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A Systematic Review of Cardiometabolic Risk Factors Associated with Sedentary Behavior in the Occupational Domain

Usman T Shehu[1], Abdulsalam M Yakasai[2,*] and Musa S Danazumi[3,4]

[1]Department of Public Health, School of Health Sciences, University of Salford, Manchester, United Kingdom
[2]Department of Rehabilitation and Exercise Therapy, CDUTCM-KEELE joint Health and Medical Sciences Institute, Chengdu China
[3]Department of Physiotherapy, Federal Medical Center, Nguru, Yobe State, Nigeria
[4]Discipline of Physiotherapy, College of Science, Health & Engineering, La Trobe University, Bundoora, Victoria 3085, Australia

[*]**Corresponding Author:** Abdulsalam Mohammed Yakasai, Department of Rehabilitation and Exercise Therapy, CDUTCM--KEELE joint Health and Medical Sciences Institute, Chengdu China, Tel.: +8615308205043, E-mail: abdulsalam.yakasai@keele.cdutcm.edu.cn

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Abstract

Background: Due to recent advancements in technology, workplace settings are becoming more inhabitant leading to a growing rate of sedentary behaviour during occupational duties. Sedentary behaviour is associated with increased cardiometabolic risks and poor health outcomes.

Objective: The purpose of this systematic review was to examine the cardiometabolic risk factors associated with sedentary behaviour in the occupational domain.

Methods: An electronic database search of titles and abstracts was conducted on MEDLINE (Ovid), CINAHL (EBSCOhost) and Web of Science databases from 1st January,1999 until July, 2024. Two independent reviewers screened the retrieved citations against pre-defined eligibility criteria. The methodological quality of the included studies was assessed using a quality assessment tool for observational cohort and cross-sectional studies developed by the US Department of Health and Human Services (National Heart, Lung and Blood Institute [NHLBI]).

Results: A total of 13 studies were obtained out of the 9,011 papers identified through database searches. Out of the thirteen (13) included studies, eight (8) were rated as high quality (≥70% score) and the remaining five were rated as moderate quality (50%—69%). A positive association was found between sedentary behaviour and cardiometabolic risk factors in the occupational domain. HDL-cholesterol and BMI had the greatest association while high blood pressure (systolic and diastolic) and waist circumference were moderately associated. On the other hand, triglycerides, fasting blood glucose and insulin had the least association.

Conclusion: A positive association was found between sedentary behaviour and cardiometabolic risk factors in the occupational domain with HDL-cholesterol and BMI having the greatest association, while triglycerides, fasting blood glucose and insulin had the least association.

Registration: PROSPERO–CRD42020180316

Keywords: Sedentary behaviour, cardiometabolic factors, occupation, workplace, systematic review

Introduction

Globally, sedentary behaviour level has increased over the decades [1]. There has been a tremendous increase in sedentary time in the developed countries such as the US (1965-2009) from 26 hours per week to 38 hours per week and 28 hours per week to 42 hours per week in the UK (1961-2005) [2]. This increased in sedentary time has been associated or linked to recent technological advancement across the leisure and occupational domains. These include transport (sitting on bus or during driving); workplace (sitting at work or using a computer); communication, and technology (sitting watching TV, reading, music listening, or eating, and other screen-based entertainment or leisure communication devices) [3].

On the other hand, cardiometabolic diseases otherwise knowns as cardiovascular and metabolic diseases are the leading cause of deaths and its incidence is rapidly increasing in every region of the world. In addition, it is also a major threat to the modern society [4]. In 2008, more than 17 million people died from cardiovascular disease (CVD), and more than three million of these deaths occurred before the age of 60 years that could be prevented [5]. The Global Burden of Disease estimated that almost 30% of all deaths worldwide were caused by CVD [4]. At present, cardiovascular diseases prevention becomes a major issue for world health, and the burden and risk factors remain alarmingly high. The magnitude of CVD continues to accelerate globally because of increasing various risk factors or determinants, but these can be controlled, modified, and treated if certain steps can be taken and followed [6]. Moreover, increased incidence of chronic diseases including CVD is one of the most important challenges for the health system throughout the countries. CVD is largely preventable if population wide measures and access to individual health care become possible for the people [6].

Nevertheless, in the occupational domain, sedentary behaviour is common and differs from physical inactivity [7]. Studies have reported that spending a long time sitting at work such as working on a computer, or laptops tend to increase risk of becoming obese and thus increases risk for developing cardiometabolic diseases and increase mortality rate [8, 9]. However, there are several studies that explored time spent for working individuals, prior to common sitting domains including total sitting time [10], transport-related sitting time [11], and the occupational sitting time as prolonged sitting duration for working adults [12].

It was discovered that workplace (occupation) is the major contributor for daily sitting time for several working individuals (like sitting in the office, using a computer, secretariat work, call canter operators, and customer care services) and was recently described as the primary setting whereby sedentary sitting time at work could be minimised in order to improve the workers' health conditions [13]. However, it has been recommended that to formulate workplaces or occupations with implemented strategies to decrease the level or frequency of sedentary sitting time as well as to avoiding poor posture or sitting positions, with an expectation to decrease the occurrences or incidences of chronic diseases such as diabetes, cardiovascular diseases, and premature mortality as a result [13]. Yet, most of the studies related to the impact of sedentary sitting at work on health outcomes come from the musculoskeletal (MSK) literature [14]. Research on the impact of occupational sitting on the other health related conditions are scarce [15]. In the context of cardiometabolic diseases and sedentary lifestyle, the major contributions of sedentary behaviour are occupational sitting due to many working adults particularly in sedentary occupations. Hence, there is a need to clarify the strength of evidence on the potential detrimental effect of occupational sedentary sitting at work on cardiovascular and metabolic systems.

The aim of the present study is to exploit existing long-term data for the question on the association between sedentary behaviours in occupational sitting and cardiometabolic risk factors. The focus was on the relation between long-term sedentary behaviour in occupational sitting and cardiovascular and metabolic health using data over a period of 20 years.

Methods

Literature Search

Three reviewers (UTS, AMY, and MSD) independently searched the literature from 1st January 1999 until 31st July, 2024 using Ovid MEDLINE(R) and In-Process & Other Non-Indexed Citations, CINAHL and Science Web: Core Collection database. However, these electronic databases were selected due to relevance and homogeneity of the research question. In addition, they provide authoritative medical information across various discipline, health care, allied health, medical sciences, and public health. Similarly, indexing several thousands of published research materials, medical subject headings, internal subject thesaurus, and English language publications. The term Medical Subject Headings (MeSH) were developed considering the different pronunciations for the search term and alternative names that different authors can use. The Boolean operator (OR) was used to combine terms under same concepts (sedentary behaviour OR physical inactivity OR sedentary OR sit OR sat), and (AND) was used to combine the three concepts (the sum of the terms under sedentary behaviour AND the sum of the terms under cardiometabolic risk factors AND the sum of the terms occupation).

