

BMJ Open Impact of incarceration on cardiovascular disease risk factors: a systematic review and meta-regression on weight and BMI change

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ABSTRACT

Objective Cardiovascular disease is an underappreciated issue in prison medicine. Recent studies have revealed a higher prevalence of cardiovascular disease risk factors (CVDRFs) among individuals in prison, but the impact of incarceration on CVDRFs over time is not well understood. This review aimed to assess available literature and quantify the relationship between incarceration and trends in major CVDRFs in high-income countries.

Design Systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. Meta-regression on weight change and obesity.

Data sources Medline, Embase, PubMed, Cochrane Central Wiley and Web of Science.

Eligibility criteria for selecting studies Longitudinal studies reporting on the incidence of, or trends in any CVDRF among current or former people in prison over time, in high-income countries.

Data extraction and synthesis Two authors independently screened articles for eligibility, extracted data and assessed quality using an adapted version of the Newcastle-Ottawa Scale. Trends in CVDRFs during and following incarceration were summarised and in those with sufficient data a meta-regression was performed.

Results Twenty-six articles were identified. CVDRFs assessed included obesity, hypertension, diabetes, dyslipidaemia, tobacco use, physical inactivity and unhealthy diet. A meta-regression on change in weight during incarceration found a mean increase of 5.3 kg (95% CI 0.5 to 10.1) and change in body mass index of 1.8 kg/m² (95% CI -0.9 to 4.6) at 2 years. Weight gain appeared most pronounced right after entering prison and then plateaued at 2 years. Concerning hypertension, the results were inconclusive, despite a trend towards rising blood pressure or prevalence of hypertension during incarceration, and an increased incidence of hypertension following incarceration. Results are contradictory or inconclusive for the other CVDRFs reviewed.

Conclusion Possible explanations for the association between incarceration and weight include a sedentary lifestyle, unhealthy diet, forced smoking cessation, psychotropic medication use and high levels of stress. Incarceration may be an independent risk factor for cardiovascular disease.

Strengths and limitations of this study

- Our statistical approach (a random-effects meta-regression model) allowed us to assess the dose-response relationship between time spent in prison and weight and body mass index changes.
- The methodology used to assess the relationship between time spent in prison and changes in weight can contribute to a better understanding of the temporal relationship between weight gain and incarceration and help identify key mediating factors.
- The uncertainty in the estimates of the meta regression were high due to the small number of included studies, reflected by the large CIs.
- Substantial heterogeneity between studies, including differences in prison contexts and population characteristics, limited our ability to draw clear conclusions about which factors contribute to the trends in CVDRFs described.
- Findings have limited generalisability to low-income or middle-income countries given they were excluded from the analysis.

INTRODUCTION

Background

Cardiovascular disease (CVD) is the leading cause of death worldwide¹ and among the primary causes of disability.² CVD is also a leading cause of death in people currently or previously incarcerated.³ In 2018, in the USA, over 2.1 million people experienced incarceration, amounting to 0.65% of the US population, nearly five times the rate in the UK.⁴ This disproportionately affects African-American men in whom it has been estimated that up to a third have had contact with the prison system.⁵ Furthermore, in high-income countries, the prison population is growing older along with the general population and it is estimated that one-third of the US prison population will be over 55 by 2030.⁶ Like the general population, older people in prison have a different and more complex health

profile, and in particular, a higher incidence of chronic diseases.⁷ Currently, clinical guidelines^{8,9} and research in prison medicine tend to focus on infectious diseases, substance use, psychiatric disorders and trauma.¹⁰ With this demographic shift towards older prison populations there is a need to better understand trends in chronic conditions that are expected to emerge.

Recently, there is growing evidence that people in prison experience a high prevalence of CVDRFs including hypertension (HTN), obesity, diabetes and tobacco use, compared with the general population.^{11–17} In the USA, this trend is especially evident among women in prison.¹⁸ Furthermore, about 80%^{19–21} of prisoners are smokers, which is 1.7–8 times higher than the general population.²² Conversely, other evidence^{18,23} suggests a lower level of obesity among people in prison compared with the general population, challenging the common belief that the prison environment is detrimental to health.

It is unclear whether the prison environment is the cause of health issues or whether it mirrors an overrepresentation of morbid people or people with pre-existing CVD risks factors.¹² There is a gap of knowledge about the impact of incarceration on the emergence or change in major CVDRFs over time. To address this knowledge gap, this review aims to summarise and quantify, where possible, the relationship between incarceration and trends in major CVDRFs over time including obesity (weight gain), HTN, diabetes, tobacco use, dyslipidaemia, unhealthy diet and physical inactivity in high-income countries.

METHOD

Literature search

A literature search was conducted with the assistance of a medical librarian in five databases: Medline Ovid SP (1946 to December 2018), Embase.com (1947 to December 2018), PubMed (1946 to December 2018) with restriction to non-Medline articles, Cochrane Central Wiley and Web of Science Core Collection (1900 to December 2018). All keywords, MeSH and Emtree terms that describe prison, and major CVDRFs were used, including obesity (including the concepts of body mass index (BMI), or weight), HTN, diabetes (DM), dyslipidaemia, tobacco use, physical inactivity and unhealthy diet. The type of study, or population type was not specified at this stage. The detailed search strategy is available in the online supplemental appendix A. Additional studies were identified through a review of all references in the included articles.

Screening articles for eligibility

Two authors (CB and AA) independently screened articles for eligibility in two phases: 1) screening by a title and abstract and 2) a full-text screening. Disagreements that could not be resolved between CB and AA were resolved through discussion with a third author (PB).

Inclusion and exclusion criteria

Studies reporting at least two values of any CVDRFs at two different time points, or studies that described the incidence of any CVDRF, irrespective of the baseline CVDRFs of the population, were included. Only studies conducted in high-income countries were eligible. The full eligibility criteria used during screening can be found in [table 1](#).

Data extraction

The data extracted from each article included: study design, study population characteristics (sex, age), time already served at baseline and follow-up duration. In cases where the same study population was used in several studies, only the results of the main study were reported (ie, the one with more participants or CVDRF evaluations). For all studies, we also extracted and reported the first and last value of each CVDRF or its incidence rate. For randomised controlled trials (RCTs), only the values in the control arm were extracted. When needed, study authors were contacted by email to verify their methodology or to request additional data.

Quality appraisal

The quality of each article was assessed independently by CB and AA. A quality scale of 1–8 was created based on the Newcastle-Ottawa Scale for quality assessments of cohort studies.²⁴ Articles with 1–3 stars were considered of poor quality, 4–6 stars of moderate quality and 7–8 stars of good quality. The scores are indicated with star symbols (*) in [table 2](#).

Statistical methods

Findings for all associations between incarceration and individual CVDRFs were reported using descriptive statistics. The data on mean follow-up time, weight and BMI changes from baseline, along with SEs, were extracted and presented on a forest plot with studies sorted according to the mean follow-up time. As the forest plot clearly exhibited both the presence of strong heterogeneity and a dose-response relation of the outcomes with time, we conducted a random-effects meta-regression analysis. Estimation was carried out by restricted maximum likelihood. Based on the regression coefficients, the dose-response relationship between time spent in prison and each of the outcomes (ie, change in weight and BMI over time) were graphed on scatter plots with the size of the points (or ‘bubbles’) proportional to the precision of the effect size estimates. A pointwise CI around the regression line was computed. We used Stata V.15 (StataCorp, College Station, Texas, USA) to conduct the statistical analysis. Due to insufficient data, no statistical analysis could be performed on all other CVDRFs assessed in this review.

