
**Diagnostic accuracy of wearable technologies for atrial fibrillation detection:
a systematic review and meta-analysis**

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Database	Search strategy	Result	Search Date
Pubmed	("Atrial Fibrillation"[Mesh] OR "atrial fibrillation" OR "AF") AND ("Wearable Electronic Devices"[Mesh] OR "wearable" OR "smartwatch" OR "smart watch" OR "wearable device" OR "mobile health" OR "mHealth" OR "digital health") AND ("Photoplethysmography"[Mesh] OR "photoplethysmography" OR "PPG" OR "optical sensor" OR "pulse detection") AND ("Electrocardiography"[Mesh] OR "ECG" OR "electrocardiogram" OR "single-lead ECG" OR "ECG patch" OR "mobile ECG") AND ("Diagnosis"[Mesh] OR "diagnostic accuracy" OR "sensitivity and specificity" OR "screening" OR "detection")	137	2/25/2026
Embase	('atrial fibrillation'/exp OR 'atrial fibrillation' OR AF) AND ('wearable electronic device'/exp OR wearable:ti,ab OR smartwatch:ti,ab OR 'smart watch':ti,ab OR 'mobile health':ti,ab OR mhealth:ti,ab) AND ('photoplethysmography'/exp OR PPG:ti,ab OR photoplethysmography:ti,ab) AND ('electrocardiography'/exp OR ECG:ti,ab OR electrocardiogram:ti,ab OR 'single-lead ECG':ti,ab) AND ('diagnostic accuracy'/exp OR sensitivity:ti,ab OR specificity:ti,ab OR screening:ti,ab)	54	2/25/2026
Web of Science	("atrial fibrillation" OR AF) AND ("wearable OR smartwatch OR "smart watch" OR "wearable device" OR mHealth OR "mobile health") AND ("PPG OR photoplethysmography OR ECG OR electrocardiogram OR "single-lead ECG") AND ("detection OR diagnosis OR "diagnostic accuracy" OR screening)	83	2/25/2026

Table S1. Search strategy

Author ID	Country	Subjects (N)	Mean Age	Male (%)	Type of Sensor	Gold Standard
Dörr et al. (2019)	Germany/Switz.	672	76.4	55.7	PPG Smartwatch	12-Lead ECG
Chang et al. (2022)	Taiwan	200	66.1	63.5	PPG Smartwatch	12-Lead ECG

Selder et al. (2023)	Netherlands	78	66	53.5	PPG Smartwatch	12-Lead ECG
Nonoguchi et al. (2022)	Japan	1500	66.5	68	PPG Smartwatch	12-Lead ECG
Bashar et al. (2019)	USA	46	-	-	PPG Smartwatch	12-Lead ECG
Bonomi et al. (2018)	Netherlands	20	59.6	55.5	PPG Smartwatch	12-Lead ECG
Liao et al. (2022)	Taiwan	116	59.6	67	PPG Smartwatch	12-Lead ECG
Han et al. (2020)	USA	37	70.49	78.3	PPG Smartwatch	12-Lead ECG
Tison et al. (2018)	USA	9750	42	63	PPG Smartwatch	12-Lead ECG
Ding et al. (2019)	USA	40	71	80	PPG Smartwatch	12-Lead ECG
Mannhart et al. (2023)	Switzerland	201	66.7	69	ECG Apple Watch 6	12-Lead ECG
					ECG Samsung Watch 3	12-Lead ECG
					ECG Withings Scanwatch	12-Lead ECG
					ECG Fitbit Sense	12-Lead ECG
Fiorina et al. (2024)	France	400	64.8	70.8	Smartwatch (DNN)	12-Lead ECG
					Apple Watch app	12-Lead ECG
Müller et al. (2024)	Norway	105	68	78.5	ECG Apple Watch 5	12-Lead ECG
					ECG Apple Watch 5	12-Lead ECG
Fiorina et al. (2022)	France	101	-	-	Apple Watch (ECG 2.0 App)	12-Lead ECG
					Apple Watch (DNN)	12-Lead ECG
Campo et al. (2022)	France	262	67.7	61.1	ScanWatch (Single-lead ECG)	12-Lead ECG
Rajakariar et al. (2020)	Australia	200	67	56.5	ECG (AliveCor KardiaBand)	12-Lead ECG
Wasserlauf et al. (2019)	USA	26	72.1	65.4	Apple Watch (KardiaBand)	ICM (Reveal LINQ)
Abu-Alrub et al. (2022)	France	200	62	56	Apple Watch (ECG)	12-Lead ECG
					Samsung (ECG)	12-Lead ECG

					Withings (ECG)	12-Lead ECG
Badertscher et al. (2022)	Switzerland	319	67	52	Withings Scanwatch (ECG)	12-Lead ECG
Seshadri et al. (2020)	USA	50	-	-	Apple Watch Series 4 (ECG)	12-Lead ECG
Bumgarner et al. (2018)	USA	100	68.2	83	Apple Watch (ECG)	12-Lead ECG
Racine et al. (2022)	France	734	66		Apple Watch Series 5	12-lead ECG
Apple et al. (2018)	USA	588	nr		Apple Watch Series 4, 5, 6	12-lead ECG
Tison et al. (2018)	USA	51	66.1 +/- 10.7		Apple Watch Series 4 (Cardiogram application)	12-lead ECG
Pasli et al. (2024)	Turkey	721	66.5 +/- 17.1		Apple Watch series 7	Standard 12-lead ECGs
Mannhart et al. (2023)	Switzerland	201	67		Apple Watch Series 6	12-lead ECG
Alnasser et al. (2023)	Saudi Arabia	469	56.43 +/- 16.3		Apple Watch Series 6	12-lead ECG
Scholten et al. (2020)	Netherlands	220	70 +/- 10		Apple Watch series 5	12-lead ECG
Ploux et al. (2022)	France	260	66 +/- 6		Apple watch Series 4	12-lead ECG
Haverkamp et al. (2019)	Norway	144	58	63	PPG Smartphone	12-lead ECG interpreted by cardiologists
Himmelreich et al. (2019)	Netherlands	214	64.1 +/- 14.7	53.7	Kardia (ECG) Smartphone	12-lead ECG interpreted by cardiologists
Jaakkola et al. (2018)	Finland	300	74.8	56	Mechanocardio Smartphone	12-lead ECG interpreted by cardiologists
Krivoshei et al. (2016)	Finland	80	78 +/- 7.5	71	PPG Smartphone	12-lead ECG interpreted by cardiologists
Lown et al. (2018)	UK	418	73.9 +/- 6.1	N/A	AliveCor (ECG) Smartphone	12-lead ECG interpreted by cardiologists
McManus et al. (2016)	USA	121	66	72	PPG Smartphone	12-lead ECG interpreted by cardiologists
Proesmans et al. (2019)	Belgium	223	77 +/- 8	46.6	PPG Smartphone	12-lead ECG interpreted by cardiologists
Rozen et al. (2018)	USA	98	67.7 +/- 10.5	75.5	PPG Smartphone	12-lead ECG interpreted by cardiologists
Selder et al. (2019)	Netherlands	233	58.4 +/- 14	52	Single-lead ECG Smartphone	12-lead ECG interpreted by cardiologists

