

Defining the relationship between arm and leg blood pressure readings

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1 **Defining the relationship between arm and leg blood pressure readings: a systematic review and meta-**
2 **analysis**

3 *Arm-leg blood pressure difference*

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32

33 **Conflicts of interest**

34 The authors report no relevant conflicts of interest.

35 **Abstract**

36

37 **Objectives:** To define the relationship between arm and leg blood pressure to inform the interpretation of
38 leg blood pressure readings in routine clinical practice where arm readings are not available.

39 **Methods:** Systematic review of all existing studies comparing arm and leg blood pressure measurements. A
40 search strategy was designed in MEDLINE and adapted to be run across six further databases. Articles were
41 deemed eligible for inclusion if they measured and reported arm and leg blood pressure taken in the supine
42 position and/or the difference between the two. Mean values for arm-leg blood pressure difference and
43 measures of precision (95% confidence intervals [CI] or standard deviation) were extracted and entered
44 into a random-effects meta-analysis.

45 **Results:** A total of 887 articles were screened and 44 were included in the descriptive analyses, including
46 9,771 patients. In the general population, ankle systolic blood pressure was 17.0 mmHg (95%CI 15.4 to 21.3
47 mmHg) higher than arm blood pressure in the supine position. For diastolic blood pressure, there was no
48 difference between arm and ankle blood pressure (-0.3 mmHg, 95%CI -1.5 to 1.0 mmHg). In patients with
49 vascular disease, systolic blood pressure was -33.3 mmHg (95%CI -59.1 to -7.6 mmHg) lower in the ankle
50 compared to the arm.

51 **Conclusions:** This is the first review to provide empirical data defining the difference between blood
52 pressure in the arm and leg in the general population. Findings suggest a diagnostic threshold of 155/90
53 mmHg could be used for diagnosing hypertension when only ankle measurements are available in routine
54 practice.

55

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57

58

59 **Condensed abstract** (100 words)

60 This study systematically reviewed all existing studies comparing arm and leg blood pressure
61 measurements. Mean values for arm-leg blood pressure difference were entered into a random-effects
62 meta-analysis. Based on a total of 44 included studies and 9,771 patients, ankle systolic blood pressure was
63 17.0 mmHg (95%CI 15.4 to 21.3 mmHg) higher than arm blood pressure in the general population. For
64 diastolic blood pressure, there was no difference. These findings suggest a diagnostic threshold of 155/90
65 mmHg could be used for diagnosing hypertension when only ankle measurements are available in routine
66 practice.

67

68 **Key words:** Ankle blood pressure, calf blood pressure, arm-leg blood pressure difference, hypertension,
69 diagnostic threshold, meta-regression

70 **Introduction**

71 Blood pressure is normally measured on the upper arm,[1] but occasionally this is not possible for a variety
72 of reasons that prevent placement of the cuff, for example, the presence of fractures, wounds, vascular
73 access devices, morbid obesity, surgical procedures, limb deformities and amputations. Additionally, blood
74 pressure measurement may be inaccurate in the presence of bilateral subclavian artery stenosis, such as
75 that which can occur with Takayasu's arteritis[2] or atherosclerosis.[3] In these circumstances,
76 measurement of blood pressure on the leg may be necessary but currently, there are no clinical guidelines
77 to guide measurement technique or interpretation.

78

79 A number of previous studies have compared blood pressure readings made in the leg to those in the upper
80 arm.[4-6] However, these studies have examined different populations using varying measurement
81 techniques, so it is unclear what standard blood pressure difference between upper and lower limbs should
82 be expected. It is also unclear how diagnostic and treatment thresholds should be adjusted when leg blood
83 pressure measurements are relied upon to guide treatment. One previous study has suggested that in the
84 absence of vascular disease, an elevated ankle systolic blood pressure of >175 mmHg should be considered
85 abnormal, based on the risk of cardiovascular disease (CVD).[7] However, it is not clear whether this is
86 equivalent to the 140 mmHg threshold used for brachial blood pressure.[1]

87

88 This study aimed to systematically review the literature and summarise existing evidence describing 1)
89 appropriate methods of leg blood pressure measurement and 2) the relationship between arm and leg
90 blood pressure, to provide recommendations on how leg measurements should be interpreted in routine
91 clinical practice.

92

93 **Methods**

94 *Design*

95 Systematic review aiming to capture all existing studies comparing arm and leg blood pressure
96 measurements in the same patients. Mean values for arm-leg blood pressure difference and measures of
97 precision (95% confidence intervals [CI], standard deviation [SD] or 95% limits of agreement) were
98 extracted and entered into a random-effects meta-analysis.

99

100 *Search strategy*

101 A scoping search was carried out to identify background literature and provide an estimate of the volume
102 of literature on the topic. The search strategy was originally designed in the MEDLINE database (for search
103 terms, see appendix) and was adapted to be run across the following databases: CINAHL (EBSCO), The
104 Cochrane (Wiley) CENTRAL Register of Controlled Trials, EMBASE (Ovid), MEDLINE In Process (Ovid), Science
105 Citation Index – Expanded & Conference Proceedings Citation Index – Science and the ZETOC (Mimas)
106 database.

107

108 No date limits were applied to the searches, although animal studies, letters, comments and review articles
109 were excluded. Furthermore, it was not possible to assess non-English language articles (due to resource
110 limitations). In addition to searches of electronic databases, reference lists of included studies were
111 checked to identify any further relevant papers. Searches were conducted in August 2016.

112

113 *Selection criteria*

114 All studies were screened by at least two reviewers (JS, AA, MF or BF) at each stage of screening.
115 Disagreements were resolved with a third reviewer. Articles were selected for data extraction based on the
116 following inclusion criteria:

- 117 - Measure arm blood pressure
- 118 - Measure leg blood pressure
- 119 - Estimate the difference between arm and leg blood pressure and provide a measure of precision
- 120 for this estimate (95% CIs, SD, 95% limits of agreement)
- 121 - Readings taken either simultaneously or sequentially within the same clinic visit
- 122 - Cross-sectional, cohort or randomised controlled trial study design
- 123 - Describe method of arm and leg blood pressure measurement in sufficient detail that it could be
- 124 repeated
- 125 - Include primary data

126

127 Studies were excluded from data extraction if they:

- 128 - Examined assessments made in a non-clinical or pharmacy setting
- 129 - Studied patients aged <18 years or who were pregnant

130

131 *Data collection*

132 Data were extracted by four reviewers (JS, AA, BF and LP) who all initially examined 10% of included articles
133 and resolved discrepancies prior to commencing data extraction in the rest of the studies. Data were
134 extracted using a pre-defined data extraction sheet (see online appendix). Data relating to the definition
135 and method of measurement of arm and leg blood pressure, along with mean values for each, mean
136 difference and an estimate of precision were extracted. In addition, any information about the setting and
137 sample population were recorded, including patient demographics, prescribed medication and history of
138 cardiovascular disease events or risk factors.