Patient and public involvement

Due to the nature of our systematic review (ie, not original research), it was not appropriate or possible to involve patients or the public in the design, conduct, reporting or dissemination plans for our study.

Table 1 Eligibility criteria

Inclusion criteria	Exclusion criteria
Population	
Adults (aged ≥18 years)	Children or adolescents
Men and women	Custody, community correction supervision (eg, probation, parole) or war prisoner
Current or ex-prisoners	Focused only on people in prison with a specific health condition like chronic infectious diseases (HIV, hepatitis, etc), mental disease or addiction, unless a control group exists
High-income country	
Languages	
English, French, Spanish, Portuguese, German, Italian	
Duration	
Minimum 2 weeks follow-up	<2 weeks
Study type	
Longitudinal or cohort studies prospective or retrospective	Systematic reviews, conference proceedings, book reviews, commentaries, fact sheets, discussion or policy statements
Randomised controlled trials or intervention studies only if a control group exists	
Cross-sectional only if compared with previous data from the same population	
Outcome	
Changes in major CVDRFs levels during or after incarceration at two independent timepoints	

CVDRF, cardiovascular disease risk factors.

RESULTS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart (figure 1) summarises the study selection process. A total of 5494 articles were identified through the prespecified search strategy (see online supplemental appendix A). Twenty-six articles met criteria for inclusion in the final analysis, of which 22 reported on unique study populations. One author^{25–27} published three papers on the same population, and another two authors^{28–31} published two papers.

Ten authors^{29 32–40} were contacted due to missing data or difficulties interpreting study results in the published papers. One⁴⁰ responded that the data were no longer available. Four others were able to share results^{33 34 37} or assist in their interpretation.²⁹ The remaining authors could not be reached. A summary of the 22 included studies is provided in table 2. Three studies were rated of good quality, 13 of moderate quality and 4 of poor quality. A table summarising the quality assessments for each article is available in online supplemental appendix B. The majority of studies addressed CVDRFs during incarceration. Only three studies addressed changes in CVDRFs following incarceration.^{36 39 41}

In the following sections, all studies followed by a star (***) reported a statistically significant value ($p < 0.05$) for

the difference between baseline and end of follow-up for the CVDRF of interest.

Hypertension

Seven studies addressed the impact of incarceration on blood pressure (BP).^{30 32 38 39 42–44} In four studies the mean level of BP rose during incarceration.^{32 38 42 43} Two studies^{30 38} found a non-significant increase in the number of people in prison suffering from HTN during incarceration (+2.5% and +0.6 %, respectively). One study, derived from a US cohort followed for 5 years after incarceration, reported a 12% cumulative incidence of HTN among ex-prisoners compared with 7% among non-ex-prisoners.^{39*} This difference was particularly marked in those who were less educated and in black men. One study focusing on the concept of crowding found that people in prison who moved from individual cells to dormitory-style cells experienced a small but statistically significant mean rise in systolic BP of 2.6 mm Hg.^{42*} However, this effect was reversible when they moved back to an individual cell. In contrast, one Japanese study showed a significant decrease in BP^{44*} during incarceration over a 1-year period.

Diabetes

Five studies addressed trends in diabetes during incarceration.^{35 39 45–47} Three reported an improvement in

Table 2 Characteristics, findings and quality of the included studies

Study, country	Study design and study population	Cohort size (N)	Follow-up (months) Frequency of data collection	Sex (% male)	Mean age (SD) (years)	Time served at baseline (mean)	CVDRFs at baseline Mean (SD) or (95% CI)	CVDRFs at final follow-up Mean (SD) or (95% CI)	Overall quality (total score)
Baldwin, 2016, USA ³³	Cross-sectional study comparing weight/height with values at entry. All male in medium security facility for <12 months	103	6 Entry/Study	100	34.8 (11)	No time	BMI (kg/m ²): 27.4 Weight (kg): 85.5 25% are obese	BMI change (kg/m ²): +1.25 (0.74 to 1.76) [†] Weight change (kg): +3.86 (2.26 to 5.46) [†] 75% gain weight, 21% lost weight [†] 35% are obese*	Moderate (6/8*)
Battaglia, 2013, Italy ³²	RCT (two training protocols, one control group). All male aged <50 years, in a maximum-security prison who have ≥1 year of detention left	18	9 Baseline/End	100	32.8 (9)	4.3 years	BP (mm Hg): 119.2 (6.4)/ 66.5 (9.0) Lipids (mmol/L): LDL: 3.0 (0.6); HDL: 1.2 (0.4); TC: 5.1 (0.6); TG: 1.9 (0.4) BMI (kg/m ²): 26.3 (2.7)	BP (mm Hg): 120.8 (16.6) [†] / 71.9 (7.5) [†] Lipids (mmol/L): LDL: 3.1 (0.9) [†] ; HDL: 1.2 (0.3) [†] ; TC: 5.2 (0.9) [†] ; TG: 2.0 (0.4) [†] BMI (kg/m ²): 28.7 (2.7)*	Moderate (5/8*)
Clarke, 2012, USA ⁴⁰	Prospective observational study All women (non-pregnant) in general facility of one prison	109	0.5 Baseline/End	0	35.7 (9)	Median: 23 days	33% have a normal weight, 34.9% are overweight, 32.1% are obese	BMI change (kg/m ²): +1.0 (-0.86 to 2.86)* Weight: 70.6% gain weight in prison. [†] Those incarcerated for <2 weeks gained 0.77 kg/week*. Those incarcerated for >2 weeks gained 0.36 kg/week*	Moderate (6/8*)
Clarke, 2013, USA ⁴¹	RCT: intervention to reduce tobacco use at exit versus control group Tobacco-free prison. Smokers (≥10 cigarette/day before incarceration), both sexes, <8 weeks of detention left	110	0.75 (1, 7, 21 days)	65	35.7 (9)	-	Tobacco use: 100% forced abstinence in prison	Tobacco use: 92.8% relapsed smoking 3 weeks after release [†]	Good (7/8*)
Cropsey, 2008, 2009 & 2010, USA ²⁵⁻²⁷	RCT: intervention versus control to reduce smoking in prison. Female smokers (≥10 cig/day) with ≥1 year of detention left. Results only for the control group	289	6 (0, 2.5, 3, 6 months)	0	34 (9)	-	Tobacco use: all smokers at baseline	Weight change ²⁶ (kg): -1.86 (-2.51 to 1.21) [†] Tobacco use ²⁵ : 2.8% gave up smoking [†]	Moderate (6/8*)
D'Atri, 1981, USA ⁴²	Prospective observational study. All men, one prison, eligible if present for <7 days. HTN assessed among four groups: single cell or dormitory; work release or not	242	4 (1-2x/month)	100	25	1-7 days	BP (mm Hg): 116.4 (13.1)/ 73.0 (9.7)	BP (mm Hg): control+ 2.0 (9.3) [†] Transfer: C to D: +2.6* , C to WR-D: +3.8* C to WR-C: -3.8* D to C: -0.9* [†] Weight: 'Little change' in weight over time [†]	Moderate (6/8*)
Davoust, 2016, France ⁴⁵	RCT assessing DM control: DM medication-related workshop versus placebo Men with diabetes in prison	15	3 Baseline/End	100	48.7 (14)	No time	C=cell (alone), D=dormitory, WR-C=work-release cell (alone), WR-D=work-release dormitory	DM in change of HbA1c (%): +0.26 (0.28) [†]	Moderate (4/8*)
Drach, 2016, USA ³⁴	Cross-sectional study comparing weight/height with values at prison entry. All women, incarcerated for 6-24 months in one prison	134	6-24 Entry/Study	0	39 (11)	No time	BMI (kg/m ²): 26.9 (5.2) 42% are overweight, 22% are obese	BMI (kg/m ²): 30.4 (6.0) [†] . BMI change (kg/m ²): +3.42 (2.79 to 4.05) [†] Weight change (kg): +9.10 (7.44 to 10.76) [†] 39% are overweight, 48% are obese	Moderate (5/8*)