Tarakji et al. (2015)	USA	60	60 +/- 12	78	Single-lead ECG Smartphone	Recorded ECG
Wegner et al. (2019)	Germany	99	64 +/- 15	61.2	Single-lead ECG Smartphone	12-lead ECG interpreted by cardiologists
William et al. (2018)	USA	52	68.1	67.3	Single-lead ECG Smartphone	12-lead ECG interpreted by cardiologists
Yan et al. (2018, facial PPG)	Hong Kong	217	70.3 +/- 13.9	71.4	PPG (facial) Smartphone AND PPG (fingertip)	12-lead ECG interpreted by cardiologists
Bumgarner et al. (2016)	USA	100	68 +/- 11	83	Kardia (ECG) Smartwatch	12-lead ECG interpreted by cardiologists
Chan et al. (2018)	Hong Kong	10,735	78.6 +/- 8.1	17.2	Kardia (ECG) Smartwatch	5-lead telemetry ECG interpreted by cardiologists
Haberman et al. (2014)	USA	381	36 +/- 20	49	AliveCor (ECG) Smartwatch	12-lead ECG interpreted by cardiologists
Gala et al. (2023)	UK	400	63	73%	Apple Watch Series 6 Smartwatch	12-Lead ECG
Zhang et al. (2019)	China	263	NR	NR	Huawei Watch GT	12-lead ECG
Poh et al. (2013)	Hong Kong	1013	68.4 ± 12.2	46.8	PPG (smartphone camera)	12-lead ECG
Badertscher et al. (2022)	Switzerland	319	67	52	ECG smartwatch	12-lead ECG

Table S2. Study characteristics

Study	Risk of Bias				Applicability concerns		
	Patient Selection	Index Test	Reference Standard	Flow & Timing	Patient Selection	Index Test	Reference Standard
Dörr et al. (2019)	Low	Low	Low	Low	Low	Low	Low
Chang 2022	Low	Low	Low	Low	Low	Low	Low
Selder 2023	Low	Low	Low	Low	Low	Low	Low
Nonoguchi 2022	Low	Low	Low	Low	Low	Low	Low
Bashar 2019	Low	Unclear	Low	Low	Low	Low	Low
Bonomi 2018	High	Low	Low	Low	Low	Low	Low
Liao 2022	Low	Low	Low	Low	Low	Low	Low

Han 2020	Low	Unclear	Low	Low	Low	Low	Low
Tison 2018 (Cardiogram)	Low	Low	Low	Low	Low	Low	Low
Ding 2019	Low	Low	Unclear	Low	Low	Low	Low
Mannhart 2023 (multiwatch)	High	Low	Low	Low	Low	Low	Low
Fiorina 2024	Low	Low	Low	Low	Low	Low	Low
Müller 2024	Low	Low	Low	Low	Low	Low	Low
Fiorina 2022	Low	Unclear	Low	Low	Low	Low	Low
Campo 2022	High	Low	Low	Low	Low	Low	Low
Rajakariar 2020	High	Low	Low	Low	Low	Low	Low
Wasserlauf 2019	Low	Low	Unclear	Unclear	Low	Low	Low
Abu-Alrub 2022	High	Low	Low	Low	Low	Low	Low
Badertscher 2022	Low	Low	Low	Low	Low	Low	Low
Seshadri 2020	Low	Low	Low	Unclear	Low	Low	Low
Bumgarner 2018	High	Low	Low	Low	Low	Low	Low
Racine 2022	Low	Low	Low	Low	Low	Low	Low
Apple 2018	Unclear	Low	Low	Low	Low	Low	Low
Tison 2018 (AW subset)	Low	Low	Low	Low	Low	Low	Low
Pasli 2024	Low	Low	Low	Low	Low	Low	Low
Mannhart 2023 (AW subset)	High	Low	Low	Low	Low	Low	Low
Wasserlauf 2019	Low	Low	Low	Low	Low	Low	Low
Scholten 2020	Low	Low	Low	Low	Low	Low	Low
Ploux 2022	Low	Low	Low	Low	Low	Low	Low
Haverkamp 2019	Low	Low	Low	Low	Low	Low	Low
Himmelreich 2019	Low	Low	Low	Low	Low	Low	Low
Jaakkola 2018	Low	Low	Low	Low	Low	Low	Low
Krivoshei 2016	High	Low	Low	Low	Low	Low	Low
Lown 2018	Low	Low	Low	Low	Low	Low	Low
McManus 2016	Low	Unclear	Low	Low	Low	Low	Low
Proesmans 2019	Low	Low	Low	Low	Low	Low	Low
Rozen 2018	High	Low	Low	Low	Low	Low	Low
Selder 2019	Low	Low	Low	Low	Low	Low	Low
Tarakji 2015	High	Low	Low	Low	Low	Low	Unclear
Wegner 2019	Low	Low	Low	Low	Low	Low	Low
William 2018	Low	Low	Low	Low	Low	Low	Low

Yan 2018	Low	Low	Unclear	Low	Low	Low	Low
Bumgarner 2016	High	Low	Low	Low	Low	Low	Low
Chan 2018	Low	Low	Low	Low	Low	Low	Low
Haberman 2014	Low	Low	Low	Low	Low	Low	Low
Gala 2023	Low	Low	Low	Low	Low	Low	Low
Zhang 2019	Low	Unclear	Low	Low	Low	Low	Low
Poh 2013	Low	Unclear	Low	Low	Low	Low	Low
Badertscher 2022	Low	Low	Low	Low	Low	Low	Low

Table S3. Quality assessment of included studies

Device	Sensitivity	Specificity	LR+	LR-	DOR
PPG Smart Watch	0.970 (0.948–0.982)	0.965 (0.946–0.978)	27.91 (17.74–43.89)	0.032 (0.018–0.054)	885.37 (424.18–1847.99)
ECG Smart Watch	0.890 (0.847–0.922)	0.928 (0.892–0.953)	12.35 (8.05–18.92)	0.119 (0.084–0.168)	103.93 (53.12–203.34)
Smartphone ECG	0.945 (0.896–0.972)	0.958 (0.933–0.974)	22.63 (14.12–36.26)	0.057 (0.030–0.110)	396.39 (180.14–872.27)
Smartphone PPG (Bayesian, approximated)	0.920 (0.869–0.971)	0.919 (0.860–0.978)	11.34 (5.34–22.53)	0.087 (0.048–0.169)	128.14 (35.84–397.36)
Apple Watch (dedicated subset)	0.941 (0.900–0.966)	0.946 (0.891–0.974)	17.49 (8.42–36.32)	0.062 (0.036–0.108)	282.36 (103.68–769.00)

Table S4. Summary of pooled diagnostic accuracy of wearable and smartphone-based devices for atrial fibrillation detection.