2.1. Eligibility Criteria Studies were included within the final review based on the association of sedentary behaviour at the workplace (occupations, workplace, employment, work, or profession) and resultant effects on cardiometabolic risk factors. Papers were included from 1999 to 2024. The Biomedical research ethics committee of xxxxxx university decided this study did not need ethics approval.

Inclusion Criteria

1. Working adults (16 years and above).

2. Any study that measures sedentary behaviour in the occupational domain.

3. Any study aimed at measuring cardiometabolic risk factors (high blood pressure, HDL-cholesterol, triglycerides, waist circumference or BMI, and fasting blood glucose) as outcome data.

4. Studies published 1999 to date.

5. Studies that took place in the developed countries, the UK, US, Australia and Europe and published in English speaking language.

6. Any form of quantitative study design.

Exclusion Criteria

1. Unemployed adults, children and adolescent.

2. Studies published before 1999.

3. Studies conducted outside developed countries and not published in the English-speaking language.

Data Extraction

The following information was extracted from the included studies: author details (name, year, and country in which the study was carried out); study design (study description, number of participants, and age), domain of occupation, outcome measure (cardiometabolic biomarkers assessed), sedentary behaviour measurement (subjective or objective), different covarients and confounders addjusted for, cardiometabolic risk factors measured, and relavant information associated with sedentary behaviour and cardiometabolic risk factors (see Table 1).

Table1: Summary of included study characteristics

Author/Year Country	Study Design	Occupation Domain	Outcome	SedentaryBehaviour (SB)Measurement	Confounders Measured(Adjustment Factors)	Findings (Positive or Negative Association SB to CMRF Biomarkers)
Alkhajah et al. (2012).Australia	Quasi-experimental18intervention, 14comparison, aged 20 – 65 years.	Office workers.	Fasting total cholesterol, high-density lipoprotein (HDL) cholesterol, triglycerides, glucose levels.	ActivPAL3 activity monitor device, self-administered questionnaire.	Participants' randomization, sample size, workplace layout, baseline models.	Positive association. Decrease sedentary = increase high-density lipoprotein (HDL) cholesterol.
Carr et al. (2016)	Cross-sectional study69 adults mean age 44.	Company employees,desk sitting at work.	Weight, lean mass, fat mass, BMI, Body fat, Waist circumference (WC), systolic blood pressure, diastolic blood pressure, resting heart rate, VO2.	ActivPAL3 VT, PAL Technologies, Glasgow, UK.	Sample size gender, age, overweight/obese.	Found inverse correlation between workplace sitting time (walking, steps at work) and systolic blood pressure, weight, lean mass, BMI.
Genin et al. (2018).France	Quasi-experimental study 193 office employees (tertiary workers 83 females, 110 males) adults, average age 44.2	Office workers.	Fat mass, fat-free mass, BMI, waist circumference.	Self-reported using Physical Activity Questionnaire (PAQ).	Physical fitness, physical activity, health profile.	Positive association.Significant improvement in fat mass and WC in active compared to inactive workers.Negative association.No significant difference with fat-free mass and BMI.
Lin et al. (2015).USA	National longitudinal study5,285 adults aged 38–45 years.	Workplace sitting time.	Body mass index.	Self-reported.	Age, education, work hours, and hours of vigorous and light/moderate physical activities.controlled	Positive association.Prolonged occupational sitting was significantly associated with higher BMI and in men. No significant association for women.
Mummery et al. (2005).Australia	Cross-sectional study5611 adults aged 18 and above	Occupational sitting time.	Body mass index.	Self-reported.	Age, occupation, and physical activity.	Positive association.Significant association between occupational sitting time BMI in men not women. After adjusting for age, occupation, and physical activity.
Pereira et al. (2012).UK	Cross-sectional study7660 adults aged 44-45 years.	Sitting at work.	Total cholesterol, HDL-cholesterol, LDL-cholesterol, triglyceride, C-reactive protein, blood pressure, HbA1c, fibrinogen, hypertension, metabolic syndrome	EPAQ-2 questionnaire, self-reported.	Diet, MVPA,Smoking, occupation, education, chronic illness, weight, BMI, drugs (oral contraceptives and hormone replacement therapy), menopause, age, sex	Positive association.Weak association between sitting at work and biomarkers (HDL-cholesterol) in men. But not significant in women.
Pesola et al. (2017).Finland	Cluster-randomized controlled trial71 intervention, 62 control adults aged 28-53 years.	Total sedentary time, work time.	Height, weight, blood pressure, total lipids, glucose and insulin, serum apolipoprotein, lipoproteins	Accelerometer, (ActiGraph GT3X monitor).	Age, sex, starting season, worktime/day, number of children, single parent, moderate-to-vigorous physical activity, energy intake.	Positive association.Decrease sedentary = improve cardiometabolic markers.

Peterman et al.(2019).USA	Pre/post study12 intervention group, 9 delayed intervention control group aged 18-55 years.	Office workers.	Resting blood pressure, blood lipid profile, VO2 max., body composition, 2-h oral glucose tolerance test.	ActiGraph GT3X+; ActiGraph, Pensacola, FL.	Stationary cycling, physical activity, participants' population.	Positive association.The workplace cycling intervention (decrease sedentary) is significantly associated with increase HDL-cholesterol.
Picavet et al.(2016).Netherlands	Longitudinal cohort study1509 adults aged 20-60 years.	Occupational sitting.	BMI, overweight, hypertension, hypercholesterolemia.	Self-reported using Physical Activity Questionnaire (PAQ).	Age, gender, level of education, marital status, smoking, working hours, physical activity.	Negative association.No significant association was found with any cardiometabolic biomarker.
Saidj et al. (2013)Denmark	Cross-sectional study2544 adults aged 18-69 years.	Sitting at work.	WC, BMI, body fat percentage, total cholesterol, HDL-cholesterol, LDL-cholesterol, triglycerides, insulin, HbA1c, plasma glucose	Physical Activity Scale 2 (PAS2).	Sex, age, education, smoking, alcohol, diet, moderate to vigorous physical activity (MVPA).	Positive association.Occupational sitting time was significantly association to HDL-cholesterol, triglyceride, insulin.
Stamatakis et al. (2012).UK	Cross-sectional study5948 adults (2669 men) aged 16–65 years.	Occupational sitting.	WC, BMI, systolic and diastolic blood pressure, total cholesterol, HDL-cholesterol, glycated haemoglobin.	Self-reported, accelerometer (Actigraph model GT1M, Pensacola, FL, USA).	Age, sex, social class, employment status, alcohol consumption in the past week, fruit and vegetable consumption, unhealthy eating index, psychological distress. cardiovascular or diabetes medication, occupational physical activity and self-reported accelerometry-assessed MVPA	Positive association.Positive total self-reported association was found between sedentary time and the biomarkers except for glycated haemoglobin. Accelerometery sedentary time was associated with total cholesterol.
Tigbe et al. (2017).UK	Cross-sectional study 111 adults aged 22-60 years.	Postal workers,Occupational sedentary time.	BMI, WC, total cholesterol, HDL-cholesterol, LDL-cholesterol, triglycerides, systolic and diastolic blood pressure, fasting glucose, adiponectin.	activPAL, PAL Technologies Ltd, Glasgow, UK.	Age, sex, family history of CHD, shift worked, job type and socio-economic status.	Positive association.Sedentary time was significantly associated with cardiometabolic markers (WC, fasting triglycerides, HDL-cholesterol. Prolonged time spent in sedentary posture was significantly connected with increased risk for CHD and larger WC.
Zhu et al. (2017).USA	Natural experiment with appropriately matched comparison, 24 intervention, 12 comparison aged 18-65 years.	Office workers,Work sitting.	BMI, blood pressure, total cholesterol, HDL-cholesterol, LDL-cholesterol, high sensitivity C-reactive protein, triglycerides, plasma glucose, insulin.	activPAL3c (PALTechnologiesLim-ited, Glasgow, UK).	Study design	Positive association.Small effect was observed in the intervention arm for BMI, systolic blood pressure, fasting glucose, triglycerides, C-reactive protein. However, there were mixed results and changes after follow-up for fasting insulin and glucose (favouring comparison), total cholesterol, LDL-cholesterol, C-reactive protein.