Continued

Table 2 Continued

Study, country	Study design and study population	Cohort size (N)	Follow-up (months) Frequency of data collection	Sex (% male)	Mean age (SD) (years)	Time served at baseline (mean)	CVDRFs at baseline Mean (SD) or (95% CI)	CVDRFs at final follow-up Mean (SD) or (95% CI)	Overall quality (total score)
Firth, 2015, USA ³⁵	Retrospective observational study on medical records/laboratory results comparing metabolic change in reduced calorie menu (RCM) group versus normal menu (NM) group. All females with diabetes in one prison	63	24 Mean 3.7x	0	45.9 (12)	23.1 months	DM in HbA1c (%): (for RCM) 7.3% BMI (kg/m ²): 33.3 (6.8)	DM in HbA1c (%): (for RCM): 6.9%† Change in HbA1c (%): RCM: -0.04%/month* Change in HbA1c (%): NM: -0.01%/month* BMI change (kg/m ²): +0.9 if incarcerated for <1 year†, +0.4 if incarcerated for >1 year†.	Good (7/8*)
Gates, 2015 & 2016, USA ^{28,29}	Retrospective observational study on electronic records (2005–2011), all offenders (both sexes) in one prison looking at change in BMI in subgroups (gender, race, psychiatric treatment or none)	2728	26 (NR)	94	40.2 (10)	No time	Weight (kg): 85.6	BMI change (kg/m ²): +0.45 (0.20 to 0.71)† Weight change (kg): +1.43 (0.66 to 2.19)† Older people in prison are not more overweight or obese than younger, nor gaining more weight†.	Good (7/8*)
Hinata, 2007, Japan ⁴⁶	Retrospective observational study. Medical records screened 1998–2004. Looked at metabolic control of males with DM in one prison	109	14 Every 1–6 months	100	51 (10)	0.5–4 years	DM in HbA1c (%): 8.4 (2.1) DM in FBG (mmol/L): 10.2 (4.1) Lipids (mmol/L): HDL: 1.03 (0.34), TC: 4.27 (1.03), TG: 1.58 (1.13)	DM in HbA1c (%): 5.9 (1.2)* DM in FBG (mmol/L): 6.3 (2.1)* Lipids (mmol/L): HDL: 0.98 (0.28) ^{††} , TC: 3.85 (1.01)*, TG: 1.34 (0.88)†	Moderate (6/8*)
Houle, 2014, USA ^{36,†}	Analysis from a large national cohort, all male, aged 18–49 years, from 1981 to 2006. Growth curve model to see evolution of BMI over time. Incarceration assessed by place of residence indicator	61 200	300 Every 1–2 years	100	–	–	Incarceration increases BMI compared with those never incarcerated during and after incarceration, with a cumulative effect. Especially in black men and those with lower education. This effect decreases for those with a diploma more than high school†.		Poor (2/8*)
Ingram-Fogel, 1991 & 1993, USA ³⁰	Longitudinal prospective observational study. Only women (non-pregnant), sentenced ≥2 years. One prison	55	6 Baseline/End	0	28.5 (8)††	<7 days	HTN: 1.3% have hypertension† 44% are obese†	HTN: 3.8% have hypertension† Weight change (kg): +6.34† (4.05 to 8.63) 57% are obese†. 17% had a normal weight at entry became obese in the first 6 months†	Poor (3/8*)
Johnson, 2018, Canada ⁴⁵	Retrospective cohort study, comparing weight/height with values at entry, among people in prison who volunteered in five federal penitentiaries	1420	60 Baseline/End	89.9	–	No time	39.4% are overweight, 26.6% are obese	BMI change (kg/m ²): +2.00 (1.79 to 2.21)† Weight change (kg): +6.20 (5.55 to 6.85)† 38.8% are overweight†, 45.4% are obese†	Good (7/8*)
Lagarigue, 2017, France ³⁷	Cross-sectional study comparing weight/height with values at entry. All women (non-pregnant) included and matched to a group of men	51	10 Entry/Study	35	41.1 (14.6)	No time	21.6% are overweight, 15.7% are obese	BMI change (kg/m ²): -2.31 (0.27 to 4.36)† 56.9% gain weight †, 25.4% lost weight † 19.6% are obese†	Moderate (6/8*)
MacFarlane, 1992, UK ⁴⁷	Longitudinal prospective observational study in one prison, following males with diabetes to assess metabolic control	23	2.5 Baseline/End	100	39.1	12 months	DM in HbA1c (%): 9.9 (2.7%) BMI (kg/m ²): 25.38 (3.8)	DM in HbA1c (%): 6.8 (2.2%)* BMI 'did not change significantly in the prisoners†	Moderate (6/8*)
Nara, 1998, Japan ⁴⁴	Longitudinal prospective observational study. All women eligible from one prison, separated in pre/post menopause groups, assessed for metabolic change	400	12 Baseline/End	0	38.8 (13)	No time	BP (mm Hg): 117.3 (0.4)/71.1 (0.5) Lipids (mmol/L): LDL: 3.16 (0.1); HDL: 1.23 (0.02), TC: 5.23 (0.06); TG: 1.07 (0.04) BMI (kg/m ²): 22.1 (SD=0.3)	BP: 113.8 (0.6)/68.3 (0.2)* Lipids (mmol/L): LDL: 2.72 (0.04)*; HDL: 1.29 (0.03)*, TC: 4.97 (0.04)*; TG: 1.03 (0.04)* BMI (kg/m ²): 21.1 (SD=0.4)*	Moderate (5/8*)

Continued

Table 2 Continued

Study, country	Study design and study population	Cohort size (N)	Follow-up (months) Frequency of data collection	Sex (% male)	Mean age (SD) (years)	Time served at baseline (mean)	CVDRFs at baseline Mean (SD) or (95% CI)	CVDRFs at final follow-up Mean (SD) or (95% CI)	Overall quality (total score)
Plugge, 2009, UK ³⁸	Longitudinal prospective observational study. All women in one prison assessed for change in CVDRFs over time	220	1 Baseline/End	0	31.5 (9)	<3 days	BP (mm Hg): 114.7 (17)/ 69.7 (13) HTN: 12.2% have hypertension Tobacco: 81.2% are smokers [†] Tobacco, quantity (g/day): 19.9 † Weight (kg): 65.3 37.6% are overweight or obese	BP (mm Hg): 116 (17)/ 70.1 (11.9)† HTN: 12.8% † have hypertension Tobacco: 80.3% † are smokers. Tobacco, quantity (g/day): 11.7 * Weight (kg): 66.8 . Change (kg): +1.5 (1.00 to 2.00)† 39.5% are overweight or obese [†]	Poor (3/8*)
Rocca, 2018, Italy ³⁹	Cross-sectional study comparing weight / height with values at entry in one prison. Males incarcerated for 1 month to 2 years.	142	9 Baseline/End	100	39.4	No time	BMI (kg/m ²): 27.2 Weight (kg): 77.3	BMI (kg/m ²): 27.6 . Change (kg/m ²): +0.47 (0.08 to 0.86)* Weight (kg): 78.6 . Change (kg): +1.30 (0.16 to 2.44)*	Moderate (5/8*)
Shaw, 1985, USA ⁴⁹	Cross-sectional study comparing weight of selected women with values at entry in one prison	56	0.25–36 months Entry/Study	0	–	No time	30.3% are obese§	86% gained weight (range 0.45 to 18.48 kg); 91% who stayed ≥3 months gained: +6.35 kg† 48.5% are obese§ at 3 months follow-up†	Moderate (5/8*)
Thomas, 1961, USA ⁴³	Longitudinal prospective observational study. Men aged 20–29 years. Incarcerated for >1 year and with >1 year of detention left. Observe variation in total cholesterol level	24	12 (once a month)	100	Range 22–28	>1 year	BP (mm Hg): 120.7/74.9 Lipids (mmol/L): TC: 5.84 † BMI (kg/m ²): 23.3	BP (mm Hg): 123.2/64.0† Lipids (mmol/L): TC: 5.94 † BMI (kg/m ²): 23.2†	Moderate (5/8*)
Wang, 2009, USA	Cohort in general population of four cities. Both sexes. History of incarceration assessed at year Two groups: with/without history of incarceration HTN incidence assessed at year 5	288	60 Baseline, 2–5 years	75	24 (4)	–	HTN: 12% new diagnoses* (incidence) in ex-prisoners compared with 7% in non-ex-prisoners DM: 2% incidence in ex-prisoners vs 3% in non-ex-prisoners† ¹	HTN: 12% new diagnoses* (incidence) in ex-prisoners compared with 7% in non-ex-prisoners DM: 2% incidence in ex-prisoners vs 3% in non-ex-prisoners† ¹	Poor (3/8*)