Parameter	Posterior Median	Standard Deviation	95% Posterior Interval
Between-study Correlation(ρ)	0.275	0.145	(-0.009, 0.553)

Between-study SD for logit(Sensitivity) (σ_1)	0.991	0.113	(0.810, 1.256)
Between-study SD for logit(Specificity) (σ_0)	0.969	0.119	(0.772, 1.228)
Shape parameter (β)	-0.027	0.157	(-0.335, 0.284)
SD of cutpoint parameter (σ_θ)	0.348	0.087	(0.210, 0.542)
SD of accuracy parameter (σ_α)	1.391	0.347	(0.840, 2.169)

Table S5. Results of meta-regression evaluating the effect of device type (ECG smartwatch, PPG smartwatch, smartphone ECG, and smartphone PPG) on pooled sensitivity estimates. Coefficients represent the change in logit sensitivity relative to the reference category.

	Posterior Median	Standard Deviation	95% Posterior Interval		
Parameters for comparison ECG smart watch vs PPG smart watch:			NA		
Difference in sensitivities	-0.08	0.022	(-0.128, -0.040)		
Difference in specificities	-0.04	0.018	(-0.075, -0.005)		
Ratio of sensitivities	0.917	0.023	(0.867, 0.958)		

Ratio of specificities	0.958	0.019	(0.923, 0.995)		
 Parameters for comparison ECG smart watch vs Smartphone ECG: 					
Difference in sensitivities	-0.049	0.026	(-0.098, 0.008)		
Difference in specificities	-0.032	0.02	(-0.070, 0.008)		
Ratio of sensitivities	0.947	0.028	(0.897, 1.009)		
Ratio of specificities	0.966	0.021	(0.928, 1.008)		
 Parameters for comparison ECG smart watch vs Smartphone PPG: 					
Difference in sensitivities	-0.035	0.036	(-0.092, 0.050)		
Difference in specificities	0	0.032	(-0.052, 0.073)		
Ratio of sensitivities	0.962	0.039	(0.903, 1.059)		
Ratio of specificities	1	0.036	(0.945, 1.084)		
 Parameters for comparison PPG smart watch vs Smartphone ECG: 					
Difference in sensitivities	0.032	0.021	(-0.002, 0.078)		
Difference in specificities	0.008	0.017	(-0.025, 0.046)		
Ratio of sensitivities	1.034	0.024	(0.998, 1.087)		
Ratio of specificities	1.009	0.018	(0.974, 1.049)		
 Parameters for comparison PPG smart watch vs Smartphone PPG: 					
Difference in sensitivities	0.044	0.032	(-0.001, 0.126)		
Difference in specificities	0.04	0.031	(-0.006, 0.112)		

Ratio of sensitivities	1.048	0.038	(0.999, 1.150)		
Ratio of specificities	1.043	0.036	(0.993, 1.131)		
 Parameters for comparison Smartphone ECG vs Smartphone PPG: 					
Difference in sensitivities	0.013	0.035	(-0.048, 0.096)		
Difference in specificities	0.031	0.031	(-0.019, 0.103)		
Ratio of sensitivities	1.014	0.04	(0.949, 1.114)		
Ratio of specificities	1.034	0.036	(0.980, 1.119)		

Table S6. Results of meta-regression assessing the impact of device type on pooled specificity estimates. Coefficients are presented on the logit scale with corresponding confidence intervals and p-values.

	Posterior Median	Standard Deviation	95% Posterior Interval
 Parameters for ECG smart watch: 			NA
logit(sensitivity) ($\mu_{₁}$ L=ECG smart watch)	2.032	0.195	(1.651, 2.438)
logit(specificity) ($\mu_{₀}$ L=ECG smart watch)	2.468	0.2	(2.093, 2.875)
Sensitivity (logit ^{<sup>-1</sup>} ($\mu_{₁}$ L=ECG smart watch))	0.884	0.02	(0.839, 0.920)
Specificity (logit ^{<sup>-1</sup>} ($\mu_{₀}$ L=ECG smart watch))	0.922	0.015	(0.890, 0.947)

False positive rate (1 - specificity)	0.078	0.015	(0.053, 0.110)
Diagnostic Odds Ratio	90.415	30.212	(50.106, 165.096)
Likelihood Ratio +ve	11.304	2.259	(7.917, 16.603)
Likelihood Ratio -ve	0.126	0.022	(0.086, 0.177)
Cutpoint parameter (θ ; L=ECG smart watch)	-0.248	0.217	(-0.667, 0.190)
Accuracy parameter (λ ; L=ECG smart watch)	4.527	0.308	(3.921, 5.127)
 Parameters for PPG smart watch: 			
logit(sensitivity) (μ_1 ; L=PPG smart watch)	3.316	0.281	(2.804, 3.885)
logit(specificity) (μ_0 ; L=PPG smart watch)	3.252	0.291	(2.663, 3.822)
Sensitivity (μ_1 ; L=PPG smart watch))	0.965	0.01	(0.943, 0.980)
Specificity (μ_0 ; L=PPG smart watch))	0.963	0.011	(0.935, 0.979)
False positive rate (1 - specificity)	0.037	0.011	(0.021, 0.065)

Diagnostic Odds Ratio	722.54	359.585	(308.053, 1660.356)
Likelihood Ratio +ve	25.882	7.708	(14.766, 45.161)
Likelihood Ratio -ve	0.036	0.01	(0.021, 0.060)
Cutpoint parameter (θ ; L=PPG smart watch)	-0.008	0.317	(-0.631, 0.613)
Accuracy parameter (λ ; L=PPG smart watch)	6.602	0.437	(5.768, 7.451)
 Parameters for Smartphone ECG: 			
logit(sensitivity) (μ ; $\mu_{>1}$ L=Smartphone ECG)	2.639	0.29	(2.069, 3.188)
logit(specificity) (μ ; $\mu_{>0}$ L=Smartphone ECG)	3.034	0.295	(2.472, 3.625)
Sensitivity (logit ⁻¹ (μ ; $\mu_{>1}$ L=Smartphone ECG))	0.933	0.019	(0.888, 0.960)
Specificity (logit ⁻¹ (μ ; $\mu_{>0}$ L=Smartphone ECG))	0.954	0.013	(0.922, 0.974)
False positive rate (1 - specificity)	0.046	0.013	(0.026, 0.078)
Diagnostic Odds Ratio	290.993	151.209	(115.684, 688.706)

Likelihood Ratio +ve	20.279	6.333	(11.817, 36.063)
Likelihood Ratio -ve	0.07	0.021	(0.041, 0.119)
Cutpoint parameter (θL=Smartpho ne ECG)	-0.241	0.289	(-0.811, 0.339)
Accuracy parameter (λL=Smartp hone ECG)	5.694	0.456	(4.781, 6.563)
 Parameters for Smartphone PPG: 			
logit(sensitivity) (μ₁ L=Smartphone PPG)	2.449	0.385	(1.687, 3.189)
logit(specificity) (μ₀ L=Smartphone PPG)	2.476	0.374	(1.776, 3.211)
Sensitivity (logit^{- 1}(μ_{ >1}L=Smartp hone PPG))	0.92	0.031	(0.844, 0.960)
Specificity (logit^{- 1}(μ_{ >0}L=Smartp hone PPG))	0.922	0.028	(0.855, 0.961)
False positive rate (1 - specificity)	0.078	0.028	(0.039, 0.145)
Diagnostic Odds Ratio	138.874	96.84	(41.187, 399.097)
Likelihood Ratio +ve	11.806	4.647	(6.188, 23.699)

Likelihood Ratio -ve	0.086	0.034	(0.043, 0.176)
Cutpoint parameter (θ ; L=Smartphone PPG)	-0.049	0.31	(-0.652, 0.577)
Accuracy parameter (λ ; L=Smartphone PPG)	4.953	0.588	(3.749, 6.008)

Table S7. Results of the bivariate meta-regression model evaluating the association between device type and overall diagnostic accuracy, incorporating both sensitivity and specificity while accounting for their correlation and between-study heterogeneity.