Assess Study Quality

Two independent reviewers assessed the quality of reporting the included articles using National Heart, Lung and Blood Institute (NHLBI). The tool has been chosen to assess the methodological quality of the included studies in the review due to its focus design to critically appraise the internal validity of the studies [16]. Moreover, the tool has a 14-item checklist that can be used to examine the potential flaws in the included studies. For example, the methods, sources of bias, confounding, study power, and the strength of causal relationship or association between the outcomes and interventions or exposure. Each study was marked as "yes," "no," or "cannot determine/not reported/not applicable" according to each item in the 14-item checklist on the tool. For each item where "no" was selected, it was considered as having a potential risk of bias in the study design. Cannot determine and not reported were also noted as representing potential flaws. Any study that scores 70% and above was regarded as high quality while any study that scores between 50%-69% was considered as of moderate quality. This is obtained by dividing each paper total score by 14 expressed in 100 percent [16].

Data Synthesis

Results analysis was conducted using narrative synthesis [17]. Additionally, the data was analysed in line with the study details, the outcome of the cardiometabolic risk factors measured, results concerning positive or negative associations, and quality.

Literature Search Results

A total of 9,011 records were identified through the database searching. The EndNote X9 electronic software was used to download all citations. Out of the 9,011 papers received, a total of 2,923 duplicates were manually removed. The remaining 6,088 records identified were screened against the titles and abstracts. In addition, after the titles and abstracts screening the sum of 6,141 articles were removed and a total of 53 studies were obtained. Of these 53 studies, a total of 13 eligible studies were recorded after full texts screening against the inclusion and exclusion criteria.

The PRISMA flow diagram was used to elaborate the study selection process (Figure 1). Moreover, 40 of the 53 studies were excluded based on exclusion criteria and 13 studies were synthesise having met the inclusion criteria (Table 1).

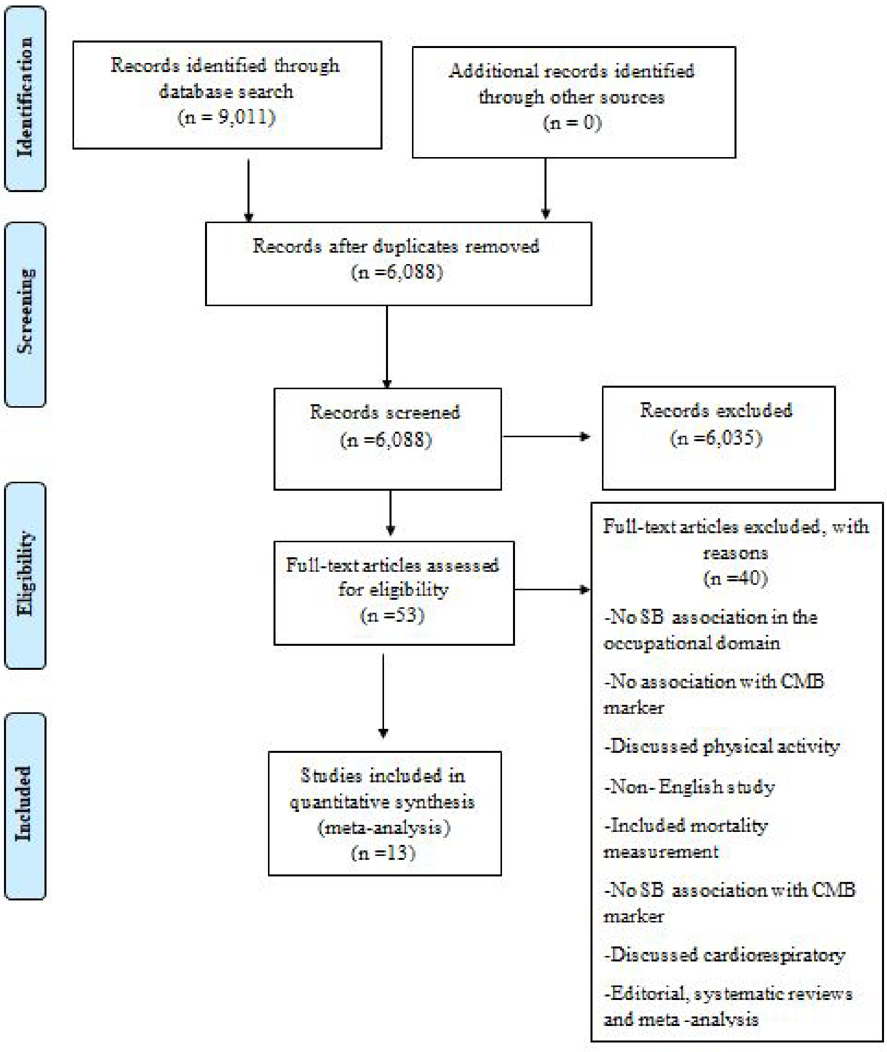

Figure 1: Prisma flow diagram of study selection process (Prisma, 2009)
Key: SB= Sedentary behaviour CMB= Cardiometabolic

Included Study Characteristics: Characteristics of included studies in this review are summarized in Table1.