139

140 *Assessment of methodological quality*

141 As part of the data extraction, the methodological quality and risk of bias of individual studies was
142 assessed. This quality assessment covered domains of selection bias, detection bias, accuracy of
143 measurement, analysis and confounding using a combination of questions from the QUADAS-2[8] and
144 CASP[9] checklists for assessment of cohort studies. For sensitivity analyses, studies fulfilling the majority of
145 quality domains (≥ 4 domains) were deemed high quality. Those with unclear reporting or failing to fulfil the
146 majority of quality domains were deemed low or moderate quality.

147

148 *Outcome measures*

149 The primary outcome of this review was to compare the mean difference between blood pressure
150 measured in the arm and leg in the supine position. Leg blood pressure was defined by readings taken in
151 the ankle, calf or thigh and readings from each location were considered separately. Secondary outcomes
152 were to define this difference in population subgroups (patients with high cardiovascular disease risk or
153 history of vascular disease) and by method of measurement (sequential/simultaneous), arm blood pressure
154 level and age. Further, this review aimed to describe the different approaches to measuring leg blood
155 pressure and arm/leg blood pressure difference in order to inform future clinical guidance on this
156 procedure.

157

158 *Data synthesis*

159 Descriptive statistics were used to summarise included study characteristics. Blood pressure measurement
160 techniques were described qualitatively. The primary outcome was examined in a random-effects meta-
161 analysis of mean arm-leg blood pressure difference, considering comparisons with ankle, calf and thigh
162 readings separately. Where mean difference was not published, it was estimated from the mean and

163 standard deviation of values in the arm and leg. Analyses focused on measurements taken in the supine
164 position. Where the position of measurement was unclear, it was assumed that readings were taken in the
165 supine position and comparisons were included in the analysis. Heterogeneity was summarised using I-
166 squared statistics.

167

168 Data are presented according to measurement technique where feasible. Sub-group analyses were
169 conducted focusing on populations at high risk of cardiovascular disease, those with a history of vascular
170 disease and by measurement device to explore possible sources of heterogeneity. Meta-regression was
171 undertaken to examine the possible association between arm-ankle blood pressure difference and mean
172 arm blood pressure and age.

173

174 Sensitivity analyses were conducted using a fixed effects model to examine the assumption of random
175 effect in the primary analysis. Further sensitivity analyses explored:

- 176 1) the impact of study quality on the primary outcome (with moderate and low quality studies
177 excluded)
- 178 2) excluding studies which did not measure both systolic and diastolic blood pressure in the same
179 patients or those which did not use either auscultation or a validated upper arm device.
- 180 3) the difference in arm-ankle blood pressure as a percentage of the arm blood pressure (arm-ankle
181 blood pressure difference divided by arm blood pressure)

182

183 Screening was conducted using Covidence (Vertitas Health Innovation Ltd, Melbourne, Australia) and all
184 analyses were undertaken in STATA version 13.1 (MP parallel edition, StataCorp, Texas, USA). Data are
185 presented as proportions of the total study population, means with standard deviation or 95% confidence
186 intervals unless otherwise stated.

187

188 **Results**

189 *Description of included studies*

190 A total of 887 articles were screened after exclusion of duplicates (figure 1). Of the 340 full text articles
191 assessed for eligibility, 44 were included in the final descriptive analyses. Included studies examined a total
192 of 9,771 patients, just under half were female (46%) and the mean age ranged from 30 to 74 years (table 1).
193 Populations were heterogeneous with some including patients with a history of hypertension, diabetes,
194 chronic kidney disease and cardiovascular disease (table 1), conducted in a variety of settings (eTable 1,
195 online appendix).

196

197 The methodological quality of included studies was mixed (table 2). Most studies avoided inappropriate
198 exclusions and measured the outcome variables appropriately. However, the method of participant
199 selection was rarely described and it was difficult to judge whether the intended population had been
200 captured in the majority of studies.

201

202 There was no consistent method or standardised approach for measuring the arm-leg blood pressure
203 difference. Studies compared blood pressure measured over the brachial artery to readings taken on the
204 ankle, calf, foot or thigh, using a variety of measurement techniques and devices (eTable 3). These included
205 standard auscultatory and oscillometric sphygmomanometers, Doppler probes and mercury strain-gauge
206 plethysmography. Most studies (n=35/44) clearly stated that readings were taken with patients in the
207 supine position and simultaneous readings were more common than sequential readings (18 studies vs. 16
208 studies [10 studies did not state the order of readings]; eTables 2 and 3, online appendix).

209

210 *Primary outcome*

211 *Ankle-arm difference in a supine position*

212 In the general population, ankle systolic blood pressure was 17.0 mmHg (95% CI 15.4 to 21.3 mmHg) higher
213 than arm blood pressure, and this difference was consistent whether blood pressure was measured
214 simultaneously (18.3 mmHg, 95% CI 17.1 to 19.5 mmHg) or sequentially (16.1 mmHg, 95% CI 13.4 to 19.0
215 mmHg; figure 2). Overall heterogeneity was significant ($I^2=95.1\%$; $p<0.001$) and was not reduced in
216 subgroups examining simultaneous or sequential measurements. For diastolic blood pressure, there was no
217 difference between arm and ankle blood pressure (-0.3 mmHg, 95% CI -1.5 to 1.0 mmHg; figure 3). Once
218 again this was unaffected by whether readings were taken simultaneously (-1.2 mmHg, 95% CI -2.8 to 0.3
219 mmHg) or sequentially (1.9 mmHg, 95% CI -3.9 to 7.7 mmHg), and there was significant heterogeneity
220 across studies ($I^2=93.6\%$; $p<0.001$).

221

222 *Calf/thigh-arm differences in supine position*

223 Average calf systolic blood pressure was higher than arm blood pressure, but the mean difference was not
224 as large as arm-ankle differences (10.1 mmHg, 95% CI 4.5 to 15.6 mmHg; $I^2=94.8$; $p<0.001$; eFigure 1, online
225 appendix). There was no difference between arm and calf diastolic blood pressure (0.2 mmHg, 95% CI -1.5
226 to 1.8 mmHg; $I^2=99.1$; $p<0.001$). There were not enough studies in similar populations to provide pooled
227 estimates of the arm-thigh blood pressure difference.