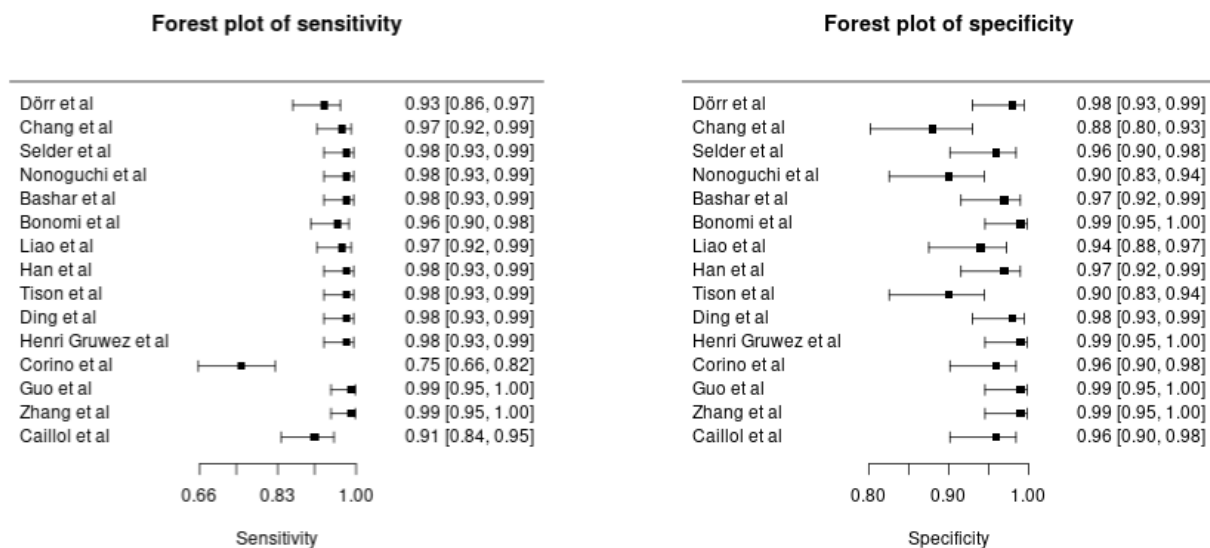


Figure S1. Forest plots of diagnostic accuracy showing the sensitivity and specificity estimates with 95% confidence intervals for Smartwatch-Based PPG

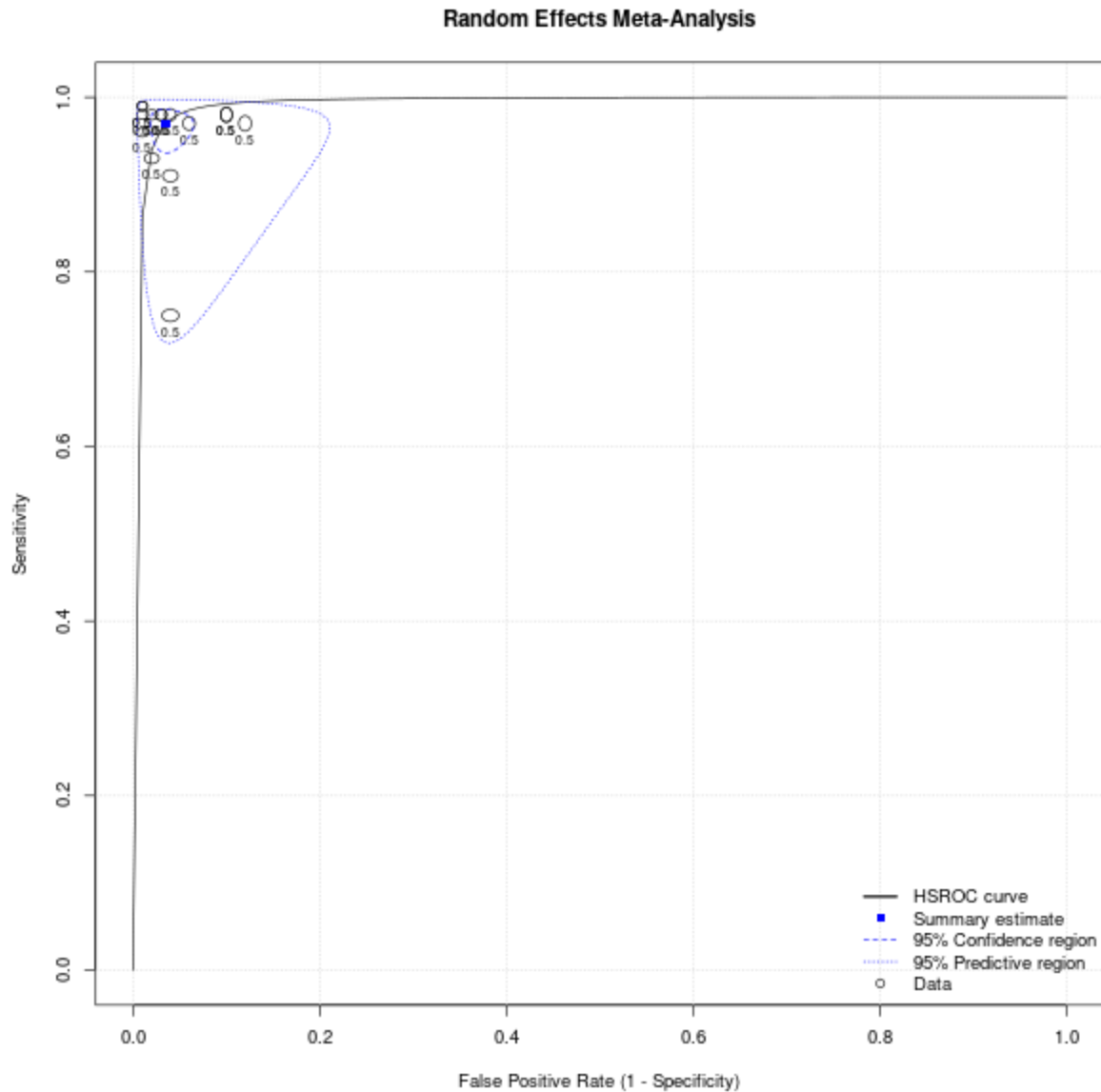


Figure S2. SROC curve for Smartwatch-Based PPG and handheld devices, demonstrating the hierarchical SROC (HSROC) curve with the pooled sensitivity and specificity estimate, along with the 95% confidence region and 95% prediction region for the included studies

