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- 6 Pediatric Eye Disease Investigator Group. Treatment of anisometropic amblyopia in children with refractive correction. Ophthalmology 2006;113:895-903.
- 7 Moseley MJ, Neufield M, McCarry B, Charnock A, McNamara R, Rice T. Remediation of refractive amblyopia by optical correction alone. Ophthalmic Physiol Opt 2002;22:296-9.
- 8 Stewart CE, Moseley MJ, Stephens DA, Fielder AR, on behalf of the MOTAS cooperative. Refractive adaptation in amblyopia: quantification of effect and implications for practice. *Br J Ophthalmol* 2004;88:1552-6.
- 9 Stewart CE, Moseley MJ, Fielder AR. Defining and measuring treatment outcome for unilateral amblyopia Br J Ophthalmol 2003;87:1229-31.
- 10 Fielder AR, Irwin M, Auld R, Cocker KD, Jones HS, Moseley MJ. Compliance monitoring in amblyopia therapy: objective monitoring of occlusion. *Br J Ophthalmol* 1995;79:585-9.
- 11 Stewart CE, Fielder AR, Stephens DA, Moseley MJ. Design of the monitored occlusion treatment of amblyopia study (MOTAS). Br J Ophthalmol 2002;86:915-9.
- 12 Stewart CE, Stephens DA, Fielder AR, Moseley MJ, MOT AS Cooperative. Modelling dose-response in amblyopia: toward a child-specific treatment plan. *Invest Ophthalmol Vis Sci* 2007;48:2589-94.
- 13 Hrisos S, Clarke MP, Wright CM. The emotional impact of amblyopia treatment in preschool children. Ophthalmology 2004;111:1550-6.
- 14 Searle A, Norman P, Harrad R, Vedhara K. Psychosocial and clinical determinants of compliance with occlusion therapy for amblyopic children. *Eye* 2002;16:150-5.

- 15 Kushner BJ. Patching regimens for amblyopia. *Ophthalmology* 2004;112:736.
- 16 Newsham D. A randomised controlled trial of written information: the effect on parental non-compliance with occlusion therapy. Br J Ophthalmol 1997;86:787-91.
- 17 Massie H. Fixing eye for occlusion: survey of 1,000 cases of patients receiving occlusion of the fixing eye. *Trans Ophthalmol Soc Aust* 1965;24:39-46.
- 18 Hiscox FN, Strong N, Thompson JR, Minshull C, Woodruff G. Occlusion for amblyopia: a comprehensive survey of outcome. *Eye* 1992;6:300-4.
- 19 Lea HSJ, Rubenstein JLMP. The sensitive period for anisometropic amblyopia. *Eye* 1989;3:783-90.
- 20 Kutschke PJ, Scott WE, Keech RV. Anisometropic amblyopia. Ophthalmology 1991;98:259-63.
- 21 Cobb CJ, Russell K, Cox A, MacEwan CJ. Factors influencing visual outcome in anisometropic amblyopes. *Br J Ophthalmol* 2002;86:1278-81.
- 22 Flynn JT, Woodruff G, Thompson JR, Hiscox F, Fever W, Shiftman J. The therapy of amblyopia: an analysis comparing the results of amblyopia therapy utilizing two pooled sets. *Trans Am Ophthalmol Soc* 1999;97:373-90.
- 23 Fulton AB, Mayer DL. Esotropic children with amblyopia: effects of patching on acuity. *Graefes Arch Clin Exp Ophthalmol* 1988;226:309-12.

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Accuracy of electrocardiography in diagnosis of left ventricular hypertrophy in arterial hypertension: systematic review

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ABSTRACT

Objective To review the accuracy of electrocardiography in screening for left ventricular hypertrophy in patients with hypertension.

Design Systematic review of studies of test accuracy of six electrocardiographic indexes: the Sokolow-Lyon index, Cornell voltage index, Cornell product index, Gubner index, and Romhilt-Estes scores with thresholds for a positive test of ≥4 points or ≥5 points.

Data sources Electronic databases ((Pre-)Medline, Embase), reference lists of relevant studies and previous reviews, and experts.

Study selection Two reviewers scrutinised abstracts and examined potentially eligible studies. Studies comparing the electrocardiographic index with echocardiography in hypertensive patients and reporting sufficient data were included.

Data extraction Data on study populations,

echocardiographic criteria, and methodological quality of studies were extracted.

Data synthesis Negative likelihood ratios, which indicate to what extent the posterior odds of left ventricular hypertrophy is reduced by a negative test, were calculated.

