mean age $\geq$18 years). South Asian populations included those who reside in, were born in, have parentage, and/or have emigrated from South Asia (as defined by The World Bank) including Bangladesh, Sri Lanka, India, Pakistan, Afghanistan, Bhutan, Maldives, and Nepal (The World Bank 2015). Exclusion criteria included non-South Asian populations and/or non-adult populations (mean age $<$18 years).

Types of exposures

The review included studies that reported sedentary time or time spent in domains of sedentary behaviours (e.g., TV time, sitting time, etc.) as a risk factor for cardiometabolic disease. Quantification of sedentary time was extracted based on what was provided in individual studies. Both self-reported and objectively measured sedentary time were included. Sedentary time was either reported on a continuous scale (e.g., minutes/day with beta coefficients, mean measures) or categorized based on the data (e.g., $>$2 h of TV time vs. $\leq$2 h and reported as odds ratios or relative risks). Total exposure to sedentary time and time spent in specific domains were examined including sitting time, TV time, screen time, computer time and reading time.

Types of comparators

The review compared greater and lower levels of sedentary time as risk factors for cardiometabolic disease and markers of disease.

Types of outcomes

The primary outcomes of interest in this systematic review were presence of diabetes mellitus II, cardiovascular disease (including coronary heart disease and stroke) and metabolic syndrome X (MetS). Secondary outcomes included markers of cardiometabolic disease such as elevated fasting blood glucose, elevated fasting insulin, percentage of hemoglobin A1c (HbA1c), total cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL), triglycerides and BP and anthropomorphic characteristics such as WC, BMI and waist-to-hip ratio (WHR).

Type of studies

No restriction was placed on the type of study design.

Search strategy

This review originally retrieved studies completed prior to and including September 2014 written in English or French language (or with translations). An updated search was performed to identify all studies from October 2014 to December 1, 2016. Relevant studies were systematically searched and identified using the following electronic bibliographic databases: ovid medline (R) In-process & other non-indexed citation and ovid medline (R) (1946 to December 2016); Embase Classic + Embase (1947–2016 December 1); EBM Reviews—Cochrane Central Register of Controlled Trials (December 2016); SPORTDiscus (1830–December 2016); CINAHL; and Dissertations and Theses (1861–December 2016). Grey literature included conference abstracts and dissertations, provided that the abstract allowed reviewers to ascertain the inclusion and exclusion criteria of the study.

Formal search strategies were developed with guidance from an experienced research librarian to ensure quality, transparency and maximum sensitivity during article retrieval. Due to the recent and upcoming nature of sedentary behaviour research, traditional and related terms were included in the search strategy to ensure maximum exposure to all relevant and existing literature. A sample search strategy for Medline is provided in Supplemental Table 1. This search strategy was modified according to the indexing systems of other databases. All searches were imported into Endnote X7 (Thompson Reuters, San Fransisco, CA, USA). A list of included studies is provided in Table 1, whereas the list of excluded studies is reported in Supplemental Table 2.

Selection of studies

Two authors (SS and SA or SAP) independently performed title and abstract screening of all records to identify potentially relevant articles. Two authors (SS and SA or KLW) also independently performed full text screening to confirm studies met inclusion and exclusion criteria, with mutual consensus. Discrepancies were resolved with discussion between all authors.

Data extraction and analysis

Standardized data abstraction forms in Microsoft Excel (Microsoft, 2011) were compiled by SA or SAP and verified by SAP or KLW. Information was extracted on study characteristics (year, author, title, study design), population characteristics (age range population description), country of study, sample size analyzed (total and by sex), sedentary behaviour exposure [self-report vs. direct measure, domain (e.g., TV, sitting, total, units) and methods (e.g., questionnaire, accelerometer)], outcome measurement (e.g., primary vs. secondary, self-report vs. objective), and measure of effect (odds ratio, relative risk, β-estimate) or correlation. Additional secondary outcomes [e.g., insulin resistance (HOMA-IR), sum of skin folds, C-reactive protein (CRP)] were obtained from the studies depending on applicability to cardiometabolic risk.

Quality of evidence

The quality of individual studies was assessed using a modified version of the Downs and Black checklist (Downs and Black 1998) and individual study scores can be found in Table 2. The Downs and Black checklist assessed study quality using an adapted 20-item checklist (originally 27 items), including reporting, external validity, internal validity and power of study. The assessment provided an overall numeric score for quality out of possible 20 points, with those studies higher than the 15/20 median split considered good quality. One assessor (SA or SAP) independently assessed the quality using the checklist with a second assessor (SA, SAP or KLW) reviewing all scores. Disagreements were resolved upon consensus. Although planned, the Cochrane Collaboration's tool for assessing risk of bias in randomized trials (Higgins et al. 2011) was not employed in this review due to limited availability of randomized controlled trials meeting eligibility criteria.

Table 1 Study characteristics of all included studies in a systematic review looking at the association between sedentary behaviours and cardiometabolic diseases and their risk factors among South Asian adults