Authors and Study details: A total sum of thirteen (13) studies were obtained after a comprehensive and rigorous literature search through three main electronic databases (MEDLINE via Ovid, CINAHL, and Web of Science: core collection) to address the research aim: Cardiometabolic risk factors associated sedentary behaviour in the occupational domain. These are Alkhajah et al. [18]; Carr, Swift, Ferrer & Benzo[19]; Genin et al. [20]; Lin, Courtney, Lombardi & Verma [21] ; Mummery, Schofield, Steele, Eakin & Brown [22] ; Pereira, Ki & Power [23]; Pesola et al. [24]; Peterman, Morris, Kram & Byrnes [25]; Picavet et al. [26]; Saidj, Jørgensen, Jacobsen, Linneberg & Aadah [27] ; Stamatakis, Hamer, Tilling & Lawlor[28] ; Tigbe, Granat, Sattar & Lean[29]; Zhu et al. [30].

Out of the thirteen (13) studies; 7 were carried out in European countries (France, UK, Finland, Netherlands, and Denmark) [20, 22-24, 26-29]. Four (4) studies were conducted in the USA [19, 21, 25, 30], whereas 2 were carried out in Australia[18, 22].

Moreover, in terms of study design, six (6) studies were cross-sectional studies representing a large proportion of the included studies [19, 23], [27-29]. Two (2) studies were quasi-experimental[18], [20]; one (1) longitudinal cohort study[26] ; one (1) national longitudinal study[21]; one (1) cluster randomised control trial[24]; one (1) pre/post study[25]; and one (1) natural experimental study[30]. However, the cross-sectional and prospective cohort studies recruited large number of participants comprising of both adult working males and females varying from 7,660 [23]; 5,948 [28]; 5,611[22]; 5,285 [21]; 2,544 [27]; 1,509 [26]; to 111[29]; and 69 [19]. Similarly, the quasi-experimental 193[20],18 interventions, 14 controlled [18]; cluster randomised controlled trial 71 intervention, 62 control[24]; natural experimental 24 intervention, 12 controlled [30]; and pre/post study 12 intervention, 12 control respectively[25].

Additionally, all the studied participants were between 18years and above;[22] up to 60 years in the Stamatakis, Hamer, Tilling & Lawlor study[28]. While Alkhajah et al.,[18] recruited participants between the age range 20-65 years. Moreover, Carr and colleagues [19], and Genin et al.,[20] recruited participants with a mean age of 44 and 44.4 respectively. However, Lin and co--workers[21], Pereira, Ki & Power [23], and Pesola et al., [24] recruited participants between the ages of 38 to 45; 44 to 45; and 28 to 53 years respectively. Whereas other studies recruited participants within similar age range: 18-55 years [25]; 20-60 years [26]; 18-69 years [27]; 22-60 years [28]; and two studies 18-65years [29, 30].

Domain of occupation: The largest domain of occupational sedentary behaviour in all the selected studies is sedentary sitting at work[18-30] . Ten (10) studies measured occupational sedentary sitting time (mainly among professionals, company employees, desk and office workers)[8- 23], [25, 26, 28, 30], office sitting [18-20, 25, 30]; occupational sitting [22, 26, 28, 30]; workplace sitting [21]; followed by total sitting time [24]; postal workers sedentary time[29]; sitting at work [23, 27].

Sedentary Behaviour Measurement: Sedentary behaviour was measured using subjective and objective methods, or a combination of both. Five (5) studies subjectively self-reported (i.e having an interviewer interviewed the participants) sedentary times [20, 21, 22, 23, 26, 28]. Similarly, same number of studies noted above-recorded workplace or occupational sedentary time objectively using accelerometer (activPAL3 VT, PAL Technologies, Glasgow, UK, ActiGraph GT3X+; ActiGraph, Pensacola, FL or Actigraph GT1M) [19, 24, 25, 29, 30]. However, two (2) studies assessed sedentary behaviour using both accelerometer, and self-report and administered questionnaire (i.e. the participants were asked to provide answers to questions concerning time spent sedentary) [18, 28]. The self- reported and administered questionnaire used includes Physical Activity Questionnaire (PAQ) and EPAQ-2 questionnaire[18, 20, 23, 26]. Lastly, one study [27] measured sedentary behaviour using Physical Activity Scale 2 (PAS2). Most of the studies that measure sedentary behaviour using objective assessment recorded a strong positive association with the cardiometabolic risk factors [19, 24, 25, 29, 30].

Adjusted Confounders: For the thirteen (13) included papers, many confounding factors were adjusted (see Table 2).

Table 2: Summary table for adjusted confounders

	Age	Gender	Education	Smoking	LMVPA	Occupational status	Physical activity	Working hours	Population size	Alcohol consumption
Alkhajah et al (2012)								✓	✓	
Carr et al. (2016)	✓	✓	✓					✓	✓	
Genin et al. (2018)							✓	✓		
Lin et al.(2015)	✓				✓		✓	✓		
Mummery et al. (2005)	✓					✓	✓	✓		
Pereira et al. (2012)	✓	✓		✓		✓		✓		✓
Pesola et al. (2017)	✓	✓			✓		✓	✓		
Peterman et al. (2019)							✓	✓		
Picavet et al. (2016)	✓	✓	✓	✓			✓	✓		✓
Saidj et al. (2013)	✓	✓	✓	✓	✓		✓	✓		✓
Stamatakis et al. (2012)	✓	✓			✓	✓	✓	✓		
Tigbe et al. (2017)	✓	✓						✓		
Zhu et al. (2018)										

Most of the studies included starting season, worktime/day, number of children, and being single parent [24]; diet [23, 27]; chronic illness[31]; medication use (oral contraceptives and hormone replacement therapy)[28], [31]; energy intake [24]; fruits and vegetable consumption [28]; marital status [26]; overweight/obese [19]; and weight/BMI/menopause [31]; study design [30].

Outcomes: The outcome assessed were cardiometabolic risk factors (biomarkers) such as high blood pressure, body mass index, waist circumference, HDL-cholesterol, total cholesterol, triglycerides, LDL-cholesterol, and fasting plasma glucose[18-22, 24-31].

Out of the thirteen (13) included studies eight (8) studies measured body mass index (BMI)[19, 20, 22, 26-30].

Seven (7) studies measured elevated blood pressure (systolic and diastolic) or hypertension and resting heart rate[19, 24, 25, 28-31] Six (6) studies assessed fasting blood glucose/glucose level/plasma glucose/insulin [18, 24, 25, 27, 29, 30].

Seven (7) studies measured HDL-cholesterol [18, 25, 27-31], while 5 studies measured variables waist circumference[19, 20], [27-29]; total cholesterol [18, 28-31]; and triglycerides [18, 27, 29-31].