Results 21 studies and data on 5608 patients were analysed. The median prevalence of left ventricular hypertrophy was 33% (interquartile range 23-41%) in primary care settings (10 studies) and 65% (37-81%) in secondary care settings (11 studies). The median negative likelihood ratio was similar across electrocardiographic indexes, ranging from 0.85 (range 0.34-1.03) for the Romhilt-Estes score (with threshold ≥4 points) to 0.91 (0.70-1.01) for the Gubner index. Using the Romhilt-Estes score in primary care, a negative electrocardiogram result would reduce the typical pre-test probability from 33% to 31%. In secondary care the typical pre-test probability of 65% would be reduced to 63%.

Conclusion Electrocardiographic criteria should not be used to rule out left ventricular hypertrophy in patients with hypertension.

INTRODUCTION

Left ventricular hypertrophy is an important risk factor in patients with hypertension, leading to a fivefold to 10-fold increase in cardiovascular risk.¹⁻⁵ Decisions about treatment should be based on assessments of hypertensive target organ damage and overall cardiovascular risk. The appropriate diagnostic work-up of suspected left ventricular hypertrophy in patients with hypertension is less clear, however. More than 30 electrocardiographic indexes for the diagnosis of left ventricular hypertrophy have been described. Many of the proposed indexes have remained anecdotal, but others are commonly used.⁶⁻¹⁰ Debate about their comparative diagnostic value continues.¹¹⁻¹³ We did a systematic review to clarify the accuracy of different electrocardiographic indexes.