First author, year	Country	Age Mean (SD)/range	Population	N analyzed			Study design	Sedentary domain	Primary outcome(s)	Secondary outcome(s)
				Men	Women	Total				
Agrawal (2013)	India	15–49	General population	0	325	325	Prospective cohort	TV time	N/A	BMI categories
Agrawal (2014a, b)	India	20–49	General population	56,742	99,574	156,316	Cross-sectional	TV time	Diabetes	WC, % BF, BMI categories
Andersen (2013)	Norway	25–60	Pakistani immigrants	126	0	126	RCT	ST	N/A	2-h insulin, 2-h glucose, HOMA-IR, % HbA1c, WC, glucose, insulin
Andersen (2015)	Norway	25–60	Pakistani immigrants	126	0	126	Prospective cohort	ST	N/A	2-h Insulin, 2-h glucose, 2-h C-peptide
Anjana (2015)	India	38.0 (17)	General population	573	803	1376	Prospective cohort	TV time, sitting time	Diabetes	N/A
Curry (2014)	United Kingdom	46.5 (14.3)/18–72	SA women (Pakistani and Bangladesh)	0	140	140	Cross-sectional	ST	N/A	WC categories, % BF; BMI categories
Ghosh (2014)	India	25–65	Rural Asian Indian women	0	343	343	Cross-sectional	TV time	N/A	BMI, WC, %BF, intra-abdominal visceral fat, fat mass, SBP, DBP, MAP
Gill (2011)	Scotland	35–89	Indian and Pakistani origin	523	705	1228	Cross-sectional	Sitting time	N/A	Fasting glucose, 2-h glucose concentrations, WC
Gupta (2015)	India	25–45	Urban affluent women	0	387	387	Cross-sectional	Sitting time, TV time	N/A	BMI categories
Khan (2016)	Pakistan	18–25	Medical students	85	159	244	Cross-sectional	TV time, computer time	N/A	BMI, WHR
Little (2016)	India	20–80	General population	341	412	753	Cross-sectional	Sitting time, TV time	N/A	BMI categories
Mani (2014)	India	N/A	Medical students	43%	57%	55	Cross-sectional	ST	N/A	BMI categories
Nag (2015)	India	20–80	Rural residents	645	362	1007	Cross-sectional	TV time	N/A	Weight, WC, hip circumference, WHR, sum of skin folds, % BF, BMI, FM, FFM, TC, TG, HDL, LDL, VLDL, SBP, DBP, MAP, insulin, HOMA-IR

Table 1 (continued)

First author, year	Country	Age Mean (SD)/range	Population	N analyzed			Study design	Sedentary domain	Primary outcome(s)	Secondary outcome(s)
				Men	Women	Total				
Nang (2013)	Singapore	24.4–94.8	Urban Asian population	N/R	N/R	955	Cross-sectional	Screen time	N/A	BMI, BP, lipids, glucose, adiponectin, CRP, HOMA-IR
Pomerleau (1999)	UK	40–66	SA women	0	291	291	Cross-sectional	TV time	N/A	BMI, obesity (>30 kg/m^2), WHR, sum of skin folds
Rastogi (2004)	India	52 (11)	Hospital-based study	576	79	655	Case-control	Sedentary activities time	Hypertension, diabetes, acute myocardial infarction	BMI, WHR
Shah (2015)	US	40–84	SA immigrants	483	416	899	Cross-sectional	TV time	Diabetes	N/A
Singh (2012)	India	NR	Dental health care professionals	143	181	324	Cross-sectional	ST	N/A	BMI categories
Sullivan (2012)	India	40.7 (10.3)	Urban and rural groups in India	4102	2898	7000	Cross-sectional	ST	N/A	BMI, % BF
Tandon (2011)	India	18–71	General population	381	424	805	Cross-sectional	TV time	N/A	BMI categories, subcutaneous fat mass
Waidyatilaka (2013)	Sri Lanka	30–45	Urban SA women	0	617	617	Cross-sectional	Sitting time, TV time	Dysglycemia	HbA1c
Yates (2012a)	United Kingdom	25–75	Diabetes screening program attendees	54%	46%	111	Cross-sectional	Sitting time	N/A	BMI, WC, fasting glucose, 2-h glucose, fasting insulin, CRP

%BF percent body fat, *BP* blood pressure, *BMI* body mass index, *CRP* C-reactive protein, *DBP* diastolic blood pressure, *FFM* fat free mass, *FM* fat mass, *HDL* high density lipoprotein, *%HbA1c* percent hemoglobin A1c, *HOMA-IR* homeostasis model assessment-insulin resistance, *LDL* low density lipoprotein, *MAP* mean arterial pressure, *N/A* not available, *N/R* not reported, *RCT* randomized controlled trial, *SA* South Asian, *SBP* systolic blood pressure, *SD* standard deviation, *ST* sedentary time, *TC* total cholesterol, *TG* total glucose, *TV* television, *UK* United Kingdom, *VLDL* very low density lipoprotein, *WC* waist circumference, *WHR* waist-to-hip ratio

Results

Description of studies

Searching of the six databases identified 1757 potential articles (Supplementary Fig. 1). After removing 536 duplicate articles, 1221 articles progressed to the title and abstract screening stage. Of these, 767 articles were identified in Medline, 333 in Embase, 18 in Cochrane Central, 34 in CINAHL, 17 in SPORTDiscus, and 52 in Dissertations and Theses. An additional article was identified via the authors' knowledge. The primary title and abstract screening yielded 414 articles, which progressed to the detailed full-text screening stage. Of these, 22 studies met inclusion and exclusion criteria. Common reasons for excluding studies included no sedentary behaviour exposure, no association between SB and health outcome reported, review paper, unable to obtain or locate an article, and duplicate article. Results from the studies can be found in Table 2 and Supplementary Table 2.

Results from the updated search identified two publications (Agrawal et al. 2014b; Waidyatilaka et al. 2014) that reported on duplicate data found in previous publications. Findings from the originally retrieved studies (Agrawal et al. 2014a; Waidyatilaka et al. 2013) were retained to avoid duplicate results.

Individual study quality

Based on the median split (15/20), 59% of the studies were considered high quality. Most studies minimized the effects of selection bias. Despite high scores for internal validity (mean = 6.41 out of 8), the majority of studies presented issues with external validity, reporting and power. Only a few studies ($n = 4$) reported having sufficient power to detect clinically important effects related to the exposure and outcomes under study.