*P<0.05 (significant) for the difference between baseline and end; ^{32, 33, 38, 40, 44, 50} between groups^{35, 40} or comparing with 'non-ex-prisoners' group.³⁹

†No p values reported, or †p value reported as >0.05 (not significant) for the difference between baseline and end of the study, or between two groups.

‡The study size, race and education level are for the whole population, which include ex-prisoners and non-ex-prisoners.³⁸

§Old definition for obesity: ≥20% than the weight norm for their height.

††P<0.05 (significant) compared with expected change in normal population.

BMI, body mass index; BP, blood pressure; CVDRF, cardiovascular disease risk factor; DM, diabetes; HbA1c, haemoglobin A1c; HDL, high-density lipoprotein; HTN, hypertension; LDL, low-density lipoprotein; TC, total cholesterol; TG, triglyceride.

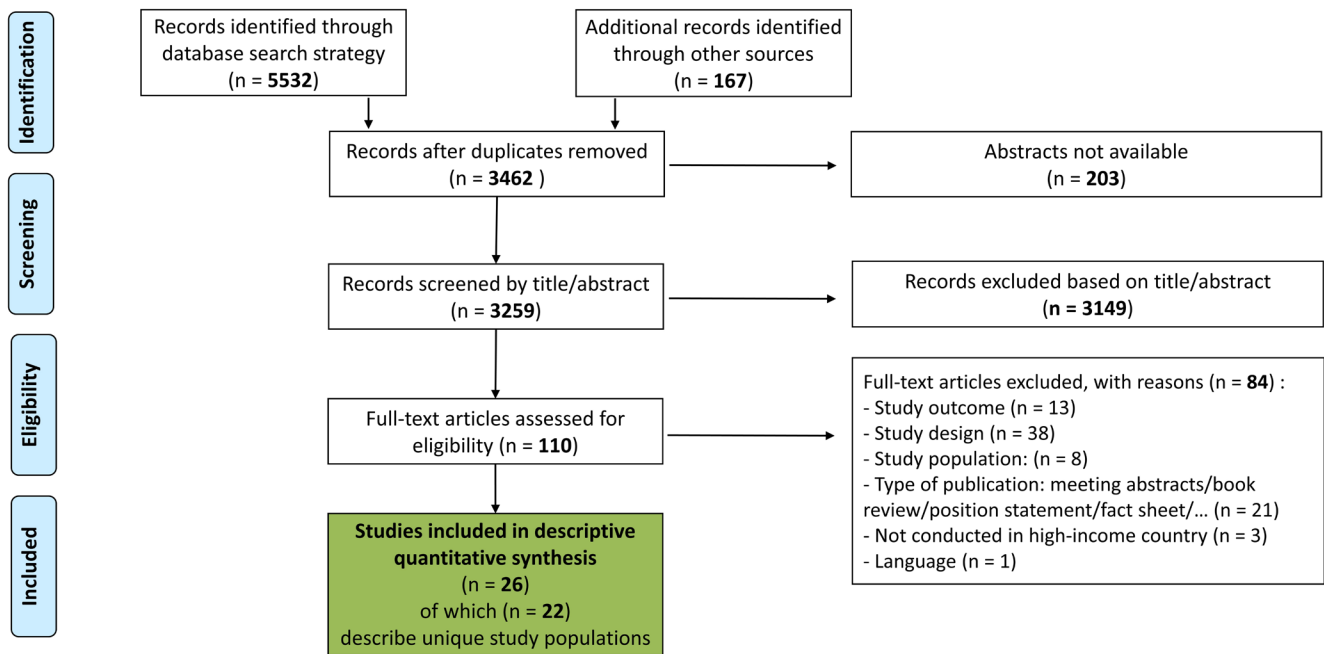


Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart.

the control of one's diabetes, reflected by a decrease in haemoglobin A1c (HbA1c)^{35 46 47*} and reduced fasting blood glucose (FBG).^{46*} Interestingly, one study from Japan^{46*} showed a significant decrease in mean HbA1c from 8.4% to 5.9% over 14 months. To explore the link between food served and the control of one's diabetes, Firth *et al* compared people in prison receiving a new reduced calorie menu (RCM) implemented by the prison administration (ie, not a research intervention) offering 2200 kcal/day to those still receiving the normal menu (NM) with 3000 kcal/day.³⁵ Improvements in mean HbA1c were reported in both groups, but the decrease was significantly more marked in the RCM group compared with the NM group. Davoust *et al*⁴⁵ found a statistically non-significant rise of 0.26% in HbA1c during the 3 months of follow-up in a cohort of 15 people. Lastly, one paper found that ex-prisoners were not at higher risk of developing DM after incarceration than those who had never been incarcerated.³⁹

Tobacco use

Five articles^{25–27 38 41} describing three original studies^{25 38 41} (one in which tobacco use was prohibited in the study setting⁴¹) addressed trends in tobacco use during and following incarceration. In prisons without a smoking ban, the incidence of smoking did not change significantly between baseline and follow-up, which ranged from 1 to 6 months.^{25 38} One study reported a significant decrease in the quantity of tobacco smoked 1 month after entering prison (from 19.9 g to 11.7 g/day).^{38*} In the study by Cropsey *et al*,²⁵ the fact that 2.8% of the smokers quit was counterbalanced by the fact that another 14.2% self-reporting that they started smoking for the first time

in prison.²⁵ Moreover, in another study, it was found that 50.8% of smokers increased their consumption after entering prison compared with 15.8% who decreased their consumption.²⁵ The self-reported increase in tobacco consumption during incarceration was especially marked among African-American smokers in one all-female cohort.³⁷ Finally, one study found that that 92.8% of smokers had relapsed at 3 weeks following release⁴¹ from a tobacco-free prison.

Dyslipidaemia

Four articles addressed the association between dyslipidaemia and incarceration with conflicting findings.^{32 43 44 46} Two reported an increase in total cholesterol (TC), low-density lipoprotein (LDL) and triglycerides (TG) levels^{32 43} and a decrease in high-density lipoprotein (HDL) during incarceration.³² However, these changes either did not reach statistical significance or the level of statistical significance was not reported. In contrast, both Japanese papers on this topic found a statistically significant decrease in TC during incarceration.^{44 46*}

Physical inactivity and unhealthy diet

One study by Plugge *et al*³⁸ addressed the association between physical activity, diet and incarceration in a cohort of 220 women in prison in the UK. What they found was a low level of physical activity at entry into prison and no significant change at a 1 month follow-up. They also found a statistically non-significant decrease in women following the recommended healthy diet each day from 13.4% to 8.3% during the same time period.