Forest plot of sensitivity

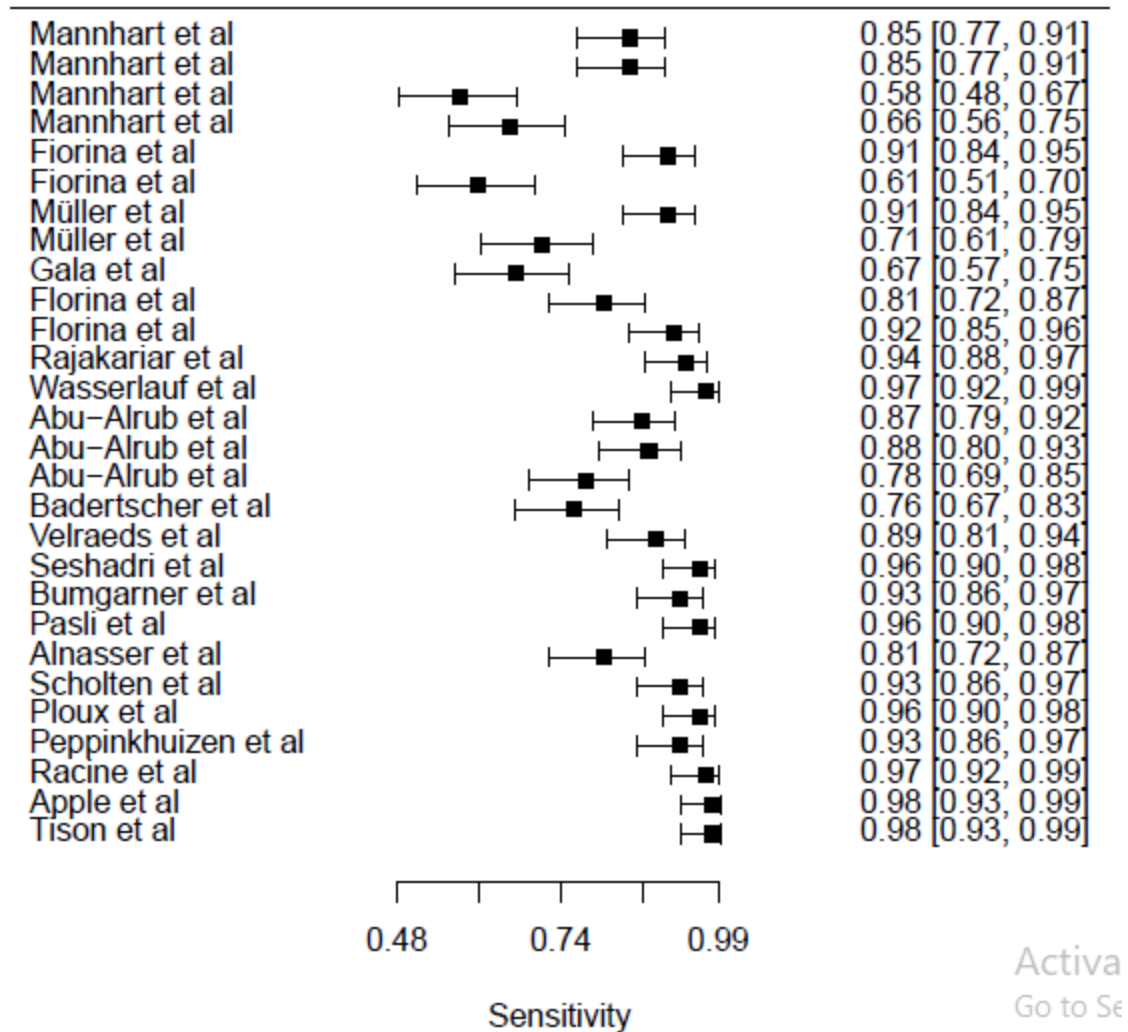


Figure S3. Forest plots of diagnostic accuracy showing the sensitivity estimates with 95% confidence intervals for Smartwatch-Based ECG

Forest plot of specificity

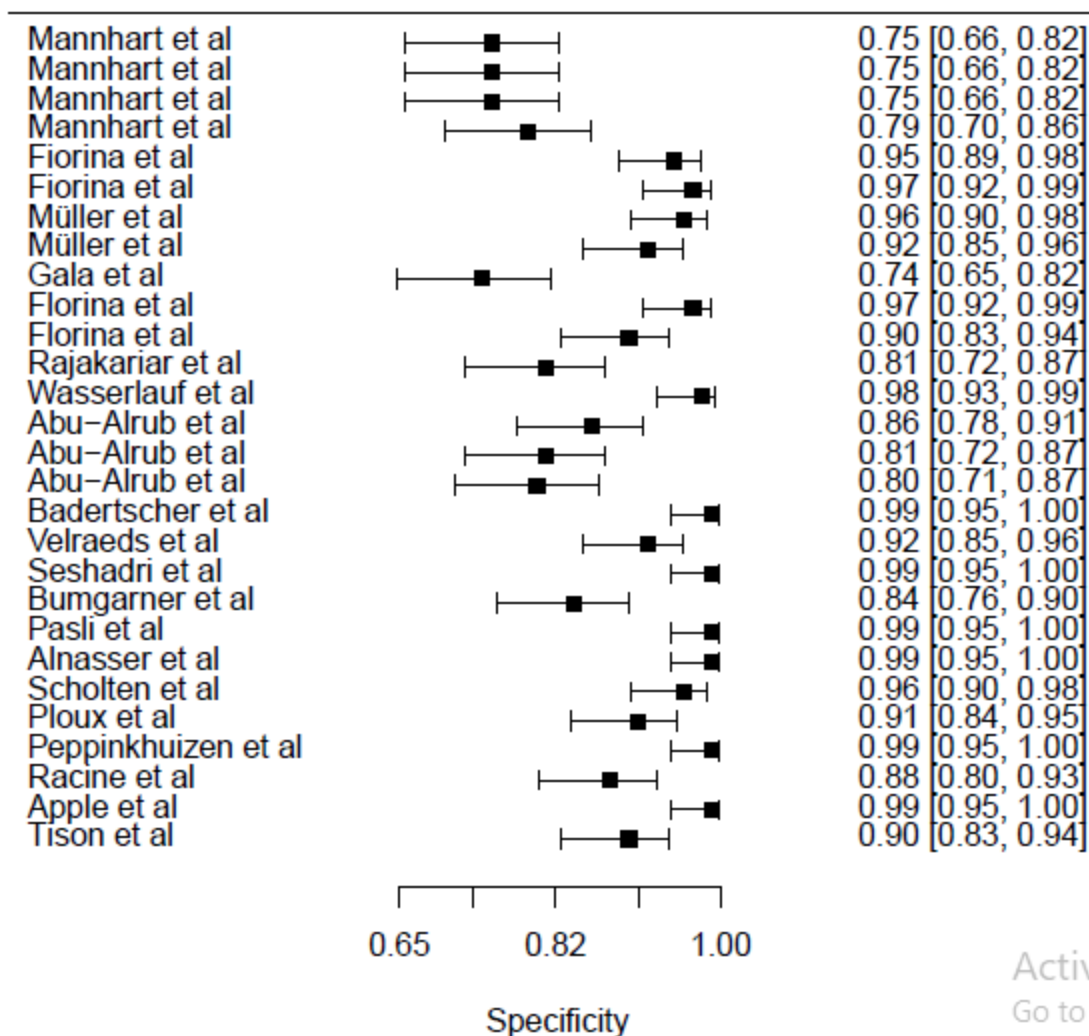


Figure S4. Forest plots of diagnostic accuracy showing the specificity estimates with 95% confidence intervals for Smartwatch-Based ECG