Data synthesis

Twenty-two studies met the inclusion criteria and were included in the qualitative analysis; six studies reported on results relating to cardiometabolic diseases (five diabetes, one myocardial infarction) and 19 studies reported on results related to markers of cardiometabolic diseases (15 BMI, five WC or WHR, six glucose, five insulin, two lipids, four BP). Results identified a general trend whereby increased time spent in sedentary behaviours was associated with increased likelihood of diabetes ($N = 5/5$), as well as higher BMI ($N = 13/15$), WC or WHR ($N = 3/5$), and glucose ($N = 4/6$).

Primary outcomes

Six studies reported on results pertaining to the association between sedentary time and cardiometabolic diseases (Table 2). One prospective cohort study (Anjana et al. 2015), one case-control study (Rastogi et al. 2004) and three cross-sectional studies (Agrawal et al. 2014a; Shah et al. 2015; Waidyatilaka et al. 2013) suggested that greater sedentary time is associated with higher prevalence of diabetes in both men and women. Using a prospective study design, Anjana and colleagues identified an 84% increased risk for developing diabetes in the highest quartile of TV and sitting time (Anjana et al. 2015). Waidyatilaka et al. reported that the odds of diabetes were 43% (OR 1.43; 95% CI 0.72–2.82) greater in those sitting ≥185 min/day versus <185 min/day and were over four times greater (OR 4.23; 95% CI 2.13–8.41) in those watching ≥85 min/day of TV compared to those with <85 min/day (Waidyatilaka et al. 2013). Agrawal et al. (2014a) and Rastogi et al. (Rastogi et al. 2004) reported higher proportions of diabetes among those watching TV almost every day (vs. those watching TV once a week or less) and those in sedentary activities longer than 215 min (vs. ≤70 min), respectively. Only one study reported on the relationship between sedentary time and CVD. After adjusting for age and sex, greater sedentary time (≥215 min/day) had a 58% greater risk of myocardial infarction than those with <70 min/day of sedentary time (Rastogi et al. 2004).

Secondary outcomes

Supplementary Table 2 provides a description of the association between sedentary behaviours and secondary outcomes.

Body mass index (BMI)

Of all the secondary outcomes, BMI was the most frequently studied risk factor. Thirteen studies reported that BMI was significantly associated with sedentary time (Agrawal et al. 2013; Curry and Thompson 2014; Ghosh and Bhagat 2014; Gupta and Siddhu 2015; Little et al. 2016; Mani 2014; Nag and Ghosh 2015; Nang et al. 2013; Rastogi et al. 2004; Singh and Purohit 2011; Sullivan et al. 2012; Tandon et al. 2011; Yates et al. 2012b), whereas two studies reported no significant association (Khan et al. 2016; Pomerleau et al. 1999).

Waist circumference (WC)

Four studies reported on WC and two on waist-to-hip ratio. Two studies found no significant association between sedentary time and WC and waist-to-hip ratio (Curry and

Table 2 Primary outcome results of all included studies looking at the association between sedentary behaviours and cardiometabolic diseases and their risk factors among South Asian adults

References		Sedentary behaviour		Outcome	Results			
First author	Year	Domain	Self-report or objective	Self-report or objective	Mean or proportion of outcome associated with sedentary behaviour	Measure of effect (e.g., rho, β, OR, RR)	Interpretation	QA score (/20)
Diabetes								
Agrawal	2014a, b	TV time frequency	Self-report	Self-report	Proportion with diabetes by frequency of watching TV: Not at all (0.8%); less than once a week (0.9%); at least once a week (1.1%); almost every day (1.5%), $p < 0.0001$	N/R	Diabetes more common among both men and women who watched television almost every day	18
Anjana	2015	TV time, sitting time	Self-report	Self-report	N/R	Highest quartile TV: RR (95% CI) = 1.84 (1.36–2.49) Highest quartile sitting: RR (95% CI) = 2.09 (1.42–3.05)	Risk for diabetes increased with increasing quartile of TV time and sitting time	17
Rastogi	2004	Time spent in sedentary activities	Self-report	Self-report	Proportion with diabetes by time spent in sedentary activities: ≤70 min (5%) vs. >215 min (20%)	N/R	Greater sedentary time associated with greater prevalence of diabetes	16
Shah	2015	TV time	Self-report	Objective	Median (25th, 75th percentile) minutes/week across glycemic status: Normal = 420 (210, 840); pre-diabetes = 420 (210, 840); diabetes = 420 (300, 840), $p < 0.001$	N/R	Greater time watching TV was associated with greater prevalence of diabetes	13
Waidyatilaka	2013	TV time, sitting time	Self-report	Objectively measured glycemic status	N/R	OR (95% CI): Sitting ≥185 min/day vs. <185 min/day: 1.43 (0.72–2.82), TV time ≥85 min/day vs. <85 min/day: 4.23 (2.13–8.41) Sitting time: rho = 0.659, $p < 0.001$; TV time: rho = 0.723, $p < 0.001$	TV time was significantly associated with dysglycemia after controlling for confounders. Among women, viewing TV for > 85 min/day were six times more likely to be dysglycemic than those watching less TV . Sitting time was significantly correlated with dysglycemia	19

Table 2 (continued)

References		Sedentary behaviour		Outcome	Results			
First author	Year	Domain	Self-report or objective	Self-report or objective	Mean or proportion of outcome associated with sedentary behaviour	Measure of effect (e.g., rho, β, OR, RR)	Interpretation	QA score (/20)
Myocardial infarction								
Rastogi	2004	Sedentary activities time	Self-report	Self-report	N/R	RR: <70 min/day = reference category, 70–30 min/day RR = 0.93 (0.63, 1.39), >130–214 min/day RR = 0.96 (0.64, 1.44), ≥215 min/day RR = 1.58 (1.05, 2.36) $p = 0.02$ for trend	Individuals in the highest level of sedentary time (≥3.6 h/day) had a greater RR of AMI then those with <70 min/day	16

**AMI* acute myocardial infarction, *β* beta, *OR* odds ratio, *N/R* not reported, *PA* physical activity, *QA* quality assessment, *RR* relative risk, *rho* spearman correlation, *SB* sedentary behaviour, *TV* television

Thompson 2014; Rastogi et al. 2004), whereas Ghosh et al. and Nag et al. showed higher WCs with increasing TV time (Ghosh and Bhagat 2014; Nag and Ghosh 2015) and Yates reported a significant correlation between screen time and WC among women only (Yates et al. 2012b).