In addition, 4 studies assessed LDL-cholesterol[24, 27, 29, 31]; 4 studies also measured Glycated haemoglobin (HbA1c) [24, 27, 28, 31]; whereas Fat mass was assessed by 2 studies[19, 20].

Others cardiometabolic biomarkers measured were: lean mass[19]; fat-free mass[20]; C-reactive protein, fibrinogen, metabolic syndrome[31]; serum apolipoprotein, lipoproteins[24]; VO2 max., body composition, 2-h oral glucose tolerance test[25]; overweight and hypercholesterolemia[26]; body fat percentage[27]; adiponectin [29]; and sensitivity C-reactive protein[30].

Results

Out of the thirteen (13) included studies, 10 studies recorded a strong positive association between occupational sedentary behaviour and cardiometabolic biomarker (risk factors)[18-22, 24, 25, 27-29], while 2 studies found weaker association[30, 31], and only one (1) study[26] noted a negative association. Addedly, the study that reported this negative associations between occupational sedentary behaviour and cardiometabolic risk factors was after adjusting for the following confounders: age, gender, education, working hours, smoking, and physical activity. Overweight OR (CI) 0.99 (0.79; 1.24), BMI β(CI) -0.14 (-0.56; 028); hypertension OR (CI) 1.04 (1.82;1.32); high cholesterol OR (CI) 0.89 (0.67; 1.16) respectively[26].

High Blood Pressure

Out of the seven (7) studies that assessed association between workplace sedentary sitting and elevated blood pressure (systolic and diastolic) or hypertension and resting heart rate[19], [24], [25], [28], [29], [30], [31]. An inverse correlation was found between sedentary sitting time (walking, steps) at work and rise in systolic blood pressure by Carr, Swift, Ferrer & Benzo[19]. Also, in study by Pereira, Ki & Power[31], a positive association between TV viewing and an increase in blood pressure was found in women. However, there was no associated blood pressure raise with sitting at work [adjusted ORs 1.11(1.01, 1.23) and 1.30 (1.15, 1.48)] and these associations were mediated by diet and body mass index[24]. Furthermore, in a cluster randomised control trial for accelerometer-assessed sedentary work, leisure time and cardio-metabolic biomarkers carried out by Pesola et al.[24], it shows that decrease sedentary improves cardiometabolic biomarkers. Systolic blood pressure (mmHg) for the intervention and control group were -0.19 (-1.87 to 1.48), 1.82 (0.13 to 3.51) *; 1.08 (-0.67 to 2.83), 2.53 (0.76 to 4.29) **. Diastolic blood pressure (mmHg), -2.29 (-3.45 to -1.13) ***, -1.89 (-3.07 to -0.72) **; -1.82 (-3.04 to -0.61) **, -1.38 (-2.61 to -0.15) * (P--values indicated as follows: * < 0.05, ** < 0.01 and *** < 0.001) after six- and twelve-months intervention respectively [24].

In addition, a positive total self-reported association between sedentary time and systolic and diastolic blood pressure was reported by Stamatakis, Hamer, Tilling & Lawlor [46]. Systolic and diastolic blood pressure results were (0.024 mmHg; 0.000-0.049) and (0.023 mmHg; 0.006-0.040) respectively[46]. However, a weak association with systolic blood pressure was reported by Zhu et al. [30].

Body Mass Index

Eight (8) studies assessed body mass index (BMI)[19-22, 26, 28, 29, 30], and 3 of the 8 studies reported a positive association between occupational sitting and BMI[21], [22], [28]. However, a statistically significant association was found in men ($p< 0.01$) compared to women [21]; and ($p<0.001$) in men but no association in women ($p=0.67$)[22]. Zhu and colleagues[30] reported a weak association while Genin and co-workers [20]found no significant difference between the sedentary time at work and BMI. Moreover, a negative association was reported by Picavet et al.[26], BMI β(CI) -0.14 (-0.56; 028) following adjustment of confounders.

Waist Circumference

Out of the five studies (5) that measured Waist circumference (WC)[19], [20], [27], [28], [29], a statistically significant improvement in WC ($p<0.05$) was reported in active employees compared to inactive employees in a study by Genin et al., [20]. Furthermore, a positive association was reported between the sedentary time at work and WC ($p=0.005$) were reported by Stamatakis and associates [28] and Tigbe, Granat, Sattar & Lean[29] respectively.

HDL- Cholesterol

Out of the seven (7) studies that assessed HDL-cholesterol and sedentary sitting time at work[18, 25, 27-31], 6 studies found a positive association[18, 25, 27-30] while only 1 study reported a weak association[31], between sedentary sitting at work and HDL-cholesterol.

Decrease sedentary sitting at workplace increases HDL-cholesterol on average (95% CI= 0.10, 0.42);[18] 0.010 (0.001-0.018);[28] 1.09 (0.17) to 1.17 (0.24), $p=0.04$;[25] $p=0.001$[29]. Occupational sitting time was significantly associated with HDL-cholesterol in a study by Saidj and colleagues[27]. However, a weaker association with sitting at work and HDL-cholesterol were reported (i.e. 1.2% (0.5%, 1.9%) and 0.9% (0.3%, 1.5%) in men but no association was found in women in a study by Pereira, Ki & Power [31].

Total Cholesterol

Out of the five (5) studies that assessed total cholesterol[18, 27, 29-31], a study by Stamatakis, Hamer, Tilling & Lawlor[27] found a positive total self-reported correlation between sedentary time and total cholesterol (0.004, 0.001-0.006), while study by Zhu et al., [30] discovered a weak association with mixed results.

Triglycerides

Out of the five (5) studies that assessed triglycerides[18, 24, 25, 27, 29], 2 studies reported a positive association between occupational sitting time and triglycerides, and statistically significant associations were found ($p=0.002$) for fasting triglycerides and triglycerides[24, 27]. In contrast, weak associations were found by Zhu and colleagues[30].

LDL- Cholesterol

In the four (4) studies that assessed LDL-cholesterol[23, 27, 29, 30], only study by Zhu et al.,[30] reported a weak association between occupational sitting and LDL-cholesterol with mixed results.

Fasting Blood Glucose/Insulin

Out of the six (6) studies that measured fasting blood glucose/glucose level/plasma glucose/insulin[18, 24, 25, 27, 29, 30], two studies[24, 27] reported a positive association and decreasing sedentary sitting at work improves fasting blood glucose and insulin level in the body. However, Zhu et al. [30] found a weak association.

Other Cardiometabolic Biomarkers

Two studies,[19, 20] reported a positive association with lean mass but with no significant difference with fat-free mass in active workers compared to inactive employees, while one study [30] reported Weak association with C-reactive protein.