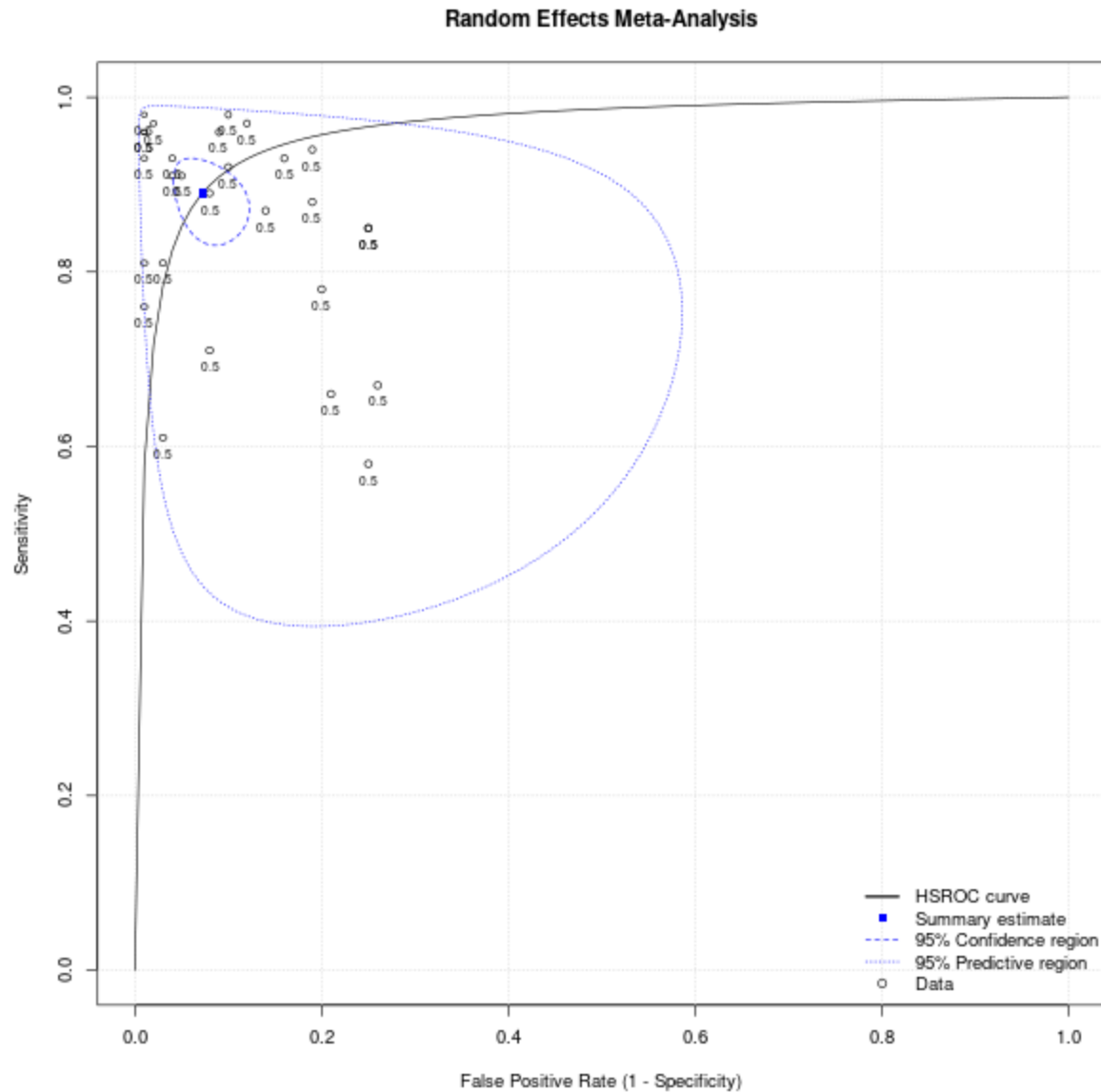


Figure S5. SROC curve for Smartwatch-Based ECG, demonstrating the hierarchical SROC (HSROC) curve with the pooled sensitivity and specificity estimate, along with the 95% confidence region and 95% prediction region for the included studies

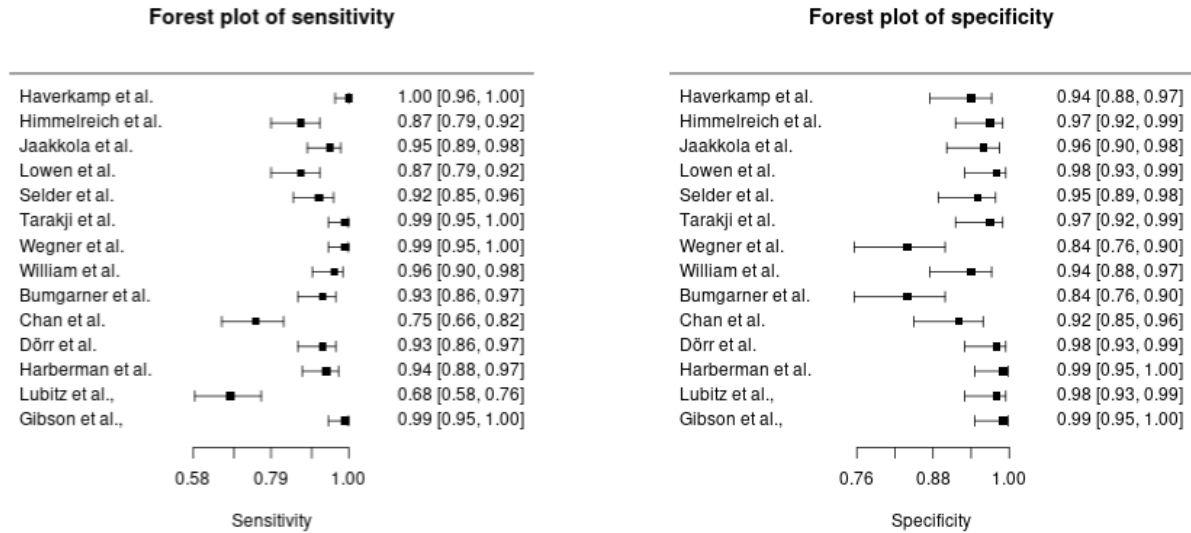


Figure S6. Forest plots of diagnostic accuracy showing the sensitivity and specificity estimates with 95% confidence intervals for Smartphone ECG