Electro-				METHODS
cardiograhic index	Study		Negative likelihood ratio (95% CI)	<i>Identification of st</i> 1966 to Decembe
Sokolow-Lyon	Casiglia 1996 ^{w13}		1.04 (0.94 to 1.14)	December 2005 t
	Chapman 2001 ^{w17}		0.88 (0.78 to 0.98)	evaluated the
	Clementy 1982 ^{w1} Crow 1995 ^{w12}		0.64 (0.46 to 0.87) 0.95 (0.90 to 1.00)	indexes for the o
	Domingos 1998 ^{w15}		0.60 (0.44 to 0.83)	
	Fragola 1993 ^{w8}		0.80 (0.68 to 0.93)	trophy and establ
	Fragola 1994 ^{w9}		0.92 (0.77 to 1.10)	ventricular hyper
	Kamide 1996 ^{w14}		0.91 (0.61 to 1.37)	checked referen
	Lee 1992 ^{w7}		1.00 (0.88 to 1.12)	contacted experts
	McLenachan 1988 ^{w2}		0.51 (0.39 to 0.67)	Study selection
	Otterstad 1991 ^{w4} Padial 1991 ^{w5}		0.78 (0.64 to 0.96) 1.01 (0.80 to 1.28)	patients with pri
	Salles 2005 ^{w21}		0.94 (0.85 to 1.04)	healthcare setting.
	Schillaci 1994 ^{w10}		0.90 (0.84 to 0.95)	•
	Sundström 2001 ^{w18}		0.81 (0.69 to 0.94)	hypertensive trea
	Tomiyama 1994 ^{w11}		1.13 (0.70 to 1.81)	treatment, and
	Verdecchia 2000 ^{w16}	-	0.91 (0.86 to 0.96)	withdrawn shortly
	Vijan 1991 ^{w6}		0.84 (0.74 to 0.95)	independently ass
	Wong 2003 ^{w19}		1.30 (1.00 to 1.68)	studies. We includ
Cornell voltage	Otterstad 1991 ^{w4}	1	0.98 (0.94 to 1.02)	cardiographic crit
connext rottuge	Tomiyama 1994 ^{w11}	_	0.95 (0.83 to 1.02)	echocardiography
	Fragola 1994 ^{w9}		0.99 (0.87 to 1.12)	• • •
	Lee 1992 ^{w7}		0.93 (0.85 to 1.01)	Data extraction-
	Padial 1991 ^{w5}		0.92 (0.76 to 1.10)	including the nur
	Fragola 1993 ^{w8}		0.80 (0.70 to 0.91)	the healthcare set
	Chapman 2001 ^{w17} Schillaci 1994 ^{w10}		0.86 (0.78 to 0.95)	graphically confi
	Verdecchia 2000 ^{w16}	+	0.87 (0.83 to 0.91) 0.88 (0.82 to 0.94)	the electrocardio
	Crow 1995 ^{w12}	-	0.92 (0.86 to 0.98)	definition of the e
	Martinez 2003 ^{w20}		0.83 (0.75 to 0.93)	Assessment of stu
	Sundström 2001 ^{w18}		0.94 (0.85 to 1.06)	0
	Wong 2003 ^{w19}		0.92 (0.81 to 1.03)	ological quality of
	Salles 2005 ^{w21}		0.85 (0.78 to 0.94)	of patient selectio
	Domingos 1998 ^{w15} Calaca 1990 ^{w3}		0.88 (0.76 to 1.02) 0.63 (0.46 to 0.88)	of descriptions
	Calaca 1990	-	0.05 (0.40 to 0.88)	completeness of b
Cornell product	Crow 1995 ^{w12}		0.92 (0.87 to 0.98)	cation bias. ¹⁴⁻¹⁶ W
-	Sundström 2001 ^{w18}		0.87 (0.75 to 1.01)	basis of the follow
	Wong 2003 ^{w6}		0.92 (0.81 to 1.03)	prospective data
	Salles 2005 ^{w21}		0.80 (0.72 to 0.89)	consecutive patier
Gubner	Clementy 1982 ^{w1}		1.01 (0.90 to 1.15)	provision of detail
Gubilei	Fragola 1993 ^{w8}		0.95 (0.88 to 1.02)	Statistical analys
	Lee 1992 ^{w7}	_	0.99 (0.93 to 1.06)	
	McLenachan 1988 ^{w2}	_	0.70 (0.55 to 0.88)	ficities, and likel
	Schillaci 1994 ^{w10}	+	0.90 (0.86 to 0.94)	intervals. As the
	Verdecchia 2000 ^{w16}	+	0.91 (0.87 to 0.95)	used to rule out th
	Domingos 1998 ^{w15}		0.90 (0.54 to 1.49)	trophy, we wer
Romhilt-Estes	Clementy 1982 ^{w1}	<u></u>	0.34 (0.18 to 0.63)	sensitivity and t
(four points)	Fragola 1994 ^{w9}		1.03 (0.90 to 1.19)	electrocardiogram
	McLenachan 1988 ^{w2}		0.53 (0.41 to 0.68)	negative test indic
	Schillaci 1994 ^{w10}	+	0.83 (0.79 to 0.87)	result among peop
	Tomiyama 1994 ^{w11}		0.96 (0.84 to 1.11)	01 1
	Vijan 1991 ^{w6} Crow 1995 ^{w12}		0.83 (0.70 to 0.97)	compared with
	Clow 1995 Casiglia 1996 ^{w13}		0.86 (0.80 to 0.93) 0.99 (0.89 to 1.09)	results by plotting
	Casiglia 1990		0.99 (0.09 to 1.09)	receiver operatin
Romhilt-Estes	Clementy 1982 ^{w1}		0.61 (0.43 to 0.87)	medians, ranges, a
(five points)	Fragola 1993 ^{w8}		0.86 (0.78 to 0.94)	
	Fragola 1994 ^{w9}		0.97 (0.90 to 1.06)	RESULTS
	Lee 1992 ^{w7}		0.96 (0.90 to 1.03)	Our search identi
	Schillaci 1994 ^{w10} Verdecchia 2000 ^{w16}	+	0.86 (0.82 to 0.90)	142 as potentially
	Kamide 1996 ^{w14}		0.95 (0.92 to 0.99) 1.19 (0.84 to 1.68)	full text articles w
	Domingos 1998 ^{w15}		0.88 (0.76 to 1.02)	Tun text atticles W
		25 0.5 0.75 1 2		Study characteristic
	0.			Study characteristic
Negative likelihood ratio				The 21 studies inc

Fig 1 Forest plots of negative likelihood ratio from test accuracy studies of six electrocardiographic indexes in diagnosis of left ventricular hypertrophy. Points represent estimates of likelihood ratio; lines represent 95% confidence intervals

studies-We searched Medline from per 2005 and Embase from 1980 to to identify observational studies that accuracy of electrocardiographic diagnosis of left ventricular hyperlished the presence or absence of left rtrophy with echocardiography. We nce lists of relevant studies and s to complement electronic searches.