228

229 *Secondary outcomes*

230 In patients with a history of cardiovascular disease, ankle systolic blood pressure was lower than arm blood
231 pressure (-33.3 mmHg, 95% CI -59.1 to -7.6 mmHg; figure 4), although there was significant variation
232 depending on the disease type ($I^2=99.1\%$; $p<0.001$). Focusing on patients with high risk of cardiovascular
233 disease did not affect the point estimates for arm-ankle systolic or diastolic blood pressure difference,
234 compared to the general population, or reduce the overall heterogeneity observed (eFigure 2, online
235 appendix). Sub-group analyses by measurement device used for ankle measurements did not reduce the
236 observed heterogeneity within groups (eFigure 3, online appendix). No association was observed between
237 arm-ankle blood pressure difference and mean arm blood pressure or age (figure 5).

238

239 *Sensitivity analyses*

240 Sensitivity analyses were undertaken examining arm-ankle blood pressure difference in the general
241 population assuming fixed effects and found similar findings to the primary analyses (eFigures 4 and 5,
242 online appendix). Exclusion of studies deemed to be of moderate or low quality had no impact on the point
243 estimates for arm-ankle blood pressure difference, but did reduce the observed heterogeneity between
244 studies making simultaneous comparisons, albeit remaining significant ($I^2=77.4\%$; $p=0.001$; eFigures 6 and
245 7). Exclusion of studies which did not measure both systolic and diastolic pressures in the same patients
246 had no impact on the main study findings (eFigure 8). Exclusion of studies which did not use auscultation or
247 a validated upper arm device did not affect the point estimates for arm-ankle blood pressure difference,
248 but it did reduce the observed heterogeneity ($I^2=38.4\%$; $p=0.150$ [systolic comparison] eFigure 9; $I^2=42.7\%$;
249 $p=0.175$ [diastolic comparison] eFigure 10). Examining the difference in arm-ankle blood pressure as a
250 percentage of the arm blood pressure gave similar findings to the primary analysis, with systolic blood
251 pressure in the ankle being 12.9% (95% CI 11.5% to 14.3%) higher than in the arm (eFigure 11).

252 **Discussion**

253 *Summary of findings*

254 This is the first systematic review to examine studies comparing blood pressure measured in the arm to
255 measurements taken in the leg and provides average differences to guide interpretation in routine clinical
256 practice. In a general population measured in a supine position, readings taken in the ankle were found to
257 be between 16-18 mmHg higher than those taken in the arm, and this was unaffected by whether
258 measurements were taken simultaneously or sequentially. These data suggest clinicians should consider
259 adding 15 mmHg to the systolic treatment threshold for hypertension (giving a threshold of 155/90mmhg)
260 when using ankle measurements rather than readings taken in the arm.

261

262 *Strengths and limitations*

263 This large systematic review followed a pre-specified protocol (see online appendix) and utilised a
264 comprehensive search of seven relevant databases to capture all potential studies examining the difference
265 between arm and leg blood pressure. Pre-defined inclusion/exclusion criteria were applied to each article
266 identified in the search and a total of 44 relevant articles were included in the final review. Unfortunately, it
267 was not possible to locate further potentially eligible articles, despite visiting the British Library to locate
268 them. Other articles had to be excluded because they were written in non-English language and there were
269 insufficient resources to translate them for screening. Despite this, the consistent direction and magnitude
270 of differences observed in a large number of included articles suggest that even if some of these papers had
271 provided relevant data, the overall findings of the study would have likely remained the same.

272

273 It was possible to pool data for meta-analysis in the present study, however there was significant
274 heterogeneity across studies so caution should be exercised when interpreting the results. Subgroup and
275 sensitivity analyses by cardiovascular disease history, cardiovascular disease risk, measurement
276 method/device and methodological quality did not sufficiently explain the observed variation, although
277 exclusion of studies not using auscultation or a validated upper arm device did reduce some the observed
278 heterogeneity, suggesting this may have been a contributing factor. Although age has previously been
279 shown to affect the magnitude of arm-ankle blood pressure difference,[5] meta-regression by age revealed
280 no such association in the present data. Other factors contributing towards the observed heterogeneity
281 might include the blood pressure device and model used, number of readings taken and the observer
282 making the measurement (e.g. doctor, nurse, researcher), all of which were likely to have varied across the
283 included studies.

284

285 Since this study examined only aggregate data, it was not possible to study arm-leg blood pressure
286 difference at different blood pressure levels for individual patients. However, meta-regression by mean arm
287 blood pressure, and sensitivity analyses of the arm-ankle difference as a percentage of the arm blood
288 pressure suggested no relationship exists. Whilst the aim of this study was to define the average arm-leg
289 blood pressure difference for occasions where measurement in the arm is not possible, we cannot rule out
290 the possibility that such a difference would be greater in the absence of limbs, due to the effects of
291 changing resistance and altered reflection points.

292

293 *Comparison with previous literature*

294 Whilst there are many previous studies which have measured arm and leg blood pressure in the same
295 patient, most focus on estimating ankle-brachial index for detection of underlying vascular disease.[10-14]
296 Few studies have set out to measure the arm-leg blood pressure difference in the general population to aid
297 interpretation of leg measurements in clinical practice. One study by Gong *et al.*, [5] showed in 948 patients

298 that blood pressure was 17.4 mmHg (95% CI 16.7 to 18.1 mmHg) higher when measured in the ankle than
299 when measured in the arm, findings which are consistent with the present review.

300

301 *Implications for clinical practice*

302 Current clinical guidelines pay little attention to measurement of blood pressure in the leg and there is no
303 guidance on the most appropriate method of measurement.[1] The present study found no agreed
304 measurement protocol for estimating leg blood pressure across studies. Generally, older studies used
305 Doppler probes and strain-gauge plethysmography techniques.[15-19] Newer studies using validated
306 oscillometric sphygmomanometers found similar arm-leg blood pressure differences to those using other
307 devices[4, 5, 10], although the statistical heterogeneity across studies was reduced. When measuring arm-
308 leg blood pressure differences, for example in the assessment of peripheral vascular disease, the present
309 data suggest similar differences can be observed using sequential versus simultaneous methods. This
310 approach is likely to be more clinically acceptable when assessing patients, particularly where resources
311 limit the use of blood pressure monitors capable of connecting to two cuffs. Previous studies suggest that
312 like the arms, an inter-ankle difference may be associated with an increased risk of mortality and so using
313 readings from the leg which provides the higher value may be important.[20]