Two-hour (2-h) glucose/fasting glucose

Six studies reported on the relationships between 2-h or fasting blood glucose and sedentary time (total and domain-specific). Of these studies, one study found a significant relationship between sedentary time and 2-h glucose (Andersen et al. 2015). In contrast, Yates et al. reported sitting time was not significantly associated with 2-h glucose in men or women (Yates et al. 2012b). Gill et al. found a low though significant correlation between sitting time (independent of physical activity) and 2-h glucose, but not with fasting glucose (Gill et al. 2011). Nag and Ghosh reported that fasting blood glucose was higher with increasing duration of TV watching (Nag and Ghosh 2015). Three studies did not find a significant association between fasting glucose and sedentary behaviour, with two looking at screen time (Gill et al. 2011; Yates et al. 2012b) and one looking at general screen time (Nang et al. 2013).

Hemoglobin A1c (HbA1c)

Only one study examined the association between HbA1c and sedentary time among South Asian women. After controlling for confounders, greater sitting time and TV time were significantly correlated with HbA1c. Women viewing TV for ≥185 min/day were four times more likely to be dysglycemic compared to those viewing <185 min/day of TV (Waidyatilaka et al. 2013).

Insulin

Five studies reported on findings related to insulin. Andersen et al. reported that 2-h insulin was strongly related to sedentary time, with reductions of 1.6 pmol/L with every one-minute reduction of sedentary time in Pakistani men (Andersen E 2013). Using the same data, Andersen et al. also demonstrated that changes in sedentary time were significantly and beneficially associated with changes in postprandial insulin and C-peptide (Andersen et al. 2015). Yates et al. showed a significant trend with increasing screen time associated with increasing fasting insulin for women, but not for men (Yates et al. 2012b). Similarly, Nang et al. reported a significant trend with greater homeostatic model assessment to quantify insulin resistance (HOMA-IR) with increasing screen time categories adjusted for age, sex, ethnicity and education (Nang et al. 2013). Interestingly, Nag and Ghosh found higher

insulin and HOMA-IR among those watching 31–60 min of TV per day compared to those watching less than 30 and more than 60 min per day (Nag and Ghosh 2015).

Lipid profile

Two studies reported on the relationship between sedentary time and lipid profiles. Using a model adjusted for age, sex, ethnicity and education, Nang et al. reported a significant trend with greater screen time associated with lower HDL-c and higher LDL, cholesterol and triglycerides (Nang et al. 2013). Nag and Ghosh found that total cholesterol and LDL increased with greater duration of TV watching, but did not find a significant association with triglycerides, HDL or very low density lipoprotein (Nag and Ghosh 2015).

Blood pressure (BP)

Four studies reported on the relationship between sedentary time and BP. Two studies reported significantly higher BP values (Nang et al. 2013) and prevalence of hypertension (Rastogi et al. 2004) with greater amount of screen or sedentary time, respectively. Whereas two other studies reported no significant group differences for systolic or diastolic BP or mean arterial pressure across TV time categories (Ghosh and Bhagat 2014; Nag and Ghosh 2015).

Subgroup analysis

Sex differences

Sex differences were examined in a few of the studies with differences found between men and women for BMI, WC and fasting insulin levels. Yates et al. and Curry et al. noted WC and BMI were significantly associated with sedentary time in South Asian women only (Curry and Thompson 2014; Yates et al. 2012b).

Domain-specific sedentary time

When domains of sedentary time were examined, twelve studies reported on TV time (Agrawal et al. 2013, 2014a; Anjana et al. 2015; Ghosh and Bhagat 2014; Gupta and Siddhu 2015; Khan et al. 2016; Little et al. 2016; Nag and Ghosh 2015; Pomerleau et al. 1999; Shah et al. 2015; Tandon et al. 2011; Waidyatilaka et al. 2013), six on sitting time (Anjana et al. 2015; Gill et al. 2011; Gupta and Siddhu 2015; Little et al. 2016; Waidyatilaka et al. 2013; Yates et al. 2012b), one on screen time (Nang et al. 2013), and one on computer time (Khan et al. 2016). The remaining seven looked at a general measure of sedentary time (Andersen et al. 2015; Andersen 2013; Curry and Thompson 2014; Mani 2014; Rastogi et al. 2004; Singh and Purohit 2011; Sullivan et al. 2012). Qualitatively, these results showed the same trend for each domain of sedentary behaviour.

Domain-specific analysis of sedentary behaviours identified that most studies found a significant association between greater TV time and higher BMI and WC (Agrawal et al. 2013; Ghosh and Bhagat 2014; Gupta and Siddhu 2015; Little et al. 2016; Nag and Ghosh 2015; Nang et al. 2013; Tandon et al. 2011). Moreover, Waidyatilaka et al. noted TV time was significantly associated with dysglycemia after controlling for confounders; however, the relative risk of dysglycemia from longer duration of TV time was almost three times higher than sitting time (Waidyatilaka et al. 2013). Overall, there appears to be a greater cardiometabolic risk associated with higher amounts of TV time, compared to overall sedentary time.