-We included studies in asymptomatic imary arterial hypertension in any s. Studies included patients taking antiatment, those being evaluated for patients in whom treatment was ly before evaluation. Two reviewers ssessed the abstracts of all retrieved ded all studies that assessed the electroiteria in hypertensive adults against

-We extracted data in duplicate, mber and characteristics of patients, etting, the prevalence of echocardiofirmed left ventricular hypertrophy, ographic indexes evaluated, and the echocardiography threshold.

udy quality—We assessed the methodof papers. We examined the methods on and data collection, completeness of index and reference tests, blinding, and the likelihood of verifi-Ve ranked the quality of studies on the owing criteria: description of setting; ta collection, with enrolment of ents and follow-up of all patients; and ils on echocardiography and blinding.

sis—We calculated sensitivities, specilihood ratios with their confidence e electrocardiogram will mainly be he diagnosis of left ventricular hyperere particularly interested in the the likelihood ratio of a negative m result. The likelihood ratio of a cates how likely it is to find a negative ople with left ventricular hypertrophy those without.17 We summarised g sensitivities and specificities in the ng curve space and by calculating and interquartile ranges.

tified 1761 citations. We considered ly eligible, and after scrutinising the ve included 21 studies.^{w1-w21}

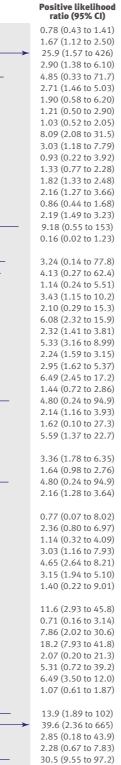
ics

The 21 studies included a total of 5608 (range 30-947) patients. Ten studies were done in primary care and 11 in secondary care. The median prevalence of left ventricular hypertrophy was 33% (interquartile range 23-41%) in primary care settings and 65% (37-81%) in

Electrocardiograhic index Study Casiglia 1996^{w13} Sokolow-Lvon Chapman 2001^{w17} Clementy 1982^{w1} Crow 1995^{w12} Fragola 1993^{w8} Domingos 1998^{w15} Fragola 1994^{w9} Kamide 1996^{w14} Lee 1992^w McLenachan 1988^{w2} Otterstad 1991^{w4} Padial 1991^{w5} Salles 2005^{w21} Schillaci 1994^{w10} Sundström 2001w18 Tomiyama 1994^{w11} Verdecchia 2000^{w16} Vijan 1991^{w6} Wong 2003^{w19} Cornell voltage Otterstad 1991^{w4} Tomiyama 1994^{w11} Fragola 1994^{w9} Lee 1992^{w7} Padial 1991^{w5} Fragola 1993^{w8} Chapman 2001^{w17} Schillaci 1994^{w10} Verdecchia 2000^{w16} Crow 1995^{w12} Martinez 2003^{w20} Sundström 2001^{w18} Wong 2003^{w19} Salles 2005^{w21} Domingos 1998^{w15} Calaca 1990^{w3} Cornell product Crow 1995^{w12} Sundström 2001^{w18} Wong 2003^{w6} Salles 2005^{w21} Clementy 1982^{w1} Gubner Fragola 1993^w Lee 1992^{w7} McLenachan 1988^{w2} Schillaci 1994^{w10} Verdecchia 2000^{w16} Domingos 1998^{w15} **Romhilt-Estes** Clementy 1982^{w1} (four points) Fragola 1994^{w9} McLenachan 1988^{w2} Schillaci 1994w10 Tomiyama 1994^{w11} Vijan 1991^{w6} Crow 1995^{w12} Casiglia 1996^{w13} **Romhilt-Estes** Clementy 1982^{w1} Fragola 1993^{w8} (five points) Fragola 1994^{w9} Lee 1992^{w7} Schillaci 1994^{w10} Verdecchia 2000^{w16} 2.34 (1.32 to 4.12) Kamide 1996^{w14} 0.55 (0.18 to 1.63) Domingos 1998^{w15} 1.62 (0.10 to 27.4) 0.25 2.5 10 250 1

Fig 2 | Forest plots of positive likelihood ratio from test accuracy studies of six electrocardiographic indexes in diagnosis of left ventricular hypertrophy. Points represent estimates of likelihood ratio; lines represent 95% confidence intervals

Positive likelihood ratio



secondary care. Three studies met all six methodological criteria and were ranked as high quality. Another 11 studies met four or five criteria and were ranked as intermediate quality, whereas seven studies met two or three quality criteria and were considered of low quality.