314

315 The present study found the mean difference between leg and arm blood pressure when measured in a
316 supine position to be 17/0 mmHg (ankle) and 10/0 mmHg (calf). Using the traditional 140/90 mmHg
317 threshold for hypertension,[21] these differences translate into a diagnostic threshold of 155/90 mmHg for
318 ankle blood pressure and 150/90 mmHg for calf blood pressure. This is in contrast to the 175 mmHg
319 threshold previously suggested by Hietanen *et al.*,[7] which was based on risk of subsequent cardiovascular
320 morbidity and mortality. Since there are no trials of treatment based on leg blood pressure, it is logical to
321 use thresholds which are equivalent to those used for the arm readings, which are underpinned by a large
322 body of evidence.[22] The slightly more conservative difference of 15 mmHg recommended here would
323 ensure maximum sensitivity albeit with reduced specificity for true hypertension. The lack of difference in
324 diastolic arm-leg blood pressure appears to support the concept of pressure amplification: systolic pressure
325 increases with greater distance toward the periphery, but there is little change in diastolic pressure. This
326 may suggest caution is warranted in using oscillometric monitors optimised for analysing brachial pressure
327 as the relationship between mean and systolic pressure may differ in the lower limb.

328

329 It should be noted that all blood pressure readings examined in this study were taken in the supine
330 position, whereas in previous blood pressure lowering trials (which have established diagnostic thresholds),
331 readings are usually taken in the sitting position.[22] It is unclear what impact this would have on the
332 proposed thresholds, since some studies suggest arm blood pressures measured in the sitting position are
333 higher than readings taken in the supine position,[23, 24] whereas others suggest no difference[24] or
334 higher readings in the supine position.[25, 26] Our sensitivity analyses suggest that blood pressure
335 measured in the ankle (in the supine position) was, on average, 12.9% higher than that in the arm (in the
336 supine position); this would equate to an equivalent diagnostic threshold based on sitting readings of
337 158/90 mmHg, assuming the relative differences are the same in both positions. Given this debate, we
338 recommend that physicians use the proposed threshold with caution, particularly when initiating new
339 treatment in patients who are found to be close to the diagnostic threshold. In addition, given that ankle
340 and calf blood pressures are likely to be significantly lower in patients with vascular occlusive diseases, it
341 may be advisable that further investigation is considered in patients with apparently low ankle systolic
342 blood pressure readings, despite the presence of cardiovascular risk factors such as diabetes, renal disease
343 or cardiovascular disease.

344 For the assessment of leg blood pressure alone (when no arm blood pressure measurement is possible) the
345 results from this review suggest that ankle blood pressure measured in a supine position using the dorsalis
346 pedis artery may be the most clinically appropriate leg measurement given the paucity of data in the
347 arm/calf and arm/thigh comparisons. In addition, ankle measurements are less likely to cause discomfort
348 than calf or thigh measurements and the cuff will be easier to fit, particularly in obese patients. Data from
349 the primary studies included in this review did not consistently report the number of repeat readings taken
350 in the ankle, with only 11/30 studies reporting this information at all (eTable 3). The vast majority of studies
351 comparing arm-ankle blood pressure took measurements in the ankle with the patient in the supine
352 position, with a 5-10 minute rest period prior to measurement.

353
354 Given the lack of detailed reporting on leg blood pressure measurement methods, it is not possible to make
355 further specific recommendations regarding measurement protocols. No oscillometric BP monitors have
356 specifically been validated for leg measurements and the use of ambulatory readings for diagnosis will not
357 be possible in patients who need to have leg blood pressure measurements. The use of auscultation may
358 present practical difficulties with placement of the stethoscope and use of Doppler “return to flow” will
359 only give a systolic reading. Further work should aim to determine the optimal leg blood pressure
360 measurement protocol to aid the clinical utility of this paper’s findings.

361
362 *Conclusions*

363 This review is the first to provide empirical data for defining the difference between blood pressure in the
364 arm with blood pressure measured in the ankle or calf. It suggests that in the general population, clinicians
365 should expect systolic readings which are at least 15 mmHg higher than those taken in the arm in the
366 supine position. A diagnostic threshold of 155/90 mmHg could therefore be used for diagnosing
367 hypertension when relying on ankle measurements alone.

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372 References

- 373 1. Whelton PK, Carey RM, Aronow WS, Casey DE, Jr., Collins KJ, Dennison Himmelfarb C *et al*: 2017
374 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection,
375 Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of
376 Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Journal of the American*
377 *College of Cardiology* 2017.
- 378 2. Hafner F, Froehlich H, Gary T, Tiesenhausen K, Scarpattetti M, Brodmann M: Blood pressure
379 measurements in patients with Takayasu arteritis: a work of caution. *The Annals of thoracic surgery* 2012,
380 **93**(4):1299-1301.
- 381 3. Aboyans V, Kamineni A, Allison MA, McDermott MM, Crouse JR, Ni H *et al*: The epidemiology of
382 subclavian stenosis and its association with markers of subclinical atherosclerosis: the Multi-Ethnic Study of
383 Atherosclerosis (MESA). *Atherosclerosis* 2010, **211**(1):266-270.
- 384 4. Cao K, Xu J, Sun H, Li P, Li J, Cheng X *et al*: The variability of ankle-arm blood pressure difference
385 and ankle-brachial index in treated hypertensive patients. *Journal of the American Society of Hypertension* :
386 *JASH* 2014, **8**(10):693-698.
- 387 5. Gong Y, Cao KW, Xu JS, Li JX, Hong K, Cheng XS *et al*: Valuation of Normal Range of Ankle Systolic
388 Blood Pressure in Subjects with Normal Arm Systolic Blood Pressure. *PloS one* 2015, **10**(6):e0122248.
- 389 6. Moore C, Dobson A, Kinagi M, Dillon B: Comparison of blood pressure measured at the arm, ankle
390 and calf. *Anaesthesia* 2008, **63**(12):1327-1331.
- 391 7. Hietanen HJ, Paakkonen R, Salomaa V: Ankle blood pressure and pulse pressure as predictors of
392 cerebrovascular morbidity and mortality in a prospective follow-up study. *Stroke research and treatment*
393 2011, **2010**:729391.
- 394 8. Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB *et al*: QUADAS-2: a revised
395 tool for the quality assessment of diagnostic accuracy studies. *Annals of internal medicine* 2011,
396 **155**(8):529-536.
- 397 9. Critical Appraisal Skills Programme (CASP): Cohort Study Checklist. In. <http://www.casp-uk.net/>:
398 CASP UK; 2013.
- 399 10. Freitas D, Toneti AN, Cesarino EJ, Desiderio VL, Pacca SdF, Godoy Sd *et al*: Cardiovascular risk in
400 white coat hypertension: an evaluation of the ankle brachial index. *Journal of Vascular Nursing* 2014,
401 **32**(2):38-45.
- 402 11. Gardner AW, Montgomery PS: Comparison of three blood pressure methods used for determining
403 ankle/brachial index in patients with intermittent claudication. *Angiology* 1998, **49**(9):723-728.
- 404 12. Maldonado J, Pereira T, Resende M, Simoes D, Carvalho M: Usefulness of the ankle-brachial index
405 in assessing vascular function in normal individuals. *Revista Portuguesa de Cardiologia* 2008, **27**(4):465-476.
- 406 13. Martins D, Pimenta G, Constantino L, Santos T, Rosendo I, Matias C *et al*: Ankle-brachial index
407 according to pulse pressure and microalbuminuria in hypertensive patients: a prospective study in family
408 medicine. *Revista Portuguesa de Cardiologia* 2010, **29**(5):751-764.
- 409 14. Weatherley BD, Chambless LE, Heiss G, Catellier DJ, Ellison CR: The reliability of the ankle-brachial
410 index in the Atherosclerosis Risk in Communities (ARIC) study and the NHLBI Family Heart Study (FHS). *BMC*
411 *Cardiovascular Disorders* 2006, **6**:7.