Table 3: A summary of results

	High blood pressure	Body mass index	Waist circumference	HDL-cholesterol	Total cholesterol	Triglycerides	LDL-cholesterol	Fasting blood glucose/insulin	Positive association	Weak association	Negative association
Alkhajah et al (2012)	X	X	X	(95% CI=0.10,0.420=)	X	X	X	X	✓	X	X
Carr et al. (2016)	✓ SBP	✓	X	X	X	X	X	X	✓	X	X
Genin et al. (2018)	X	X	P<0.05	X	X	X	X	X	✓	X	X
Lin et al.(2015)	X	P<0.05 (men & women), p<0.01 in men only	X	X	X	X	X	X	✓	X	X
Mummery et al. (2005)	X	P<0.01 in men & p=0.67 in women	X	X	X	X	X	X	In men only	X	In women
Pereira et al. (2012)	X	X	X	1.2% (0.5%, 1.9%) in men	X	X	X	X	X	✓	X
Pesola et al. (2017)	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X
Peterman et al. (2019)	X	X	X	P=0.04	X	X	X	X	✓	X	X
Picavet et al. (2016)	X OR (CI) 1.04 (0.82;1.32	X β(CI) -0.14 (-0.56; 028)	X	X	X	X	X	X	X	X	✓
Saidj et al. (2013)	X	X	X	✓	X	✓	X	✓	✓	X	X
Stamatakis et al. (2012)	✓ SBP, DBP	✓	✓	✓	✓	X	X	X	✓	X	X
Tigbe et al. (2017)	X	X	P=0.005	P=0.001	X	P=0.002	X	X	✓	X	X
Zhu et al. (2018)	✓ SBP	✓	X	X	X	✓	X	✓	X	✓	X

Quality Assessment

The methodological quality of the included studies was assessed using quality assessment tool for observational cohort and cross-sectional studies developed by the US Department of Health and Human Services (National Heart, Lung and Blood Institute (NHLBI)-[51]. Out of the thirteen (13) included studies, 8 studies[18, 20, 21, 24, 25, 26, 30, 31] were assessed as of high quality (≥70% score) while five studies [19, 22, 27-29] were assessed as of moderate quality (50%—69%). Table 4 shows the quality assessment of the included.

Table 4: Quality Assessment of the Included Studies

Studies	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Score	%
Alkhajah et al. 2012	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	Y	NR	Y	Y	12/14	85.7
Carr et al. 2016	Y	Y	Y	Y	Y	NA	NA	Y	Y	NA	Y	NR	NR	NR	9/14	64.3
Genin et al. 2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NR	NR	NR	11/14	78.6
Lin et al. 2015	Y	Y	Y	Y	NR	Y	Y	N	Y	Y	Y	NR	Y	NR	11/14	78.6

Mummery et al. 2005	Y	Y	N	Y	NR	NA	NA	Y	Y	NA	Y	NR	NR	Y	7/14	50.0
Pereira et al. 2012	Y	Y	Y	Y	NR	Y	NA	Y	Y	NA	Y	NR	NR	Y	11/14	78.6
Pesola et al. 2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NR	Y	NR	12/14	85.7
Peterman et al. 2019	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	Y	NR	Y	NA	11/14	78.6
Picavet et al. 2016	Y	Y	Y	Y	NR	Y	Y	Y	Y	Y	Y	NR	Y	Y	12/14	85.7
Saidj et al. 2013	Y	Y	Y	Y	NR	NA	NA	Y	Y	NA	Y	NR	Y	Y	9/14	64.3
Stamatakis et al. 2012	Y	Y	Y	Y	NR	NA	NA	Y	Y	NA	Y	NR	Y	Y	9/14	64.3
Tigbe et al. 2017	Y	Y	Y	Y	NR	NA	NA	Y	Y	NA	Y	NR	Y	NA	8/14	57.1
Zhu et al. 2017	Y	Y	Y	Y	NR	Y	Y	Y	Y	Y	Y	NR	Y	Y	12/14	85.7

KEY: N=No, Y=Yes, NA=Not applicable, NR=Not reporte

Discussion

This study was aimed at recognising, critically appraising and reviewing current literature of all published research papers/articles related to cardiometabolic risk factors associated with sedentary behaviour in the occupational domain between 1999-2024. A total sum of thirteen (13) included studies were obtained after a rigorous, systematic and comprehensive literature search and screening. The quality of the included studies was assessed using the NIH (National Heart, Lung and Blood Institute) quality assessment tool (NIH, 2019). The tool has 14-item quality assessment criteria checklist; all the studies quality was classified as moderate to high quality depending on the score obtained and the results were expressed in terms of percentages. Out of the thirteen (13) included studies, ten (10) studies indicated a positive association between cardiometabolic risk factors (high blood pressure, BMI, waist circumference, HDL-cholesterol, triglycerides, fasting plasma glucose, and insulin) and associated sedentary behaviour in the domain of occupation (occupational sitting, office sitting at work, desk work, prolonged sitting at work, and sedentary sitting time).[18, 19-22, 24, 25, 27-29] A statistically significant correlation was observed after adjusting for cofounders and demographic characteristics such as gender, age, level of education, physical activity, smoking, alcoholism, working hours, and health status. However, only one (1) study by Picavet et al. [26] that found negative association with the cardiometabolic biomarkers while other two (2) studies by Pereira, Ki & Power [23] and Zhu et al. [30] found a statistically weak association with some of the cardiometabolic risk factors such as HDL-cholesterol and BMI, systolic blood pressure, fasting glucose, triglycerides, total cholesterol, LDL-cholesterol, C-reactive protein respectively. This result concurred with the previous studies that indicates that prolonged sedentary sitting at workplace or during occupational duties may keep rising due to recent technological advancement at work[32-33]. Hence, leading increase sedentariness at work and low volume energy expenditure [34].