Weight and obesity

Eighteen studies addressed the association between weight and incarceration.^{29–38 40 48–50} Thirteen^{31 33 37 38 40 48 49} reported either a positive change in the prevalence of people in prison being overweight and obese or an increase of weight or BMI during or after incarceration.^{29–38 40 48–50}

The identified risk factors for weight gain during incarceration in the reviewed studies included being a black man,³⁶ being a woman^{25 34 37} (especially women who quit smoking during incarceration²⁶) and taking antidepressants or antipsychotics.²⁹

Five studies report a decrease in BMI or weight in relation to incarceration: one Japanese study^{44*} found a change in BMI of -1.0 kg/m^2 over 12–14 months of incarceration, two found trends towards decreased weight²⁵ of -1.86 kg and BMI⁴³ of -0.1 kg/m^2 that did not meet statistical significance, and two reported ‘little change’⁴² or ‘no significant change in BMI’⁴⁷ without providing quantitative data.

Meta-regression

To summarise findings related to changes in weight and BMI from baseline to follow-up, study effect sizes were graphed on a forest plot in order of increasing length of follow-up. There were marked differences in follow-up time between studies, ranging from 0.5 to 60 months. Consequently, no overall summary index could be

computed at this stage. Despite this limitation, the forest plots (figures 2 and 3) illustrate that the majority of results lie on the positive side (ie, side of increase) in both the change in weight and change in BMI. In a second stage, in order to assess the overall change in weight and BMI over time, we carried out a meta-regression on the change in weight (figure 4) and BMI (figure 5) during incarceration. Five studies^{32 35 43 44 49} could not be included in the computation as they lacked necessary data (ie, unavailable SEs) and we were unable to reach the authors to gather the required data. These studies were represented by a simple dot on the plots as shown in figures 2 and 3. It was found that the mean weight gain during incarceration was 0.30 kg (95% CI -0.03 to 0.6) at 1 month, 3.1 kg (95% CI -0.01 to 6.3) at 1 year and 5.3 kg (95% CI 0.5 to 10.1) at 2 years. The mean increase in BMI was 1.1 kg/m^2 (95% CI -0.7 to 2.9) at 1 year and 1.8 kg/m^2 (95% CI -0.9 to 4.6) after 2 years of incarceration. The τ^2 was 10.3 for the change in weight and 1.7 for the change in BMI.

DISCUSSION

The results of this study showed that the mean weight or BMI of the people in prison in high-income countries seemed to increase during incarceration. This effect appears most pronounced in the first 2 years of

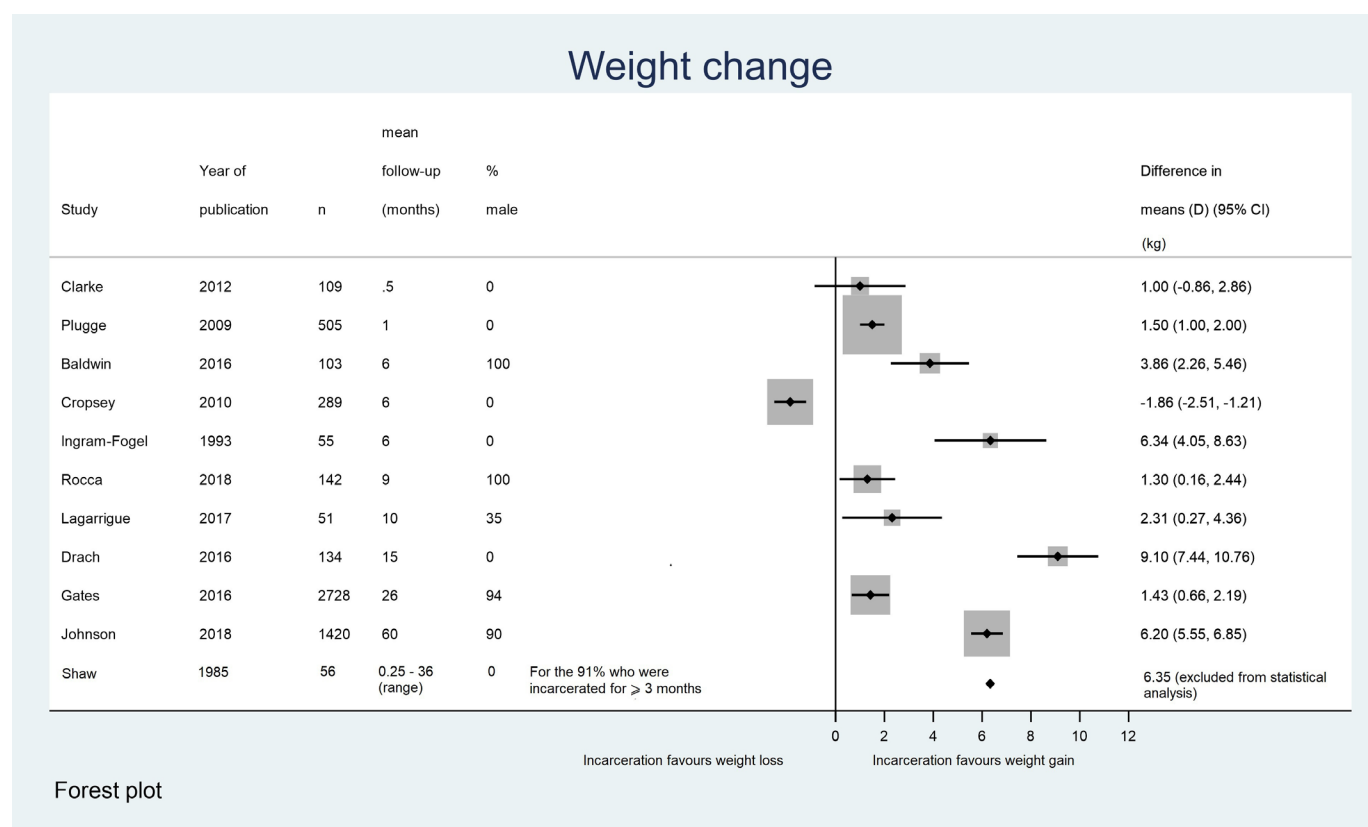
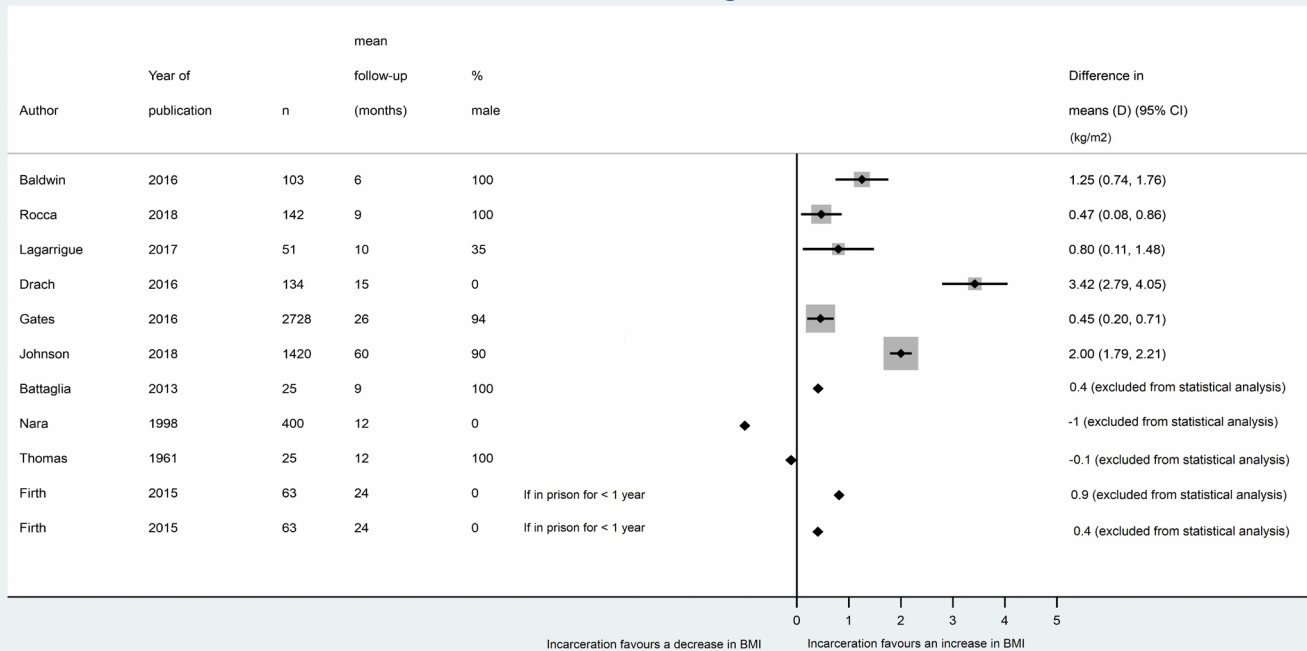