- 412 15. Bell G, Nielsen PE, Lassen NA, Wolfson B: Indirect measurement of systolic blood pressure in the
413 lower limb using a mercury in rubber strain gauge. *Cardiovascular Research* 1973, **7**(2):282-289.
- 414 16. Engvall J, Nylander E, Wranne B: Arm and ankle blood pressure response to treadmill exercise in
415 normal people. *Clinical Physiology* 1989, **9**(6):517-524.
- 416 17. Engvall J, Sonnhag C, Nylander E, Stenport G, Karlsson E, Wranne B: Arm-ankle systolic blood
417 pressure difference at rest and after exercise in the assessment of aortic coarctation. *British Heart Journal*
418 1995, **73**(3):270-276.
- 419 18. Lee BY, Campbell JS, Berkowitz P: The correlation of ankle oscillometric blood pressures and
420 segmental pulse volumes to Doppler systolic pressures in arterial occlusive disease. *Journal of Vascular*
421 *Surgery* 1996, **23**(1):116-122.
- 422 19. Siggaard-Andersen J, Ulrich J, Engell HC, Petersen FB: Blood pressure measurements of the lower
423 limb. Arterial occlusions in the calf determined by plethysmographic blood pressure measurements in the
424 thigh and at the ankle. *Angiology* 1972, **23**(6):350-357.
- 425 20. Sheng C-S, Liu M, Zeng W-F, Huang Q-F, Li Y, Wang J-G: Four-limb blood pressure as predictors of
426 mortality in elderly Chinese. *Hypertension* 2013, **61**(6):1155-1160.
- 427 21. National Clinical Guideline Centre: Hypertension: clinical management of primary hypertension in
428 adults; Clinical guideline 127. In. London: Royal College of Physicians (UK); 2011.
- 429 22. Ettehad D, Emdin CA, Kiran A, Anderson SG, Callender T, Emberson J *et al*: Blood pressure lowering
430 for prevention of cardiovascular disease and death: a systematic review and meta-analysis. *Lancet* 2016,
431 **387**(10022):957-967.
- 432 23. Lacruz ME, Kluttig A, Kuss O, Tiller D, Medenwald D, Nuding S *et al*: Short-term blood pressure
433 variability - variation between arm side, body position and successive measurements: a population-based
434 cohort study. *BMC Cardiovasc Disord* 2017, **17**(1):31.
- 435 24. Netea RT, Smits P, Lenders JW, Thien T: Does it matter whether blood pressure measurements are
436 taken with subjects sitting or supine? *J Hypertens* 1998, **16**(3):263-268.
- 437 25. Wei TM, Lu LC, Ye XL, Li S, Wang LX: Difference in blood pressure between supine and sitting
438 positions in diabetic and non-diabetic subjects. *Medical science monitor : international medical journal of*
439 *experimental and clinical research* 2009, **15**(3):Cr123-127.
- 440 26. Netea RT, Lenders JW, Smits P, Thien T: Both body and arm position significantly influence blood
441 pressure measurement. *J Hum Hypertens* 2003, **17**(7):459-462.
- 442 27. Allison RD, Barnes RN, Hayward RH: Diagnostic aids in the management of the vascular patient.
443 *Angiology* 1973, **24**(2):94-106.
- 444 28. Arveschoug AK, Vammen B, Yoshinaka E, Sorensen D, Jodal L, Brochner-Mortensen J: Reference
445 data for distal blood pressure in healthy elderly and middle-aged individuals measured with the strain
446 gauge technique. Part I: resting distal blood pressure. *Scandinavian Journal of Clinical & Laboratory*
447 *Investigation* 2008, **68**(3):249-253.
- 448 29. Atsma F, Bartelink M-LEL, Grobbee DE, van der Schouw YT: Best reproducibility of the ankle-arm
449 index was calculated using Doppler and dividing highest ankle pressure by highest arm pressure. *Journal of*
450 *Clinical Epidemiology* 2005, **58**(12):1282-1288.