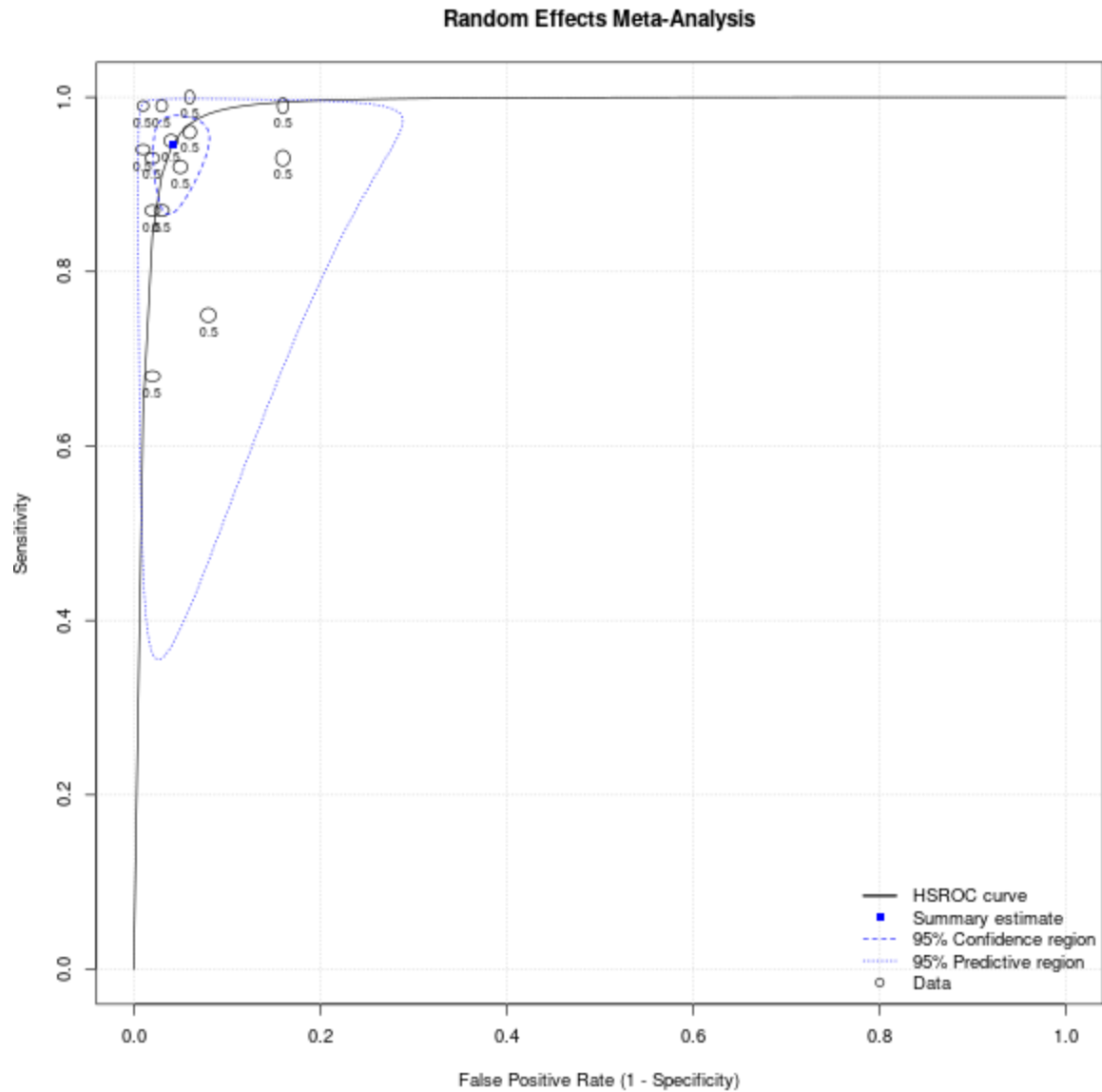


Figure S7. SROC curve for Smartphone ECG, demonstrating the hierarchical SROC (HSROC) curve with the pooled sensitivity and specificity estimate, along with the 95% confidence region and 95% prediction region for the included studies

Forest plot of sensitivity

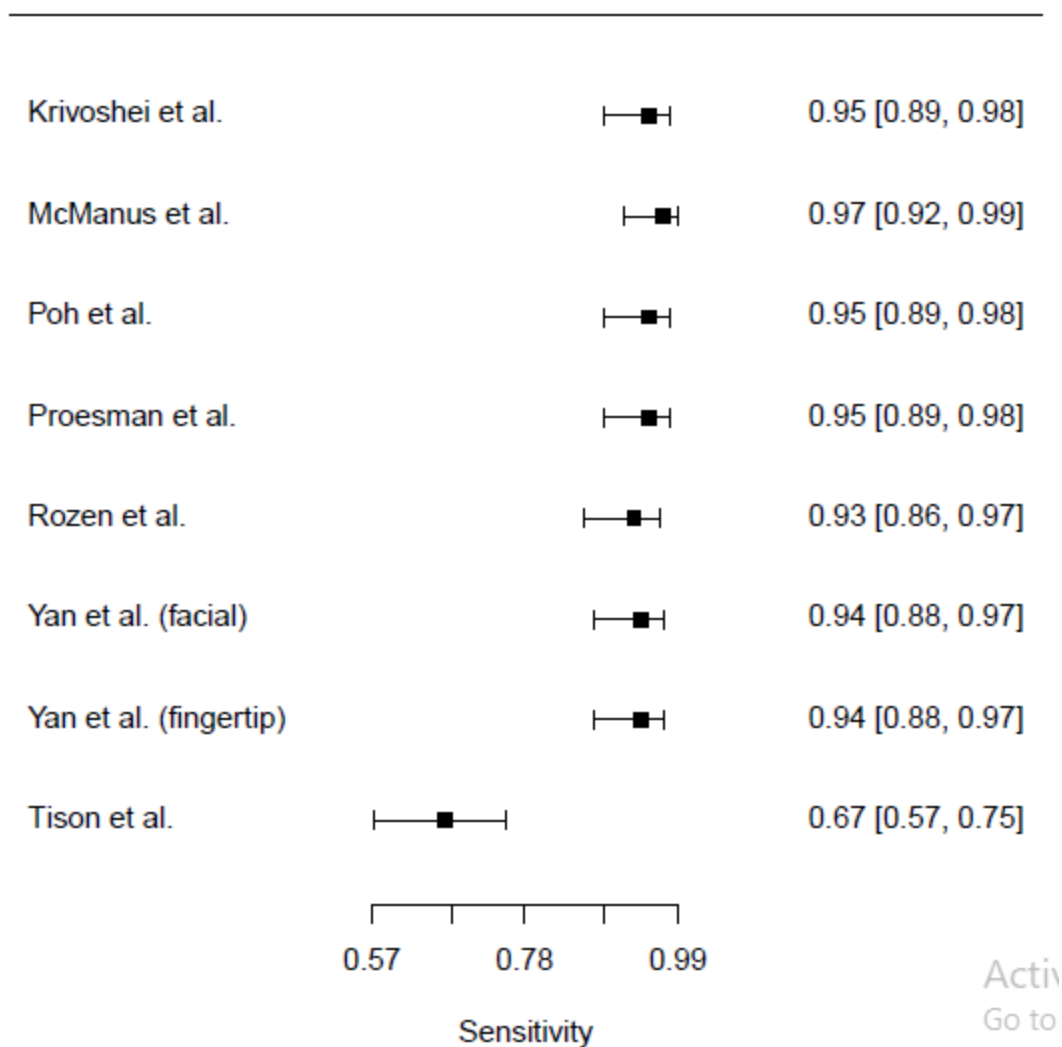


Figure S8. Forest plots of diagnostic accuracy showing the sensitivity estimates with 95% confidence intervals for Smartphone PPG.