Figure 2 Weight change during incarceration (forest plot). The follow-up periods between studies ranged from 0.5 to 60 months. Due to the presence of strong heterogeneity and the fact that there is a dose-response relation of the outcomes with time, we were unable to depict combined findings in this forest plot. Instead, a meta-regression analysis was conducted (figure 4).

BMI change



Forest plot

Figure 3 Body mass index (BMI) change during incarceration (forest plot). The follow-up periods between studies ranged from 6 to 60 months. Due to the presence of strong heterogeneity and the fact that there is a dose-response relation of the outcomes with time, we were unable to depict combined findings in this forest plot. Instead, a meta-regression analysis was conducted (figure 5).

incarceration and levels off beyond 2 years. Of the seven studies that addressed the relationship between incarceration and HTN, six showed a trend towards either an increasing blood pressure or the prevalence of HTN during incarceration, or an increased incidence of HTN following incarceration. However, as the majority of these results were not statistically significant, the relationship between incarceration and the evolution of HTN remains unclear. For all other CVDRFs assessed, the results were contradictory or inconclusive limiting our ability to draw any clear conclusions about the impact of incarceration on the trends in these CVDRFs over time based on the available evidence.

Weight and obesity

By conducting a meta-regression on available data relating to incarceration and change in weight and BMI over time, an overall rise in weight and BMI during incarceration was found. In figures 4 and 5, a steeper slope in weight and BMI over time (ie, more pronounced change) was seen at the beginning of incarceration, particularly during the first few months, and appeared to level off after 2 years. Compared with the average weight gain of the middle-aged US population, estimated to be between 0.5 and 1 kg/year,⁵¹ the mean weight gain found in this review was up to five times higher in the first 2 years of imprisonment. Hypothesised reasons for this include a combination of a sedentary lifestyle and a poor diet (the high calorie meals

served in prison and the extra snacks or sweet beverages purchased from the commissary store),^{11 52 53} forced smoking cessation (which has been associated with weight gain⁵⁴), a high prevalence of people in prison taking psychotropic medication (known to affect weight),¹¹ high rates of depressive symptoms⁵⁵ and high levels of stress.⁵⁶ Many of these factors are interconnected which might create a vicious cycle of weight gain. For instance, it has been found that depression increases the odds of developing obesity among people in prison, while obesity may increase the risk for depression.⁵⁷ Furthermore, current or recent incarceration is associated with depression and mood disorders,^{58 59} and chronic stress is associated with poor eating behaviours and obesity.⁶⁰ However, how and to what extent these diverse factors contribute to weight gain among people in prison remains unclear. To further complicate the issue, a recent systematic review²³ found that 42%–75% of people in prison gained weight while incarcerated which was thought to be due to importing poor health behaviours from the community into prison, as well as individuals adapting to the prison environment by building muscles to demonstrate strength among peers. As such, the authors of this review highlight that BMI may be a poor marker of weight gain in prison because bodybuilding positively changes the ratio of fat-to-muscle mass raising the BMI while potentially reducing cardiovascular risk. However, the extent to which physical

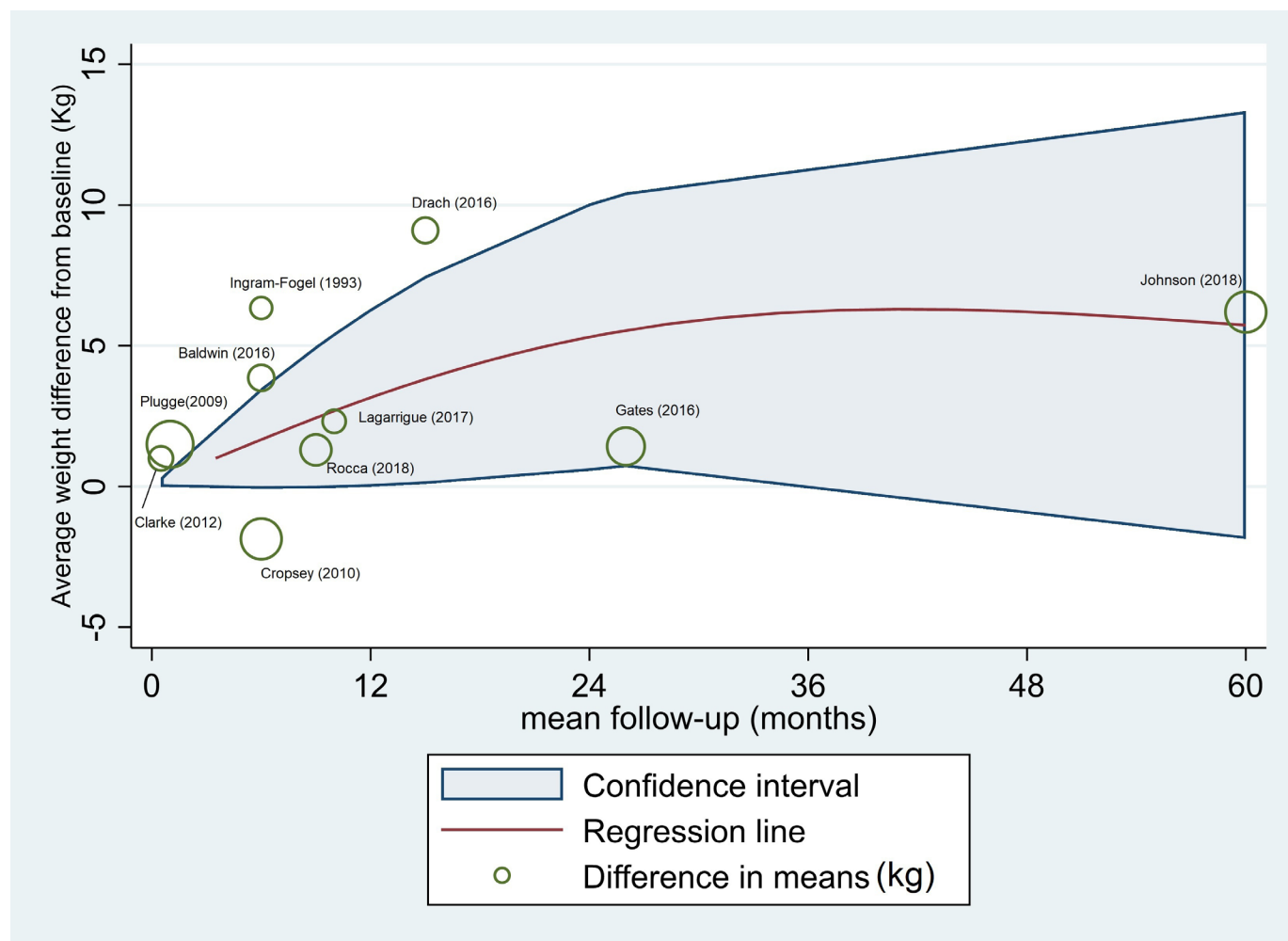


Figure 4 Weight change during incarceration (meta-regression) based on findings of 10 studies.

training can explain the rising prevalence of weight gain in people in prison during incarceration is unknown.