- 451 30. Banner TE, Gravenstein JS: Comparative effects of cuff size and tightness of fit on accuracy of blood
452 pressure measurements. *Journal of Clinical Monitoring* 1991, **7**(4):281-284.
- 453 31. Barani J, Nilsson JA, Mattiasson I, Lindblad B, Gottsater A: Inflammatory mediators are associated
454 with 1-year mortality in critical limb ischemia. *Journal of Vascular Surgery* 2005, **42**(1):75-80.
- 455 32. Bollinger A, Barras JP, Mahler F: Measurement of foot artery blood pressure by micromanometry in
456 normal subjects and in patients with arterial occlusive disease. *Circulation* 1976, **53**(3):506-512.
- 457 33. Gemignani T, Azevedo RC, Higa CM, Coelho OR, Matos-Souza JR, Nadruz W, Jr.: Increased popliteal
458 circumferential wall tension induced by orthostatic body posture is associated with local atherosclerotic
459 plaques. *Atherosclerosis* 2012, **224**(1):118-122.
- 460 34. Gemignani T, Matos-Souza JR, Franchini KG, Nadruz W, Jr.: Leg blood pressure measured in
461 orthostatic posture is associated with left ventricular mass in normotensive subjects. *American Journal of*
462 *Hypertension* 2012, **25**(10):1083-1087.
- 463 35. Goldstein LN, Wells M, Sliwa K: Blood pressure measurements in the ankle are not equivalent to
464 blood pressure measurements in the arm. *South African Medical Journal* 2014, **104**(12):869-873.
- 465 36. Goldthorp SL, Cameron A, Asbury AJ: Dinamap arm and thigh arterial pressure measurement.
466 *Anaesthesia* 1986, **41**(10):1032-1035.
- 467 37. Grenon SM, Mateus J, Hsiang Y, Sidhu R, Young L, Gagnon J: Use of Short-Radius Centrifugation to
468 Augment Ankle-Brachial Indices. *Journal of Investigative Medicine* 2009, **57**(5):640-644.
- 469 38. Instebo A, Norgard G, Helgheim V, Roksund OD, Segadal L, Greve G: Exercise capacity in young
470 adults with hypertension and systolic blood pressure difference between right arm and leg after repair of
471 coarctation of the aorta. *European Journal of Applied Physiology* 2004, **93**(1-2):116-123.
- 472 39. Koay CK, Chin MK: Indirect ankle, brachial and direct intra-arterial blood pressure measurements.
473 *Singapore Medical Journal* 1985, **26**(3):283-288.
- 474 40. Lee JH, Kim J-M, Ahn KR, Kim CS, Kang KS, Chung JH *et al*: Study for the discrepancy of arterial blood
475 pressure in accordance with method, age, body part of measurement during general anesthesia using
476 sevoflurane. *Korean Journal of Anesthesiology* 2011, **60**(5):323-328.
- 477 41. Malhotra A, Cohen D, Syms C, Townsend RR: Blood pressure changes in the leg on standing. *Journal*
478 *of Clinical Hypertension* 2002, **4**(5):350-354.
- 479 42. Oguanobi NI, Onwubere BJC, Ibegbulam OG, Ike SO, Ejim EC, Agwu O: An evaluation of ankle-
480 brachial blood pressure index in adult Nigerians with sickle cell anaemia. *Cardiovascular Journal of Africa*
481 2012, **23**(1):37-39.
- 482 43. Okada H, Fukui M, Tanaka M, Matsumoto S, Mineoka Y, Nakanishi N *et al*: A difference in systolic
483 blood pressure between arms and between lower limbs is a novel risk marker for diabetic nephropathy in
484 patients with type 2 diabetes. *Hypertension Research - Clinical & Experimental* 2013, **36**(5):403-407.
- 485 44. Pan C-R, Staessen JA, Li Y, Wang J-G: Comparison of three measures of the ankle-brachial blood
486 pressure index in a general population. *Hypertension Research - Clinical & Experimental* 2007, **30**(6):555-
487 561.
- 488 45. Quong WL, Fung ATH, Yu RY, Hsiang YNH: Reassessing the normal toe-brachial index in young
489 healthy adults. *Journal of Vascular Surgery* 2016, **63**(3):652-656.

- 490 46. Rahiala E, Tikanoja T: Suspicion of aortic coarctation in an outpatient clinic: how should blood
491 pressure measurements be performed? In: *Clinical physiology (Oxford, England)*. vol. 21; 2001: 100-104.
- 492 47. Richart T, Kuznetsova T, Wizner B, Struijker-Boudier HA, Staessen JA: Validation of automated
493 oscillometric versus manual measurement of the ankle-brachial index. *Hypertension Research* 2009,
494 **32**(10):884-888.
- 495 48. Sahli D, Eliasson B, Svensson M, Blohme G, Eliasson M, Samuelsson P *et al*: Assessment of toe blood
496 pressure is an effective screening method to identify diabetes patients with lower extremity arterial
497 disease. *Angiology* 2004, **55**(6):641-651.
- 498 49. Sareen P, Saxena K, Sareen B, Taneja B: Comparison of arm and calf blood pressure. *Indian Journal*
499 *of Anaesthesia* 2012, **56**(1):83-85.
- 500 50. Su YJ, Lai YC, Chen CC, Tang LM, Chang WH, Chang KS: Inter-arm and inter-leg systolic blood
501 pressure differences in aortic dissection. *International Journal of Gerontology* 2007, **1**(4):153-156.
- 502 51. Swan L, Goyal S, Hsia C, Hechter S, Webb G, Gatzoulis MA: Exercise systolic blood pressures are of
503 questionable value in the assessment of the adult with a previous coarctation repair. *Heart* 2003,
504 **89**(2):189-192.
- 505 52. Thulesius O: Systemic and ankle blood pressure before and after exercise in patients with arterial
506 insufficiency. *Angiology* 1978, **29**(5):374-378.
- 507 53. Vriend JWJ, Zwinderman AH, de Groot E, Kastelein JJP, Bouma BJ, Mulder BJM: Predictive value of
508 mild, residual descending aortic narrowing for blood pressure and vascular damage in patients after repair
509 of aortic coarctation. *European Heart Journal* 2005, **26**(1):84-90.
- 510 54. Wilkes JM, DiPalma JA: Brachial blood pressure monitoring versus ankle monitoring during
511 colonoscopy. *Southern Medical Journal* 2004, **97**(10):939-941.
- 512 55. Williamson OK: Comparative Systolic Blood-Pressure Readings in the Arm and Leg in Aortic
513 Incompetence. *British Medical Journal* 1921, **1**(3151):734-736.
- 514 56. Yeragani VK, Kumar R, Bar KJ, Chokka P, Tancer M: Exaggerated differences in pulse wave velocity
515 between left and right sides among patients with anxiety disorders and cardiovascular disease.
516 *Psychosomatic Medicine* 2007, **69**(8):717-722.
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Tables