Sitting time has been less examined with a total of six studies reporting on this domain. Three studies looked at anthropometrics and sitting time and reported significant positive correlations between greater sitting time and BMI and WC (Gupta and Siddhu 2015; Little et al. 2016; Yates et al. 2012b). Yates et al. however, found this relationship among women, but not men (Yates et al. 2012b). Studies looking at the relationship between sitting time and diabetes and its markers provide conflicting results. In a prospective cohort of men and women from the general population in India, Anjana et al. found a greater risk for diabetes with greater sitting time (Anjana et al. 2015). A study of urban South Asian women revealed a significant positive correlation between sitting time and dysglycemia, although there were no significant differences in the odds of dysglycemia between those who sat less than 185 min/day compared to those who sat longer (Waidyatilaka et al. 2013). In contrast, a study of attendees from a diabetes screening program reported that sitting time was not significantly correlated with either 2-h or fasting glucose (Yates et al. 2012b). Whereas a study of individuals of Indian and Pakistani origin living in Scotland found no significant correlation between sitting time and fasting glucose, the study did however report that greater sitting time was associated with 2-hour glucose (Gill et al. 2011).

All studies that reported on overall sedentary time and BMI reported a significant relationship with greater sedentary time associated with a higher BMI (Curry and Thompson 2014; Mani 2014; Rastogi et al. 2004; Singh and Purohit 2011; Sullivan et al. 2012). Interestingly studies reporting on measures of central obesity reported a lack of association between total sedentary time and WC (Curry and Thompson 2014) or waist-to-hip ratio (Rastogi et al. 2004).

Discussion

This is the first systematic review to examine sedentary behaviours as risk factors for cardiometabolic disease in the South Asian population. Ultimately the objective of this review was to provide a concise summary of the literature to date to inform the need for effective evidence-based interventions to reduce sedentary time among South Asian adults. Using a qualitative summary of all published evidence to date, this review found that greater sedentary time in South Asian adults was consistently associated with diabetes, and higher BMI, WC, insulin and HOMA-IR. Inconsistent and limited evidence was observed for relationships with the risk for myocardial infarction, glucose and BP. Very few to no studies have reported on the associations between sedentary time and lipids, MetS, cardiovascular disease, and hypertension.

This review builds on the previous evidence from two meta-analyses, which link high sedentary time with diabetes (Biswas et al. 2015; Wilmot et al. 2012). One review suggested that South Asians are more than four times as likely to develop diabetes with greater sedentary time (Waidyatilaka et al. 2013), whereas Biswas et al. and Wilmot et al. reported the magnitude of the risk to be approximately twice as high as in the general population (Biswas et al. 2015; Wilmot et al. 2012). This suggests that South Asian adults are potentially at double the risk for diabetes. Unfortunately, the scarcity of available evidence on this sub-population limits the ability to ascertain whether this risk is truly greater in this population group. One of the studies in the present review reported a 58% higher risk of coronary heart disease in South Asian adults who were in the highest category of time spent in sedentary activities (Rastogi et al. 2004). Whereas in their systematic review, Biswas et al. suggested that in general, greater sedentary time is associated with a 14% greater risk of cardiovascular disease (Biswas et al. 2015). It is possible that South Asians are at a greater risk for cardiovascular disease with greater sedentary time, but further studies are needed to establish whether this is in fact consistently the case.

Thirteen of fifteen studies reported a significant relationship between increasing sedentary time and greater BMI. These results are similar to those reported in recent systematic reviews in adults (Lynch et al. 2011; Thorp et al. 2011). Unfortunately, there remains a lack of direct comparison within individual studies to examine whether South Asians are specifically at greater risk of overweight and obesity with higher levels of sedentary time. Although more evidence is needed, it should be recognized that a number of studies have demonstrated higher risk of BMI in South Asian adults compared to the general population (Deurenberg et al. 2002; Misra and Khurana 2009).

Study limitations

This review has several limitations including the lack of available high quality studies examining the relationship between sedentary time and cardiometabolic diseases and risk factors among South Asian adults. A second limitation was that a meta-analysis was not feasible or appropriate due to the heterogeneity of study designs. A third limitation was that selective reporting of positive outcomes in the individual studies could potentially reduce the generalizability of the findings. Also, a number of articles could not be retrieved via the University of Ottawa's library lending service and several were not available in English or French. A further limitation is the predominant use of self-report data in the individual studies. Self-reported data are highly susceptible to recall, interviewer and reporting bias that could have affected the magnitude of results. Few studies to date have used objective measures such as accelerometers or inclinometers for the measurement of sedentary behaviours. Unfortunately, only two studies in the present review reported on the use of objective measures of sedentary time (Andersen 2013; Curry and Thompson 2014) and therefore, it was not possible to compare results between self-report and objective measures. Finally, analysis of results was not consistent across studies, especially with respect to adjustment of confounders.

While it was the goal to obtain studies that performed analyses adjusting for physical activity, the majority of the studies did not report on adjusted values. This has important consequences as it was not possible to adjust for individuals' engagement in physical activity and identify the true effects of sedentary time on cardiometabolic diseases. Recently, Biswas et al. reported that hazard ratios for disease associated with sedentary time are more pronounced at lower levels of physical activity than at higher levels (Biswas et al. 2015).

Sedentary behaviours in South Asian adults should be further explored as it is known that this population is generally at higher risk for cardiometabolic disease. Further, there seems to be a significant lack of awareness of the detrimental effects of a sedentary lifestyle in this population (Lawton et al. 2006). South Asian adults are more likely to hold passive beliefs regarding personal health risk (Lawton et al. 2006). It is possible that lack of awareness around the detrimental effects of sedentary behaviours on health outcomes contributes to greater engagement in these behaviours among South Asian adults (Ravikiran et al. 2010).