Electrocardiographic indexes

The 21 articles reported on 12 different electrocardiographic criteria. We analysed in detail the six most commonly used indexes, including the Sokolow-Lyon voltage index,6 the Cornell voltage and Cornell product indexes,⁷⁸ the Gubner index,⁹ and the Romhilt-Estes score with thresholds for a positive test of \geq 4 points or \geq 5 points.¹⁰

Sensitivity, specificity, and likelihood ratios

For all indexes, most studies showed low sensitivity and high specificity (see bmj.com). The median sensitivity ranged from 10.5% (range 0-39%) for the Gubner index to 21% (4-52%) for the Sokolow-Lyon index. Median specificity ranged from 89% (53-100%) for the Sokolow-Lyon index to 99% (71-100%) for the Romhilt-Estes (five points) score.

Figures 1 and 2 show forest plots of the negative and positive likelihood ratios. The median negative likelihood ratio was similar across electrocardiographic indexes, ranging from 0.85 (range 0.34-1.03) for the Romhilt-Estes score (four points) to 0.91 (0.70-1.01) for the Gubner index. More variation existed in the positive likelihood ratio, which ranged from 1.90 (0.16-25.9) for the Sokolow-Lyon index to 5.90 (0.71-18.2) for the Romhilt-Estes score (four points). Using the median likelihood ratios from the Romhilt-Estes score (four points) in primary care, a negative electrocardiogram result would reduce the typical pre-test probability of 33% to 31%, whereas a positive electrocardiogram would increase it to 74%. In secondary care, the typical pre-test probability of 65% would be reduced to 63% or increased to 92%.

DISCUSSION

This systematic review of studies of the accuracy of diagnostic tests found that the accuracy of electrocardiographic indexes in the diagnosis of left ventricular hypertrophy is unsatisfactory. Irrespective of the index used, the electrocardiogram is a poor screening tool to exclude left ventricular hypertrophy in hypertensive patients. Of note, specificity was reasonably high in most studies, but because sensitivity was low the power to rule in left ventricular hypertrophy was also unsatisfactory.

Strengths and limitations

We did a comprehensive literature search, selected studies according to pre-defined criteria, and appraised the methodological quality of studies. We excluded diagnostic case-control studies, which are known to overestimate accuracy,1415 as well as studies that did not index ventricular mass for body surface area. We also excluded studies that evaluated patients with concomitant left anterior fascicular block and left bundle

WHAT IS ALREADY KNOWN ON THIS TOPIC

Left ventricular hypertrophy leads to a fivefold to 10-fold increase in cardiovascular risk in hypertensive patients

Several indexes calculated from standard 12 lead electrocardiograms are used in the diagnostic work-up of patients with hypertension

WHAT THIS STUDY ADDS

The accuracy of the more commonly used electrocardiographic criteria for ruling out left ventricular hypertrophy is unsatisfactory in both primary and secondary care.

Echocardiography is needed for a comprehensive assessment of cardiovascular risk in hypertensive patients

branch block, because these patients usually need further examinations and referral irrespective of left ventricular hypertrophy. We summarised the evidence by calculating medians, rather than combining data in meta-analysis. We believe that a formal meta-analysis would have added little in this situation. We felt that further exploration of potential sources of heterogeneity was not warranted. The published data did not allow direct comparisons of test accuracy between the different indexes. More importantly, we did not identify any randomised comparisons of diagnostic and treatment strategies and assessed clinical end points.

Implications for clinical practice

Electrocardiograms should not be done specifically to exclude left ventricular hypertrophy in patients with hypertension. Referral for specialist examinations is often based on high cardiovascular risk scores, but echocardiography may be more informative in hypertensive patients who, on the basis of age, sex, smoking history, and blood lipids, are at low or intermediate risk. In patients known to be at high risk, echocardiographic findings will often not affect clinical management, because interventions to reduce risk are already in place.

The evidence on the capacity of various antihypertensive agents to decrease left ventricular hypertrophy is limited. Preventing cardiovascular disease through modifications of other risk factors such as smoking cessation, lifestyle change, or lipid lowering treatment is the most promising approach.^{18 19}

Future research

Further research is needed to identify cost effective diagnostic strategies in primary care settings. Such research could inform the development of algorithms to identify patients who should be referred for echocardiography. In the absence of accurate and inexpensive screening tests for left ventricular hypertrophy, research into new diagnostic technologies is also warranted. Further studies are needed to better define the pathophysiological mechanisms and outcomes in patients with echocardiographically confirmed left ventricular hypertrophy but negative electrocardiograms. Similarly, more data are needed on patients with positive electrocardiographic tests but negative echocardiography.