In terms of the long-term impact of incarceration on weight gain, only one study addressed this issue by examining weight gain in a large US-based cohort (n=61 200) of ex-prisoners with a follow-up of 25 years. The authors concluded that those incarcerated or with a history of incarceration have a higher increase in BMI over time, especially for black people in prison and those with lower education, compared with non-ex-prisoners.³⁶ Nonetheless, the quality of this study was judged poor, and the growth curve models used were hard to interpret in detail.

A meta-analysis⁶¹ published in 2018 examining a similar question to our current systematic review (ie, association between weight gain and incarceration) reported a positive weight change during incarceration, with a mean increase of 0.43 lbs (0.19 kg) per week. Implicitly, these authors assumed a linear gain in weight over time. Our results, however, challenge this hypothesis by showing that weight gain may not be linear throughout incarceration but instead may increase steeply during the initial period of incarceration and then plateau over time.

Explanations for the more pronounced weight change noted among women in one of the reviewed²⁸ study

include a smaller number of facilities and programmes in female prisons leading to fewer recreational activities and a more sedentary lifestyle; meals served containing the same amount of calories as those served to men¹⁸ and more antipsychotic medications prescribed to women than men in prisons.⁶² The only study reporting a significant decrease in BMI in this review was conducted in Japan, whose findings were likely due to low calorie diets and food restrictions implemented in Japanese prisons. Further studies are needed to elucidate whether the weight loss seen in this study is due to healthy weight loss or weight loss caused by high-stress prison conditions.

Hypertension

Among available studies examining the association between HTN and incarceration, all but one showed a trend over time towards either a rise in BP during incarceration,^{32 38 42 43} a higher prevalence of HTN among people in prison^{30 38} or a higher incidence of HTN in people released from prison compared with those never incarcerated.³⁹ Few driving factors have been hypothesised to explain this unconfirmed and non-significant trend. Although most findings were statistically non-significant, trends towards an increase in BP or in the

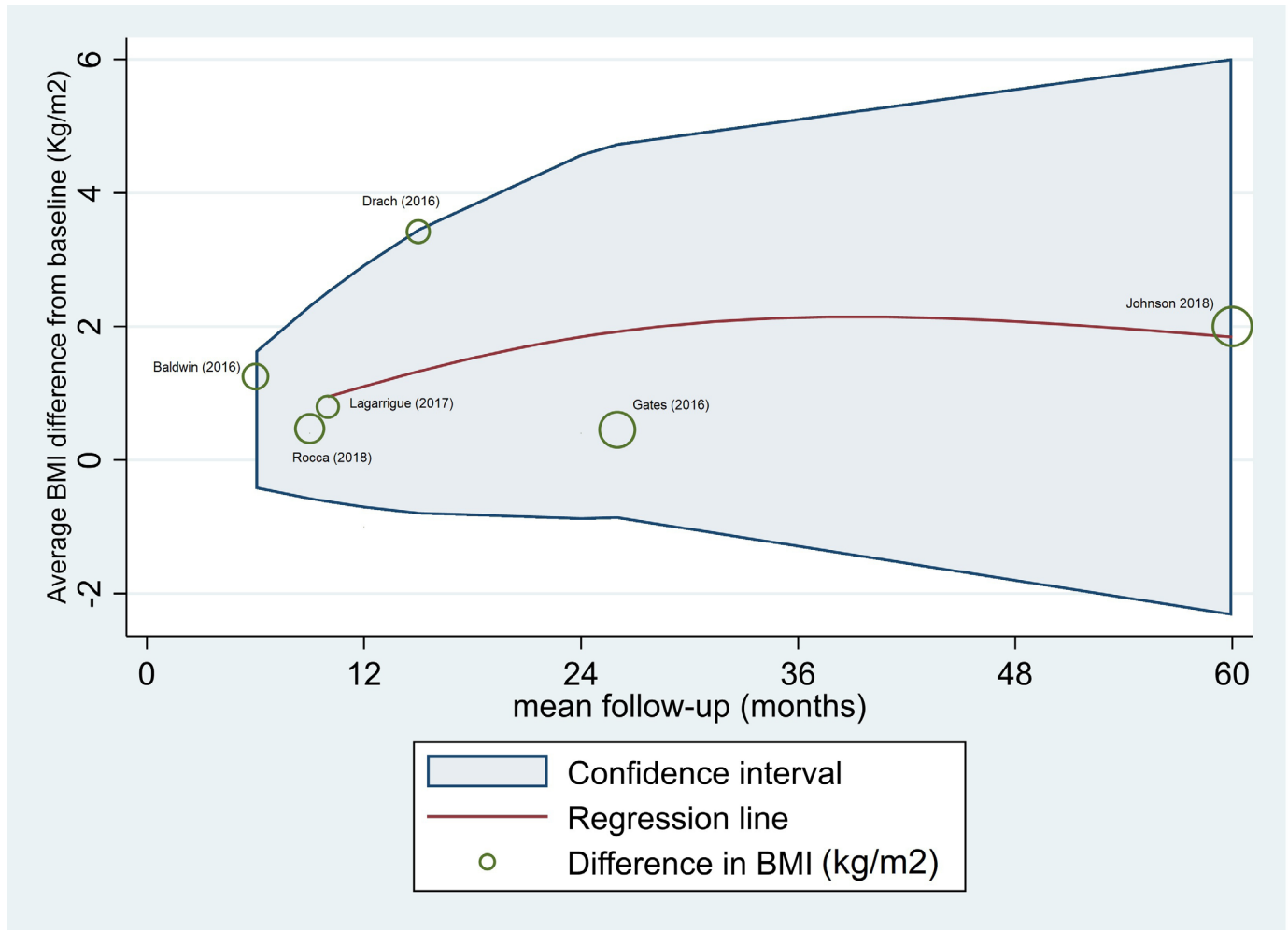


Figure 5 Body mass index (BMI) change during incarceration (meta-regression) based on findings of six studies.

prevalence of HTN during incarceration seems highly plausible due to a number of factors discussed throughout the reviewed studies. First, prison crowding,⁴² whereby people in prison are confined to a limited space and exposed to high noise stress, with an increased number of threatening interactions with other prisoners and guards. Second, incarceration conditions are inherently stressful, and the link between psychosocial stress and HTN is well established.⁶³ Third, the sedentary lifestyle of people in prison may contribute to weight gain, which is also associated with an increase in BP.⁶⁴ Finally, despite institutional efforts made in many prisons to reduce dietary sodium,⁶⁵ high salt diets are often still served.^{38 66} Interestingly, working^{42 44} appears to be a protective factor against HTN during incarceration. The causes for this association are not clear but it is plausible that work might contribute to a more active lifestyle or help reduce stress levels during incarceration. The explanation for the significant decrease in BP reported by Nara and Igarashi⁴⁴ could be related to the specific prison environment, which is described in the two Japanese articles included in this review.^{44 46} The very strict detention conditions include a smoking ban, calorie restriction for all (1800 kcal/day for women and 2500 kcal/day for men), prohibition to

eat between meals and at night and a ban on extra food like snacks or sweetened drinks. Finally, the persisting effect of incarceration on HTN after release found in one study^{39*} might be explained by psychosocial factors due to the ongoing stress caused by adaptations required to life outside prison, including a limited access to employment and changes in social relationships for ex-prisoners. Further research is needed into the causal factors behind this association between HTN and incarceration, well beyond the time of incarceration.