The results obtained from the review indicates that sedentary behaviour in various form of occupation (occupational sitting, sitting at work, office working, desk working, long hours spent at work without breaks or prolonged sedentary sitting time at work) is positively associated with significant alteration in cardiometabolic biomarkers outcomes .[18, 19, 20, 21, 22, 24, 25, 27-29] However, these alteration in cardiometabolic risk factors (raised blood pressure; systolic and diastolic; waist circumference, BMI, HDL-cholesterol, triglycerides, fasting plasma glucose and insulin), will consequently increases risk for developing cardiometabolic diseases.[18-22, 24, 25, 27-29] This is results are consistent with other research results conducted to ascertain the detrimental effect of sedentary behaviour on cardiometabolic diseases including hypertension, obesity, hyperlipidaemia, type 2 diabetes and metabolic syndrome.[7-35]

However, a study conducted by Pesola and colleagues[24], which assessed total sedentary time and work time was found to be positively associated with all the cardiometabolic biomarkers measured in the study (i.e. height, weight, blood pressure, total lipids, glucose, insulin, serum alipoprotein and lipoproteins). In addition, Alkhajah et al. [18] carried out a Quasi-experimental study (Sit-Stand Workstations) involving 18 intervention and 14 comparison group, office-based workers aimed to examine the efficacy of an intervention to decrease office workers' sitting time. Cardiometabolic biomarkers (Fasting total cholesterol, high-density lipoprotein (HDL) cholesterol, triglycerides, and glucose levels) were assessed. It was found that after the intervention sitting time was reduced at 1-week follow-up from 143 minutes/day at work (95% CI-184, -102) to 97 minutes/day during all waking time (95% CI-144, -50). These results were maintained; and after 3 months, the intervention group HDL-cholesterol increases relative to the comparison group to 0.26 mmol/L (95% CI=0.10, 0.42) on average, while other cardiometabolic biomarkers (Fasting total cholesterol, triglycerides, and glucose levels) assessed were not statistically different. This study findings may be related to another study by Henson et al. [36] which found varying results with various biomarkers. It was found that total sedentary time was associated with HDL-cholesterol and 2-hour postprandial glucose. But no association was found with the fasting glucose, body mass index and HbAlc. Furthermore, Picavet et al. [26] assessed occupational sitting and cardiometabolic health. However, there was no statistically significant association with any of the biomarkers (BMI, overweight, high blood pressure (hypertension), and hypercholesterolemia). However, two (2) studies conducted by Pereira, Ki & Power[31] and Zhu et al. [30] found a weak association with the cardiometabolic risk factors assessed. Although in Zhu et al. [30] study a small effect was observed in the intervention arm for BMI, systolic blood pressure, fasting glucose, triglycerides, C-reactive protein. However, there were mixed results and changes after the intervention follow-up for fasting insulin and glucose (favouring comparison), total cholesterol, LDL-cholesterol, C-reactive protein.

Overall, the results of this review indicate a strong positive association between sedentary behaviour and associated cardiometabolic risk factors in the domain of occupation. Out of the thirteen (13) studies included in the review, ten (10) studies show a positive association with cardiometabolic risk factors (raised blood pressure; systolic and diastolic; waist circumference, BMI, HDL-cholesterol, triglycerides, fasting plasma glucose and insulin). However, most of the studies reported HDL-cholesterol and BMI (greatest association), then high blood pressure (systolic and diastolic) and waist circumference (moderate association). Followed by triglycerides, fasting blood glucose and insulin (least association), cardiometabolic risk factors associated with sedentary behaviour in the occupational domain. Similarly, it was reported by Mummery, Schofield, Steele, Eakin & Brown, [22] and Lin, Courtney, Lombardi & Verma,[21] that there is a statistically significant association between increased BMI and occupational sitting in men, $p<0.001$,[40] and $p<0.01$, [21] but no association was found in women [21, 22].

Strengths and Limitations of Included Studies in the Review

Strengths

High-quality studies were included in the review. Eight (8) studies scored ≥70% and were assessed as high-quality studies while five (5) studies scored 50%—69% and were assessed as moderate quality studies, using the 14-item NIH quality assessment tool checklist [50].

- All the thirteen (13) included studies adjusted for several confounders that may influence the association between sedentary behaviour and the cardiometabolic risk factors, such as age, gender, level of education, smoking and alcohol consumption, physical activity, working hours, employment status, diet and health profile, and MVPA.

- Most of the included studies recruited a huge number of participants. However, few studies included were experimental studies with a few individual participants recruited.

- Measurements of cardiometabolic risk factors were standardized and carried out in well-equipped laboratories to ensured accurate results.

Limitations

- Most of the included studies in the review were cross-sectional studies, hence, they do not show causality and have a high risk of bias. Therefore, it may be hard to make a conclusive judgement despite adjusting for socio-demographic variables rather than residual confounders.

- Occupational sedentary sitting time measurement was subjectively self-reported using questionnaires or diaries in most of the included studies which could lead to recall and self-report bias. However, it is the most accessible and cost-effective method for reporting sedentary behaviour, especially when a huge number of participants are involved. Moreover, Crichton & Alkerwi [37] noted that questionnaires such as the IPAQ do not give an accurate measure for sedentary sitting.

- Non-homogeneity of results measurement and reporting; only a few results studies were stratified in terms of gender.[21, 22]

- All included papers were delimited to only developed countries, the UK, US, Australia and Europe. Hence, this limits the generalizability of results outcomes.

Strengths and Limitations of the Review

- This review critically appraised and summarized several study results findings after conducting a rigorous and comprehensive literature search and screening a large volume of papers.

- Only three (3) electronic databases (Medline Ovid, CINAHL and web of science core: collection) were used to carry out the literature search. Hence, some relevant studies may have been missed out.

Conclusion

In conclusion, this review found a strong piece of evidence-based research work on cardiometabolic risk factors associated with sedentary behaviour in the occupational domain. However, only one study found no correlation between sedentary behaviour and associated cardiometabolic risk factors. It is important to note that, most of the studies included in the review were cross--sectional studies, hence, causality cannot be inferred. Moreover, several studies have shown that decreasing sedentary behaviour, increasing physical activity, and taking breaks during occupational duties is beneficial for cardiometabolic health.

Competing Interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

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Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request. However, the findings from the study would be made available to participating researchers as required by law.

Artificial Intelligence (AI) Authoring Tools

AI was not used in preparing this manuscript in anyway, all is the natural work of the authors.

Ethics Statement

This study is a systematic review, which involves the analysis of existing literature and does not involve the direct participation of human subjects. Consequently, it does not require approval from the Research Ethics Committee.

References

1. MT Hamilton, GN Healy, DW Dunstan (2008) Too little exercise and too much sitting: inactivity physiology and the need for new recommendations on sedentary behavior, Curr Cardiovasc Risk Rep, 2: 292–8.

2. SW Ng, BM Popkin (2012) Time use and physical activity: A shift away from movement across the globe, Obesity Reviews, 13: 659–680

3. N Owen, J Salmon, MJ Koohsari, G Turrell, B Giles-Corti (2014) Sedentary behaviour and health: Mapping environmental and social contexts to underpin chronic disease prevention, British Journal of Sports Medicine, 48: 174–7.

4. R Beaglehole et al. (2011) Priority actions for the non-communicable disease crisis, The Lancet, 377: 1438–47.

5. V Fuster, BB Kelly (2010) Promoting cardiovascular health in the developing world: A critical challenge to achieve global health. National Academies Press.

6. S Kumar (2017) Cardiovascular Disease and Its Determinants: Public Health Issue, Journal of Clinical Medicine and Therapeutics, 2: 119–39.