Conclusions

The power of some of the more commonly used electrocardiographic criteria to rule out the diagnosis of left ventricular hypertrophy in patients with hypertension is poor. Further research is needed to assess the cost effectiveness of different diagnostic and treatment strategies of left ventricular hypertrophy in primary care.

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- 1 Kannel WB, Gordon T, Offutt D. Left ventricular hypertrophy by electrocardiogram: prevalence, incidence, and mortality in the Framingham study. *Ann Intern Med* 1969;71:89-105.
- 2 Kannel WB, Gordon T, Castelli WP, Margolis JR. Electrocardiographic left ventricular hypertrophy and risk of coronary heart disease: the Framingham study. Ann Intern Med 1970;72:813-22.
- 3 Haider AW, Larson MG, Benjamin EJ, Levy D. Increased left ventricular mass and hypertrophy are associated with increased risk for sudden death. J Am Coll Cardiol 1998;32:1454-9.
- 4 Verdecchia P, Schillaci G, Borgioni C, Ciucci A, Gattobigio R, Zampi I, et al. Prognostic value of a new electrocardiographic method for diagnosis of left ventricular hypertrophy in essential hypertension. J Am Coll Cardiol 1998;31:383-90.
- 5 Sundström J, Lind L, Arnlöv J, Zethelius B, Andrén B, Lithell HO. Echocardiographic and electrocardiographic diagnoses of left ventricular hypertrophy predict mortality independently of each other in a population of elderly men. *Circulation* 2001;103:2346-51.
- 6 Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. Am Heart J 1949;37:161-86.
- 7 Casale PN, Devereux RB, Kligfield P, Eisenberg RR, Miller DH, Chaudhary BS, et al. Electrocardiographic detection of left ventricular hypertrophy: development and prospective validation of improved criteria. J Am Coll Cardiol 1985;6:572-80.
- 8 Norman JE Jr, Levy D. Adjustment of ECG left ventricular hypertrophy criteria for body mass index and age improves classification accuracy: the effects of hypertension and obesity. *J Electrocardiol* 1996;29(supp):241-7.
- 9 Gubner R, Ungerleider HE. Electrocardiographic criteria of left ventricular hypertrophy. Arch Intern Med 1943;72:196-206.
- 10 Romhilt DW, Estes EH Jr. A point-score system for the ECG diagnosis of left ventricular hypertrophy. *Am Heart J* 1968;75:752-8.
- 11 Schillaci G, Verdecchia P, Pede S, Porcellati C. Electrocardiography for left ventricular hypertrophy in hypertension: time for reevaluation? *G Ital Cardiol* 1998;28:706-13.
- 12 Verdecchia P, Dovellini EV, Gorini M, Gozzelino G, Lucci D, Milletich A, et al. Comparison of electrocardiographic criteria for diagnosis of left ventricular hypertrophy in hypertension: the MAVI study. *Ital Heart J* 2000;1:207-15.
- 13 Conway D, Lip GY. The ECG and left ventricular hypertrophy in primary care hypertensives. *J Hum Hypertens* 2001;15:215-7.
- 14 Lijmer JG, Mol BW, Heisterkamp S, Bonsel GJ, Prins MH, van der Meulen JH, et al. Empirical evidence of design-related bias in studies of diagnostic tests. JAMA 1999;282:1061-6.
- 15 Whiting P, Rutjes AW, Reitsma JB, Glas AS, Bossuyt PM, Kleijnen J. Sources of variation and bias in studies of diagnostic accuracy: a systematic review. *Ann Intern Med* 2004;140:189-202.
- 16 Jaeschke R, Guyatt G, Sackett DL. Users' guides to the medical literature. III. How to use an article about a diagnostic test. A. Are the results of the study valid? JAMA 1994;271:389-91.
- 17 Pewsner D, Battaglia M, Minder C, Marx A, Bucher HC, Egger M. Ruling a diagnosis in or out with "SpPIn" and "SnNOut": a note of caution. *BMJ* 2004;329:209-13.
- 18 Appel LJ, Champagne CM, Harsha DW, Cooper LS, Obarzanek E, Elmer PJ, et al. Effects of comprehensive lifestyle modification on blood pressure control: main results of the PREMIER clinical trial. JAMA 2003;289:2083-93.
- 19 Svetkey LP, Erlinger TP, Vollmer WM, Feldstein A, Cooper LS, Appel LJ, et al. Effect of lifestyle modifications on blood pressure by race, sex, hypertension status, and age. J Hum Hypertens 2005;19:21-31.

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