Diabetes

Three of the four studies that looked at changes in blood sugar control during incarceration point to better blood sugar control during incarceration. However, of these three studies,^{35 46 47} one was conducted in Japan in a prison setting with calorie restriction for all prisoners,⁴⁶ and one³⁵ showed the most pronounced effect in those receiving a RCM (2200 kcal/day). For both studies, the main driver of improved blood sugar control may have been the calorie reduction instead of incarceration itself. Other explanations could be that some aspects of prison life contribute to improved blood sugar control such as the provision of regular meals and daily access

to the prison yard and scheduled sports, providing more opportunities for better eating and physical activity than prior to incarceration. It should also be considered that some individuals may have had limited access to health-care prior to incarceration which may have adversely impacted their diabetes control.^{18 67} Finally, despite a higher odd of DM seen among people in prison,¹² only one study identified in this review looked at the association between incarceration and the incidence of DM in people released from prison compared with those never incarcerated, in which no significant association was found.³⁹

Tobacco use

The prevalence of smoking among people in prison is very high.^{19–22} Surprisingly, very few longitudinal studies were identified that assessed the change in smoking habits during incarceration that did not involve the evaluation of a smoking cessation intervention. The only study identified in this review that addressed this question was by Plugge *et al.*,³⁸ who reported a decrease in the quantity of tobacco consumed during incarceration. However, the follow-up was only 1 month, and started right after entering prison, which raises the question of the accessibility of tobacco in the first days to weeks of incarceration. Overall, further studies are needed to better understand the impact of incarceration on tobacco use. The public health response to the high prevalence of smoking in prisons in some countries has been to implement smoking bans, including in many states across the USA⁶⁸ as well as in Japan. However, rules vary considerably by country and region,⁶⁹ as smoking bans were not reported in the French,^{37 45} Italian^{32 50} and English^{38 47} prisons described in the included studies. Although smoking bans appeared to be beneficial in reducing the health impacts of tobacco use, such as in-prison mortality,⁷⁰ the impact that smoking bans have on long-term tobacco use is inconsistent in the current literature. One study⁷¹ showed that a majority (76%) of men in prison continued to smoke 1 month after the implementation of a smoking ban. Moreover, resumption after release from a smoke-free prison appears to be very high in the few studies reporting on this topic.^{41 70 72–75} For instance, according to one systematic review,⁷⁶ >60% of former smokers relapsed on the first day after release, and almost all resumed smoking within 6 months of release. Despite this high rate of relapse another systematic review,⁷⁷ based on many of the same studies, commented that the rate of relapse varied too much to draw any clear conclusions. Finally, another review²² found a similar efficacy of counselling and behavioural interventions aimed at smoking cessation in a prison setting when compared with a community setting, thus highlighting the potential benefits of pharmacological and psychological interventions in prisons to reduce high tobacco consumption and supporting sustained smoking cessation.

Dyslipidaemia, physical inactivity and unhealthy diet

A previous systematic review highlighted that the food served in prison settings was atherogenic, lacking in fruits and vegetables and with high saturated fat and sodium content above the recommended limits.¹¹ However, due to limited findings regarding trends over time of dyslipidaemia, physical inactivity and unhealthy diet in relation to incarceration identified in this review, no conclusions could be drawn. Further research in this area is required.

Strengths and limitations

Some limitations of this systematic review require consideration. First, there is a high degree of uncertainty in the estimates of the meta-regression curve produced in the analysis. This is due to the small number of included studies and the substantial residual between-study variances as reflected by the large CIs. In addition, we found substantial heterogeneity between studies, which may be attributable to differences in incarceration conditions that were not accounted for within individual studies. Moreover, differences in prison contexts and population characteristics may have also influenced changes seen in CVDRFs during incarceration such as: smoking bans, the prison security level, access to regular physical activity, the type and quantity of food served and purchased, access to and frequency of work and whether those studied were facing incarceration for the first time or had been exposed to multiple periods of incarceration. Only studies from high-income countries were included, thus limiting the generalisability of our results to low-income or middle-income countries. Lastly, the literature search was conducted in December 2018, and more recent publications could change some of our findings. We were unable to conduct an updated search prior to publication.

The main strength of this review is that our statistical approach (a random-effects meta-regression model) allowed us to assess the dose-response relationship between time spent in prison and changes in weight and BMI over time. This methodology might help shift the focus in this area of research to improve our understanding of the temporal relationship between weight gain and incarceration and identify key mediating factors.

CONCLUSION AND RECOMMENDATIONS

This review reinforces previous results of a positive association between weight gain and incarceration but newly highlights that this effect may be most pronounced during the first 2 years of incarceration. These findings could allow us to think about incarceration like an aggregate adverse determinant of health serving as an important part of our clinical history taking (ie, whether someone has been previously incarcerated or not) when assessing individual cardiovascular risk. Concerning HTN, the results were inconclusive, despite

a trend towards either a rise in blood pressure or a raising prevalence of HTN during incarceration, and in one study a higher incidence of HTN among ex-prisoners compared with non-ex-prisoners. More studies are needed to confirm or overrule this tendency.

Since this review only focused on studies conducted in high-income countries, further research should be encouraged on a global scale to improve our understanding of the relationship between incarceration and CVDRFs over time. Despite prior reviews reporting a higher prevalence of most other CVDRFs including smoking, dyslipidaemia, unhealthy diet and physical inactivity, we could not conclude whether there was a positive (or negative) trend over time during or after incarceration given the current available literature. More studies are needed to fill this gap.

Primary prevention and treatment of non-communicable diseases including CVD in prison have largely been neglected.²¹ The prison setting offers unique opportunities for the prevention and management of CVDRFs, as its milieu is controlled in terms of daily physical activity or work, caloric intake, tobacco availability and access to healthcare. The Japanese prison environment proved to be very efficient at controlling or improving diabetes, HTN and BMI, however such conditions might not be appropriate for all countries or cultures and may have other deleterious effects that have not yet been explored (ie, excessive weight loss, increased stress or depressive mood) in comparison to less strict prison environments. Interventions involving structured physical activity, diet modification, nutrition education and smoking cessation can improve the cardiovascular health of people in prison while incarcerated.¹⁹ Additional efforts should be made to support those taking antipsychotic or antidepressant drugs in order to avoid worsening CVDRFs through associated weight gain and dyslipidaemia. Furthermore, due to possible beneficial effects on CVDRFs, we would recommend that people in prison have access to work that facilitates regular physical activity in order to tackle the inactivity and psychosocial stress inherent to the prison environment. Future studies should focus on the mediating factors in the relationship between incarceration and major CVDRFs.

Finally, due to the ubiquity of bodybuilding in prisons, studies in this area should consider reporting waist circumference, which may be a better marker of weight gain or obesity than BMI or weight gain in the prison context.²³

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