Table 1. Participant characteristics in included studies

Author/Year (sub-population)	Total pop. (n)	Gender (n, % female)	Age (years, mean ± sd)	Hypertensive (n, %)	Anihypertensive medication (n, %)	History of CVD (n, %)	Diabetes (n, %)	CKD (n, %)	BMI (kg/m ² , mean ± sd)	ABI (mean)
Allison 1973 (SVD)[27]	78	-	55 ± 14	-	-	-	-	-	-	0.81
Allison 1973 (VOD)[27]	22	-	54 ± 19	-	-	22 (100%)	-	-	-	0.73
Arveschoug 2008 (Middle aged patients)[28]	14	12 (86%)	51	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-	-	1.22
Arveschoug 2008 (Elderly patients)[28]	31	25 (81%)	71	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-	-	1.17
Atsma 2005[29]	320	320 (100%)	66 ± 6	110 (34%)	-	3 (1%)	23 (7%)	-	-	-
Banner 1991[30]	6	-	-	-	-	-	-	-	-	1.21
Barani 2005[31]	198	99 (50%)	74 ± 10	-	-	198 (100)	100 (51%)	-	25.1 ± 4.7	0.30
Bell 1973[15]	30	0 (0%)	(13-55)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-	-
Bollinger 1976 (AOD - Intra-arterial readings)[32]	13	3 (23%)	58 ± 15	-	-	-	-	-	-	0.67
Bollinger 1976 (AOD - Indirect readings)[32]	11	3 (27%)	60 ± 14	-	-	-	-	-	-	0.67
Bollinger 1976 (Healthy - Intra-arterial readings)[32]	13	0 (0%)	39 ± 11	-	-	-	-	-	-	1.15
Bollinger 1976 (Healthy - Indirect readings) [32]	3	0 (0%)	27 ± 4	-	-	-	-	-	-	1.15
Cao 2014[4]	414	214 (52%)	61 ± 13	414 (100%)	414 (100%)	-	-	-	-	1.11
Engvall 1989[16]	19	9 (47%)	34	0 (0%)	-	0 (0%)	-	-	-	1.18
Engvall 1995[17]	22	9 (41%)	33	22 (100%)	-	-	-	-	-	-
Freitas 2014 (Normotensives)[10]	50	47 (94%)	41 ± 2	0 (0%)	-	-	0 (0%)	-	28.1 ± 0.76	1.15
Freitas 2014 (Hypertensives)[10]	50	37 (74%)	58 ± 2	50 (100%)	-	-	0 (0%)	-	31.7 ± 1.1	1.12
Freitas 2014 (White coat hypertensives)[10]	35	30 (86%)	54 ± 3	35 (100%)	-	-	0 (0%)	-	30.6 ± 1.2	1.13
Gardner 1998[11]	50	3 (6%)	69 ± 7	29 (58%)	-	50 (100%)	11 (22%)	-	27.6 ± 4.3	0.67
Gemignani 2012a[33]	197	117 (59%)	52 ± 1	75 (38%)	-	-	28 (14%)	-	26.4 ± 0.3	-
Gemignani 2012b[34]	130	77 (59%)	34 ± 1	-	0 (0%)	-	-	-	24.8 ± 0.4	-
Goldstein 2014[35]	201	63 (31%)	34	-	-	0 (0%)	0 (0%)	-	25.6	1.11
Goldthorp 1986[36]	30	-	(23-76)	-	-	-	-	-	-	-
Gong 2015[5]	948	-	48 ± 19	0 (0%)	-	0 (0%)	0 (0%)	-	22.9 ± 3.5	1.15
Grenon 2009[37]	12	4 (33%)	26 ± 1	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	22.3	1.17
Instebo 2004 (Arm-leg difference <1 mmHg)[38]	13	6 (46%)	26 ± 7	0 (0%)	-	-	-	-	22.4	-
Instebo 2004 (Arm-leg difference 1-20 mmHg)[38]	12	5 (42%)	24 ± 9	12 (100%)	-	-	-	-	22.9	-
Instebo 2004 (Arm-leg difference >20 mmHg)[38]	16	5 (31%)	24 ± 7	16 (100%)	-	-	-	-	24	-
Koay 1985[39]	15	5 (33%)	45	-	-	-	-	-	-	1.11
Lee 1996[18]	110	1 (1%)	69	-	-	30 (27%)	53 (48%)	-	-	0.92
Lee 2011[40]	60	25 (42%)	43 (20-78)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-	-	1.14
Maldonado 2008[12]	224	0 (0%)	17.1 ± 5.6	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	22.3 ± 13.8	1.18
Malhotra 2002[41]	41	18 (44%)	52 ± 14	19 (46%)	-	-	-	-	25.1	1.72
Martins 2010[13]	75	36 (48%)	60 ± 10.2	75 (100%)	>50 (>50%)	-	20 (27%)	0 (0%)	29.8 ± 4.9	1.20
Moore 2008[6]	100	65 (65%)	(20 – 64)	0 (0%)	0 (0%)	0 (0%)	-	-	-	-
Oguanobi 2012 (Sickle cell anaemia patients)[42]	62	31 (50%)	28.3 ± 5.6	-	-	-	-	-	20.5 ± 2.7	0.88
Oguanobi 2012 (Healthy controls)[42]	62	31 (50%)	28.4 ± 5.9	-	-	-	-	-	23.9 ± 3.2	1.03

Okada 2013[43]	314	121 (39%)	66.2 ± 8.5	-	183 (58%)	-	314 (100%)	-	23.6 ± 3.7	1.11
Pan 2007[44]	946	481 (51%)	44.9	274 (29%)	61 (6.5%)	-	-	-	22.1	-
Quong 2016[45]	73	31 (42%)	24.3 ± 2.0	-	-	-	-	-	21.9	1.09
Rahiala 2001[46]	20	20 (100%)	18.8 ± 0.9	-	-	-	-	-	-	1.10
Richart 2009[47]	105	55 (52%)	56.5	26 (25%)	-	-	-	-	26.2	1.13
Sahli 2004[48]	437	199 (46%)	54	87 (20%)	-	-	300 (69%)	-	25.5	-
Sareen 2012[49]	250	-	-	-	-	-	-	-	-	-
Sheng 2013[20]	3,133	1,750 (56%)	69	-	1,215 (39%)	-	285 (9%)	-	23.6	-
Siggaard-Andersen 1972[19]	34	4 (12%)	55	-	-	-	-	-	-	-
Su 2007[50]	38	8 (21%)	58.7 ± 14	27 (71%)	-	-	-	-	-	-
Swan 2003 (Coarctation patients)[51]	45	17 (38%)	29.8 ± 11.0	8 (18%)	8 (18)	45 (100%)	-	-	30.3 ± 14.8	-
Swan 2003 (Controls)[51]	33	13 (39%)	30.6	0 (0%)	0 (0%)	0 (0%)	-	-	31.6 ± 12.6	-
Thulesius 1978 (Controls)[52]	18	-	52	0 (0%)	0 (0%)	0 (0%)	0 (0%)	-	-	-
Thulesius 1978 (Patients with minor PAI)[52]	14	-	60	-	-	14 (100%)	-	-	-	-
Thulesius 1978 (Patients with severe PAI)[52]	58	-	60	-	-	14 (100%)	-	-	-	-
Vriend 2005[53]	73	30 (41%)	29.8	33 (45%)	9 (12%)	33 (45%)	-	-	23.4 ± 3.3	-
Weatherley 2006[14]	119	70 (59%)	55.0 ± 5.7	43 (36)	-	-	13 (11%)	-	27.0 ± 4.78	-
Wilkes 2004[54]	45	23 (51%)	55	0 (0%)	0 (0%)	-	-	-	27.3	1.18
Williamson 1921[55]	15	1 (7%)	43.0 ± 10.6	-	-	15 (100%)	-	-	-	-
Yeragani 2007 (Controls)[56]	22	7 (32%)	47 ± 15	0 (0%)	0 (0%)	0 (0%)	-	-	24	1.06
Yeragani 2007 (Participants with anxiety)[56]	26	7 (27%)	44 ± 13	0 (0%)	0 (0%)	0 (0%)	-	-	26	1.07
Yeragani 2007 (Patients with CVD)[56]	72	19 (26%)	59 ± 13	21 (29%)	7 (10%)	72 (100%)	-	-	27	1.07