7. HP van der Ploeg, M Hillsdon (2017) Is sedentary behaviour just physical inactivity by another name?, International Journal of Behavioral Nutrition and Physical Activity, 14: 142.

8. AHY Chu, SHX Ng, CS Tan, AM Win, D Koh, F Müller-Riemenschneider (2016) A systematic review and meta-analysis of workplace intervention strategies to reduce sedentary time in white-collar workers, Obesity Reviews, 17: 467–81.

9. RV Same et al. (2016) Relationship Between Sedentary Behavior and Cardiovascular Risk," Current Cardiology Reports, 18: 1–7.

10. RP Troiano, A Hollenbeck, A Schatzkin (2017) Amount of time spent in sedentary behaviors and cause specific mortality in US adults 1 , 2 , 3, academic.oup.com, 95: 437–45.

11. TY Warren, V Barry, SP Hooker, X Sui, TS Church, SN Blair (2010) Sedentary behaviors increase risk of cardiovascular disease mortality in men, Medicine and Science in Sports and Exercise, 42: 879–885.

12. JY Chau, HP van der Ploeg, D Merom, T Chey, AE Bauman (2012) Cross-sectional associations between occupational and leisure-time sitting, physical activity and obesity in working adults, Preventive Medicine, 54: 195–200.

13. S O'Connell (2019) Standing up to sedentary working, Occupational Health & Wellbeing, 71: 10-2.

14. K Mani (2018) Ergonomics Education for Office Computer Workers: An Evidence-Based Strategy, in Anatomy, Posture, Prevalence, Pain, Treatment and Interventions of Musculoskeletal Disorders, InTech.

15. JGZ van Uffelen et al. (2010) Occupational Sitting and Health Risks, American Journal of Preventive Medicine, 39: 379–388.

16. 2019 Research Highlights-Basic Research Insights, National Institutes of Health (NIH). Accessed: Jan. 26, 2025. Online.

17. ABMGCR Dickson (2021) Doing a systematic review : a student's guide. Los Angeles : SAGE, 2017. Accessed: Jun. 03, 2021.

Online.

18. TA Alkhajah, MM Reeves, EG Eakin, EAH Winkler, N Owen, GN Healy, Sit-stand workstations: A pilot intervention to reduce office sitting time, American Journal of Preventive Medicine, 43: 298–303.

19. LJ Carr, M Swift, A Ferrer, R Benzo (2016) Cross-sectional Examination of Long-term Access to Sit-Stand Desks in a Professional Office Setting," American Journal of Preventive Medicine, 50: 96–100.

20. PM Genin et al. (2018) Effect of Work-Related Sedentary Time on Overall Health Profile in Active vs. Inactive Office Workers, Frontiers in Public Health, 279.

21. Tin-chi Lin, Theodore K Courtney, David A. Lombardi, Santosh K Verma (2015) Association Between Sedentary Work and BMI in a U.S. National Longitudinal Survey, American Journal of Preventive Medicine, 49: e117–e123.

22. WK Mummery, GM Schofield, R Steele, EG Eakin, WJ Brown (2005) Occupational sitting time and overweight and obesity in Australian workers, American Journal of Preventive Medicine, 29: 91–7.

23. S Pereira, M Ki, C Power (2012) Sedentary Behaviour and Biomarkers for Cardiovascular Disease and Diabetes in Mid-Life: The Role of Television-Viewing and Sitting at Work, PloS one, 7: e31132.

24. AJ Pesola, A Laukkanen, R Heikkinen, S Sipilä, A Sääkslahti, T Finni (2017) Accelerometer-assessed sedentary work, leisure time and cardio-metabolic biomarkers during one year: Effectiveness of a cluster randomized controlled trial in parents with a sedentary occupation and young children, PLOS ONE, 12: e0183299.

25. JE Peterman, KL Morris, R Kram, WC Byrnes (2019) Cardiometabolic Effects of a Workplace Cycling Intervention, Journal of Physical Activity and Health, 16: 547–55.

26. HSJ Picavet, LW Pas, SH van Oostrom, HP van der Ploeg, WMM Verschuren et al. (2016) The Relation between Occupational Sitting and Mental, Cardiometabolic, and Musculoskeletal Health over a Period of 15 Years – The Doetinchem Cohort Study, PLOS ONE, 11: e0146639.

27. M Saidj, T Jørgensen, RK Jacobsen, A Linneberg, M Aadahl (2013) Separate and Joint Associations of Occupational and Leisure-Time Sitting with Cardio-Metabolic Risk Factors in Working Adults: A Cross-Sectional Study, PLoS ONE, 8: e70213.

28. E Stamatakis, M Hamer, K Tilling, DA Lawlor (2012) Sedentary time in relation to cardio-metabolic risk factors: Differential associations for self-report vs accelerometry in working age adults, International Journal of Epidemiology, 41: 1328-37.

29. WW Tigbe, MH Granat, N Sattar, ME J Lean (2017) Time spent in sedentary posture is associated with waist circumference and cardiovascular risk, International Journal of Obesity, 41: 689–96.

30. W Zhu et al. (2018) Long-term effects of sit-stand workstations on workplace sitting: A natural experiment," Journal of Science and Medicine in Sport, 21: 811–6.

31. GMV Pereira, P Driusso, CHJ Ferreira, LGO Brito et al. (2020) Multidisciplinary approach between physicians and physiotherapists in urogynecology: how can we make it stronger?, International Urogynecology Journal, 31: 2187–8.

32. GN Healy, N Owen (2017) Sedentary Behaviour and Biomarkers of Cardiometabolic Health Risk in Adolescents: An Emerging Scientific and Public Health Issue, Revista Española de Cardiología (English Edition), 63: 261–4.

33. J Lakerveld et al. (2017) Sitting too much: A hierarchy of socio-demographic correlates, Preventive Medicine, 101: 77–83.

34. N Shrestha, KT Kukkonen-Harjula, JH Verbeek, S Ijaz, V Hermans, Z Pedisic (2018) Workplace interventions for reducing sitting at work, Cochrane Database of Systematic Reviews, 2018: 6.

35. A Bergouignan, F Rudwill, C Simon, S Blanc (2011) Physical inactivity as the culprit of metabolic inflexibility: evidence from bed-rest studies, Journal of Applied Physiology, 111: 1201–10.

36. J Henson et al. (2013) Associations of objectively measured sedentary behaviour and physical activity with markers of cardiometabolic health, Diabetologia, 56: 1012–20.

37. GE Crichton, A Alkerwi (2015) Physical activity, sedentary behavior time and lipid levels in the Observation of Cardiovascular Risk Factors in Luxembourg study, Lipids in Health and Disease, 14: 87.