In light of the findings of this systematic review, there is evidence to support the development of interventions targeting sedentary behaviours in South Asian adults. As suggested by Ye et al. and Agrawal and Ebrahim, prevention of cardiometabolic disease should focus on lifestyle aspects and target public health education programs geared

specifically to this population (Agrawal and Ebrahim 2012; Ye et al. 2009). The emphasis of such programs should be on embracing the differences inherent in the South Asian population and emphasizing planning and development of health programs that take such differences into account (Ye et al. 2009). Targeting sedentary behaviours specifically may lead to reductions in health risk (Buman et al. 2014). To date, most interventions have aimed to increase physical activity (Misra et al. 2009); however, it is now known that physical activity interventions alone often do not confer meaningful reductions in sedentary time (Prince et al. 2014). Further interventions addressing sedentary behaviours in South Asian adults should include educational material in South Asian languages and using culturally appropriate examples to increase knowledge and awareness of sedentary behaviours as risk factors (Castro et al. 2010). Resources to increase the awareness of risk factors and risk factor modification interventions could help South Asians to prevent/reduce these risk factors. For example, the Heart and Stroke Foundation of Canada's website provides information on heart disease and stroke in various languages to try to increase awareness and help South Asians prevent/manage their risk factors (Heart and Stroke Foundation 2016).

Conclusions

This review shows that greater total sedentary time and domain-specific sedentary behaviours were associated with cardiometabolic disease (i.e., diabetes) and markers of disease among South Asian adults. Trends in South Asians were similar if not greater than those observed in other populations, yet it is important to recognize the intercultural physical and behavioural variances that may potentially influence awareness, education and likelihood to change behaviours and subsequently improve cardiometabolic health. Further studies are required to examine whether the effects of sedentary behaviour on cardiometabolic disease and its markers are independent of moderate-to-vigorous intensity physical activity in South Asian adults and to compare these results to other ethnic groups.

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Authors' contributions SA conceived the study, design and methodology, developed the bibliographic search strategy, screened all abstracts and papers, performed data abstraction and quality assessments, and drafted and edited the manuscript. SS participated in its design and coordination, screened all abstracts and papers, and provided critical revision of the manuscript. KLW participated in the updated search, screened full texts, verified quality assessments, and provided critical review of the manuscript. SAP also conceived the study, its design and coordination, performed data abstraction and quality assessments, and provided critical revision of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

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References

Agrawal S, Ebrahim S (2012) Prevalence and risk factors for self-reported diabetes among adult men and women in India: findings from a national cross-sectional survey. Public Health Nutr 15:1065–1077. doi:10.1017/S1368980011002813

Agrawal P, Gupta K, Mishra V, Agrawal S (2013) Effects of sedentary lifestyle and dietary habits on body mass index change among adult women in India: findings from a follow-up study. Ecol Food Nutr 52:387–406. doi:10.1080/03670244.2012.719346

Agrawal S, Millett C, Subramanian SV, Ebrahim S (2014a) Frequency of fish intake and diabetes among adult Indians. J Am Coll Nutr 33:215–230. doi:10.1080/07315724.2013.867420

Agrawal S, Millett CJ, Dhillon PK, Subramanian S, Ebrahim S (2014b) Type of vegetarian diet, obesity and diabetes in adult Indian population. Nutr J 13:89. doi:10.1186/1475-2891-13-89

Andersen E, Hostmark AT, Holme I, Anderssen SA (2013) Intervention effects on physical activity and insulin levels in men of Pakistani origin living in Oslo: a randomised controlled trial. J Immigr Minor Health 15:101–110. doi:10.1007/s10903-012-9686-3

Andersen E, Ekelund U, Anderssen SA (2015) Effects of reducing sedentary time on glucose metabolism in immigrant Pakistani men. Med Sci Sports Exerc 47:775–781. doi:10.1249/MSS.0000000000000460

Anjana RM, Sudha V, Nair DH et al. (2015) Diabetes in Asian Indians-How much is preventable? Ten-year follow-up of the Chennai Urban Rural Epidemiology Study (CURES-142). Diabete Res Clin Pract 109:253–261. doi:10.1016/j.diabres.2015.05.039

Babakus WS, Thompson JL (2012) Physical activity among South Asian women: a systematic, mixed-methods review. Int J Behav Nutr Phys Act 9:150. doi:10.1186/1479-5868-9-150

Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, Alter DA (2015) Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. Ann Intern Med 162:123–132. doi:10.7326/m14-1651

Buman MP, Winkler EA, Kurka JM et al (2014) Reallocating time to sleep, sedentary behaviors, or active behaviors: associations with cardiovascular disease risk biomarkers, NHANES 2005–2006. Am J Epidemiol 179:323–334. doi:10.1093/aje/kwt292

Castro FG, Barrera M, Holleran Steiker LK (2010) Issues and challenges in the design of culturally adapted evidence-based interventions. Annu Rev Clin Psychol 6:213–239. doi:10.1146/annurev-clinpsy-033109-132032

Chomitz VR, Prabhu SS, Thanikachalam S et al (2013) Physical activity and sedentary behavior in South Indian adults: urbanicity, gender, and obesity. FASEB J 27:1055.27

Curry WB, Thompson JL (2014) Objectively measured physical activity and sedentary time in south Asian women: a cross-sectional study. BMC Public Health 14:1269. doi:10.1186/1471-2458-14-1269

Dempsey PC, Owen N, Biddle SJ, Dunstan DW (2014) Managing sedentary behavior to reduce the risk of diabetes and cardiovascular disease. Curr Diab Rep 14:522. doi:10.1007/s11892-014-0522-0

Deurenberg P, Deurenberg-Yap M, Guricci S (2002) Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. Obes Rev 3:141–146

Downs SH, Black N (1998) The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health 52:377–384