CVD=cardiovascular disease; CKD=chronic kidney disease; BMI=body mass index; ABI=Ankle-brachial index; SVD=small vessel disease; VOD=vascular occlusive disease; AOD=arterial occlusive disease; PAI=peripheral arterial insufficiency

Table 2. Methodological quality of included studies

Author	Patient selection			Outcome measurement	Analysis	Confounding	Overall quality rating*
	Was selection of patients appropriate?	Did the study avoid inappropriate exclusions?	Was the study sample representative of the intended population?	Is the outcome variable measured appropriately?	Was the arm-leg BP difference the primary focus of the study?	Were all important confounding factors identified?	
Allison 1973[27]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Arveschoug 2008[28]	Unclear	Yes	Yes	Yes	Yes	Yes	High
Atsma 2005[29]	Unclear	Yes	Unclear	Yes	Yes	Yes	High
Banner 1991[30]	Unclear	Unclear	Unclear	Yes	No	Unclear	Low
Barani 2005[31]	Yes	Yes	Yes	Unclear	No	Yes	High
Bell 1973[15]	Unclear	No	No	Yes	Yes	Unclear	Low
Bollinger 1976[32]	Unclear	Yes	Unclear	Yes	No	Yes	Moderate
Cao 2014[4]	Yes	No	Yes	Yes	Yes	Unclear	High
Engvall 1989[16]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Engvall 1995[17]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Freitas 2014[10]	No	Yes	Unclear	Yes	No	Yes	Moderate
Gardner 1998[11]	Unclear	Yes	Unclear	Yes	No	Yes	Moderate
Gemignani 2012a[33]	Unclear	Yes	Unclear	Yes	No	Yes	Moderate
Gemignani 2012b[34]	Unclear	Yes	Unclear	Yes	Yes	Yes	High
Goldstein 2014[35]	Unclear	Yes	Unclear	Yes	Yes	Yes	High
Goldthorp 1986[36]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Gong 2015[5]	Unclear	Yes	Unclear	Yes	Yes	Unclear	Moderate
Grenon 2009[37]	Unclear	Yes	Unclear	Yes	Yes	Yes	High
Instebo 2004[38]	Unclear	Yes	Unclear	Yes	No	No	Low
Koay 1985[39]	Yes	Yes	Unclear	Yes	Yes	Yes	High
Lee 1996[18]	Yes	Unclear	Yes	Yes	No	Unclear	Moderate
Lee 2011[40]	Unclear	Yes	Unclear	Yes	No	Yes	Moderate
Maldonado 2008[12]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Malhotra 2002[41]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Martins 2010[13]	Yes	Yes	Yes	Yes	No	Yes	High
Moore 2008[6]	Unclear	Yes	Unclear	Yes	Yes	Yes	High
Oguanobi 2012[42]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Okada 2013[43]	Yes	Yes	Unclear	Yes	Yes	Unclear	High
Pan 2007[44]	Yes	Yes	Unclear	Yes	Yes	Unclear	High
Quong 2016[45]	Unclear	Yes	Unclear	Yes	Yes	Unclear	Moderate
Rahiala 2001[46]	Unclear	unclear	Unclear	Yes	Yes	Unclear	Low
Richart 2009[47]	Yes	Unclear	Unclear	Yes	Yes	Unclear	Moderate

Sahli 2004[48]	Unclear	Yes	Unclear	Yes	Yes	Yes	High
Sareen 2012[49]	Unclear	Yes	Unclear	Yes	Yes	Yes	High
Sheng 2013[20]	Yes	Yes	Unclear	Yes	Yes	Yes	High
Siggaard-Andersen 1972[19]	Unclear	Unclear	Unclear	Yes	Yes	Unclear	Low
Su 2007[50]	Yes	Yes	Unclear	Unclear	Yes	Yes	High
Swan 2003[51]	Yes	Yes	No	Unclear	Yes	Unclear	Moderate
Thulesius 1978[52]	Unclear	Unclear	Unclear	Unclear	Yes	No	Low
Vriend 2005[53]	Yes	Unclear	Yes	Unclear	Yes	Yes	High
Weatherley 2006[14]	No	Unclear	Yes	Yes	Yes	Unclear	Moderate
Wilkes 2004[54]	Yes	No	No	Yes	Yes	Yes	High
Williamson 1921[55]	Unclear	Unclear	Unclear	Unclear	Yes	Unclear	Low
Yeragani 2007[56]	Yes	Yes	Unclear	Unclear	No	Yes	Moderate

*High quality = 4 or more quality domains present; Moderate = 3 quality domains present; low=2 or less quality domains present

Figure legends

Figure 1. Selection of studies

BP=blood pressure; SD=standard deviation; CI=confidence intervals; RCT=randomised controlled trial

Figure 2. Arm-ankle systolic blood pressure difference in the general population (n=24 studies)

Mean sBP difference given in mmHg. sBP=systolic blood pressure; CI=confidence intervals; ED=emergency department; CVD=cardiovascular disease; BP=blood pressure.

Figure 3. Arm-ankle diastolic blood pressure difference in the general population (n=16 studies)

Mean dBP difference given in mmHg. dBP=diastolic blood pressure; CI=confidence intervals; ED=emergency department; CVD=cardiovascular disease; BP=blood pressure.

Figure 4. Arm-ankle blood pressure difference in patients with a history of cardiovascular disease (n=7 studies)

Mean BP difference given in mmHg. BP=blood pressure; CI=confidence intervals

Figure 5. Meta-regression of arm-ankle blood pressure difference in the general population by mean arm blood pressure and age

BP=blood pressure; Moore et al., (2008) excluded due to lack of data on mean arm blood pressure and age; Banner et al., (1991) excluded due to lack of data on age.