Fischbacher CM, Hunt S, Alexander L (2004) How physically active are South Asians in the United Kingdom? A literature review. J Public Health 26:250–258. doi:10.1093/pubmed/fdh158

Ford ES, Caspersen CJ (2012) Sedentary behaviour and cardiovascular disease: a review of prospective studies. Int J Epidemiol 41:1338–1353. doi:10.1093/ije/dys078

Ghosh A, Bhagat M (2014) Association of television viewing time with central obesity status in rural Asian Indian women: Santiniketan women study. Am J Hum Biol 26:427–430. doi:10.1002/ajhb.22536

Gill JM, Bhopal R, Douglas A et al (2011) Sitting time and waist circumference are associated with glycemia in U.K. South Asians: data from 1,228 adults screened for the PODOSA trial. Diab Care 34:1214–1218 doi: 10.2337/dc10-2313

Government of Canada (2013) Designated Group Profiles (2006 Employment Equity Data Report). http://www.labour.gc.ca/eng/standards_equity/eq/pubs_eq/eedr/2006/profiles/page06.shtml#ftn4. Accessed 1 Oct 2016

Grontved A, Hu FB (2011) Television viewing and risk of type 2 diabetes, cardiovascular disease, and all-cause mortality: a meta-analysis. JAMA 305:2448–2455. doi:10.1001/jama.2011.812

Gupta M, Brister S (2006) Is South Asian ethnicity an independent cardiovascular risk factor? Can J Cardiol 22:193–197

Gupta AT, Siddhu A (2015) Desirable factors for maintaining normal BMI of urban affluent women of Delhi. Indian J Public Health 59:49–53. doi:10.4103/0019-557X.152864

Hanif W, Khunti K, Bellary S, Bharaj H, Karamat MA, Patel K, Patel V (2014) Type 2 diabetes in the UK South Asian population. An update from the South Asian Health Foundation. http://www.sahf.org.uk/sites/default/files/publications/Type%202%20Diabetes%20in%20the%20UK%20South%20Asian%20population.pdf

Healy GN, Dunstan DW, Salmon J, Shaw JE, Zimmet PZ, Owen N (2008) Television time and continuous metabolic risk in physically active adults. Med Sci Sports Exerc 40:639–645. doi:10.1249/MSS.0b013e3181607421

Healy GN, Matthews CE, Dunstan DW, Winkler EA, Owen N (2011) Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. Eur Heart J 32:590–597. doi:10.1093/eurheartj/ehq451

Heart and Stroke Foundation (2016) South Asian Resources. http://www.heartandstroke.com/site/c.ikIQLcMWJtE/b.3479045/k.6516/South_Asian_Resources.htm. Accessed 1 Oct 2016

Higgins JP, Altman DG, Gotzsche PC et al (2011) The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 343:d5928. doi:10.1136/bmj.d5928

Khan ZN, Assir MZ, Shafiq M, Chaudhary AE, Jabeen A (2016) High prevalence of preobesity and obesity among medical students of Lahore and its relation with dietary habits and physical activity. Indian J Endocrinol Metab 20:206–210. doi:10.4103/2230-8210.176357

Lawton J, Ahmad N, Hanna L, Douglas M, Hallowell N (2006) 'I can't do any serious exercise': barriers to physical activity amongst people of Pakistani and Indian origin with Type 2 diabetes. Health Educ Res 21:43–54. doi:10.1093/her/cyh042

Leenen FH, Dumais J, McInnis NH et al (2008) Results of the Ontario survey on the prevalence and control of hypertension. CMAJ 178:1441–1449. doi:10.1503/cmaj.071340

Little M, Humphries S, Patel K, Dewey C (2016) Factors associated with BMI, underweight, overweight, and obesity among adults in a population of rural south India: a cross-sectional study. BMC Obes 3:12. doi:10.1186/s40608-016-0091-7

Lynch BM, Friedenreich CM, Winkler EA, Healy GN, Vallance JK, Eakin EG, Owen N (2011) Associations of objectively assessed physical activity and sedentary time with biomarkers of breast cancer risk in postmenopausal women: findings from NHANES (2003–2006). Breast Cancer Res Treat 130:183–194. doi:10.1007/s10549-011-1559-2

Mani G (2014) Assessment of body mass index and its associated nutritional factors among undergraduate medical students in Tamil Nadu, India: a cross-sectional study. J Pioneer Med Sci 4:137–142

Manuel DG, Schultz SE (2004) Health-related quality of life and health-adjusted life expectancy of people with diabetes in Ontario, Canada, 1996–1997. Diabetes Care 27:407–414

Misra A, Khurana L (2009) The metabolic syndrome in South Asians: epidemiology, determinants, and prevention. Metab Syndr Relat Disord 7:497–514. doi:10.1089/met.2009.0024

Misra A, Chowbey P, Makkar BM et al. (2009) Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. J Assoc Phys India 57:163–170

Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ 339:b2535. doi:10.1136/bmj.b2535

Nag T, Ghosh A (2015) Cardiometabolic risk factors and TV watching in a rural community in West Bengal, India. Diabetes Metab Syndr 9:147–152. doi:10.1016/j.dsx.2015.04.013

Nang EE, Salim A, Wu Y, Tai ES, Lee J, Van Dam RM (2013) Television screen time, but not computer use and reading time, is associated with cardio-metabolic biomarkers in a multiethnic Asian population: a cross-sectional study. Int J Behav Nutr Phys Act 10:70. doi:10.1186/1479-5868-10-70

Pomerleau J, McKeigue PM, Chaturvedi N (1999) Factors associated with obesity in South Asian, Afro-Caribbean and European women. Int J Obes Relat Metab Disord 23:25–33

Prince SA, Saunders TJ, Gresty K, Reid RD (2014) A comparison of the effectiveness of physical activity and sedentary behaviour interventions in reducing sedentary time in adults: a systematic review and meta-analysis of controlled trials. Obes Rev 15:905–919. doi:10.1111/obr.12215

Proper KI, Singh AS, van Mechelen W, Chinapaw MJ (2011) Sedentary behaviors and health outcomes among adults: a systematic review of prospective studies. Am J Prev Med 40:174–182. doi:10.1016/j.amepre.2010.10.015

Rana A, de Souza RJ, Kandasamy S, Lear SA, Anand SS (2014) Cardiovascular risk among South Asians living in Canada: a systematic review and meta-analysis. CMAJ Open 2:E183–E191. doi:10.9778/cmajo.20130064

Rastogi T, Vaz M, Spiegelman D et al (2004) Physical activity and risk of coronary heart disease in India. Int J Epidemiol 33:759–767

Ravikiran M, Bhansali A, Ravikumar P et al (2010) Prevalence and risk factors of metabolic syndrome among Asian Indians: a community survey. Diabetes Res Clin Pract 89:181–188. doi:10.1016/j.diabres.2010.03.010

Rhodes RE, Mark RS, Temmel CP (2012) Adult sedentary behavior: a systematic review. Am J Prev Med 42:e3–e28. doi:10.1016/j.amepre.2011.10.020

Saunders TJ, Larouche R, Colley RC, Tremblay MS (2012) Acute sedentary behaviour and markers of cardiometabolic risk: a systematic review of intervention studies. J Nutr Metab 2012:712435. doi:10.1155/2012/712435

Sedentary Behaviour Research Network (2012) Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours". Appl Physiol Nutr Metab 37:540–542. doi:10.1139/h2012-024

Shah BR (2008) Utilization of physician services for diabetic patients from ethnic minorities. J Public Health (Oxf) 30:327–331. doi:10.1093/pubmed/fdn042

Shah AD, Vittinghoff E, Kandula NR, Srivastava S, Kanaya AM (2015) Correlates of prediabetes and type II diabetes in US South Asians: findings from the Mediators of Atherosclerosis in South Asians Living in America (MASALA) study. Ann Epidemiol 25:77–83 doi:10.1016/j.annepidem.2014.10.013

Shea BJ, Grimshaw JM, Wells GA et al (2007) Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. BMC Med Res Methodol 7:10. doi:10.1186/1471-2288-7-10

Shea BJ, Hamel C, Wells GA et al (2009) AMSTAR is a reliable and valid measurement tool to assess the methodological quality of systematic reviews. J Clin Epidemiol 62:1013–1020. doi:10.1016/j.jclinepi.2008.10.009

Singh A, Purohit B (2011) Evaluation of Global physical activity Questionnaire (GPAQ) among healthy and obese health professionals in central India. Baltic J Health Phys Act 3:34–43

Sullivan R, Kinra S, Ekelund U et al (2012) Evaluation of the Indian Migration Study Physical Activity Questionnaire (IMS-PAQ): A cross-sectional study. Int J Behav Nutr Phys Act 9:13. doi:10.1186/1479-5868-9-13

Tandon K, Kapoor S, Kapoor AK (2011) Covariates and prevalence of obesity among adult North Indian population. Coll Antropol 35:305–311

The World Bank (2015) South Asia The World Bank Group. http://data.worldbank.org/region/SAS. Accessed 1 Oct 2016

The World Bank (2016) South Asia Remains World's Fastest Growing Region, but Should Be Vigilant to Fading Tailwinds. http://www.worldbank.org/en/news/press-release/2016/04/09/south-asia-fastest-growing-region-world-vigilant-fading-tailwinds. Accessed 1 Oct 2016

Thorp AA, Owen N, Neuhaus M, Dunstan DW (2011) Sedentary behaviors and subsequent health outcomes in adults a systematic review of longitudinal studies, 1996–2011. Am J Prev Med 41:207–215. doi:10.1016/j.amepre.2011.05.004

United States Census Bureau (2012) 2010 Census Shows Asians are Fastest-Growing Race Group. https://www.census.gov/newsroom/releases/archives/2010_census/cb12-cn22.html. Accessed 1 Oct 2016

Waidyatilaka I, Lanerolle P, Wickremasinghe R, Atukorala S, Somasundaram N, de Silva A (2013) Sedentary behaviour and physical activity in South Asian women: time to review current recommendations? PLoS One 8:e58328. doi:10.1371/journal.pone.0058328

Waidyatilaka I, de Silva A, de Lanerolle-Dias M, Wickremasinghe R, Atukorala S, Somasundaram N, Lanerolle P (2014) Lifestyle patterns and dysglycaemic risk in urban Sri Lankan women. Br J Nutr 112:952–957. doi:10.1017/S0007114514001676

Williams ED, Stamatakis E, Chandola T, Hamer M (2011) Physical activity behaviour and coronary heart disease mortality among South Asian people in the UK: an observational longitudinal study. Heart 97:655–659. doi:10.1136/hrt.2010.201012

Wilmot EG, Edwardson CL, Achana FA et al (2012) Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. Diabetologia 55:2895–2905. doi:10.1007/s00125-012-2677-z

Yates T, Khunti K, Henson J, Morris D, Gray L, Davies M (2012a) The association between physical activity and impaired glucose regulation: Is there a difference between ethnic groups? J Sci Med Sport 15:S200

Yates T, Khunti K, Wilmot EG et al (2012b) Self-reported sitting time and markers of inflammation, insulin resistance, and adiposity. Am J Prev Med 42:1–7. doi:10.1016/j.amepre.2011.09.022

Ye J, Rust G, Baltrus P, Daniels E (2009) Cardiovascular risk factors among Asian Americans: results from a national health survey. Ann Epidemiol 19:18–23. doi:10.1016/j.annepidem.2009.03.022