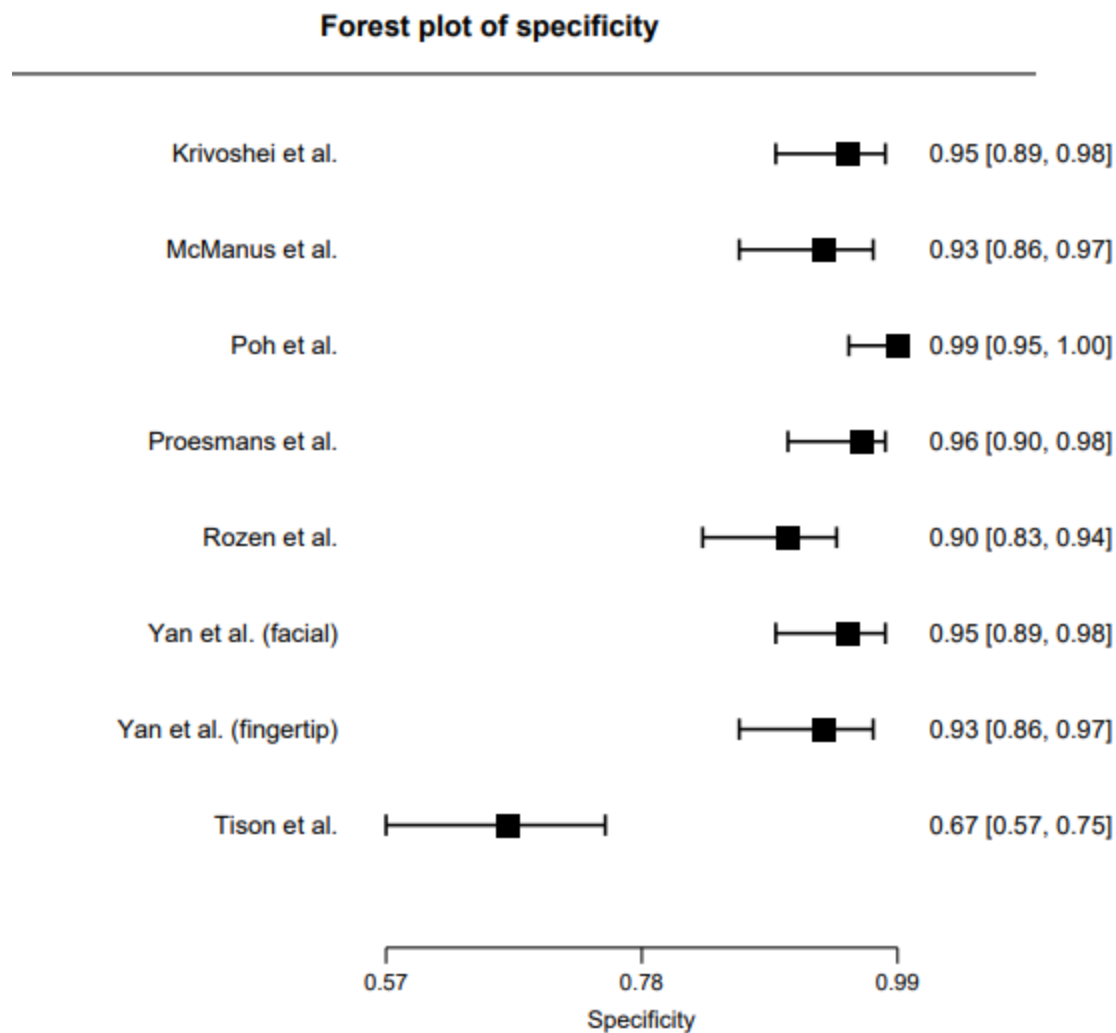


Figure S9. Forest plots of diagnostic accuracy showing the specificity estimates with 95% confidence intervals for Smartphone PPG.

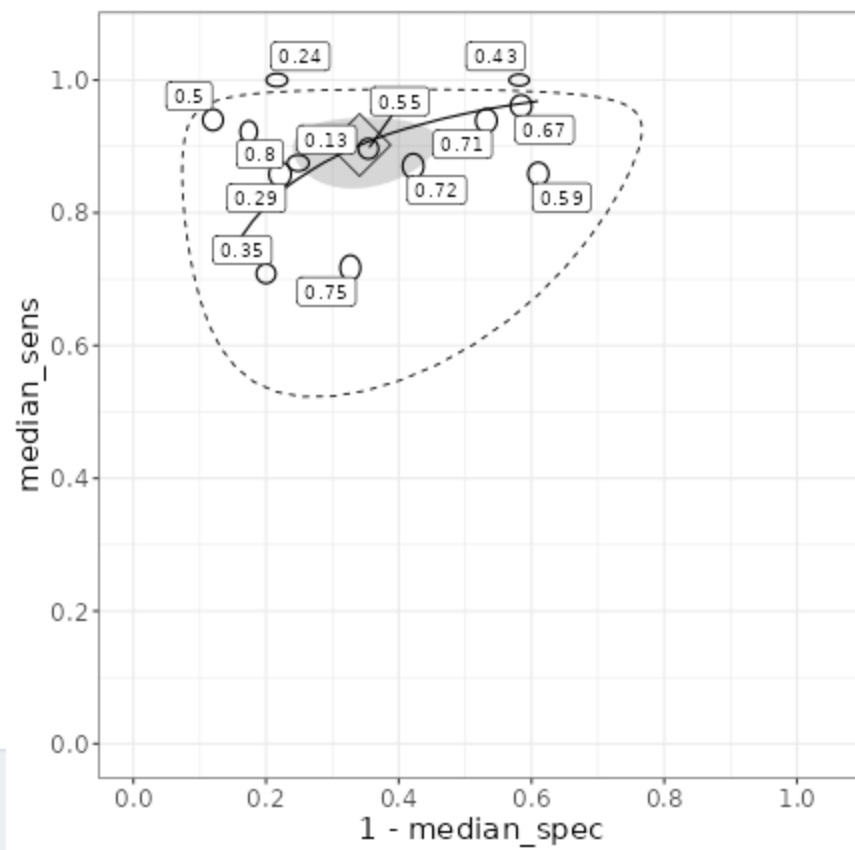


Figure S10. SROC curve for Smartphone PPG, demonstrating the hierarchical SROC (HSROC) curve with the pooled sensitivity and specificity estimate, along with the 95% confidence region and 95% prediction region for the included studies

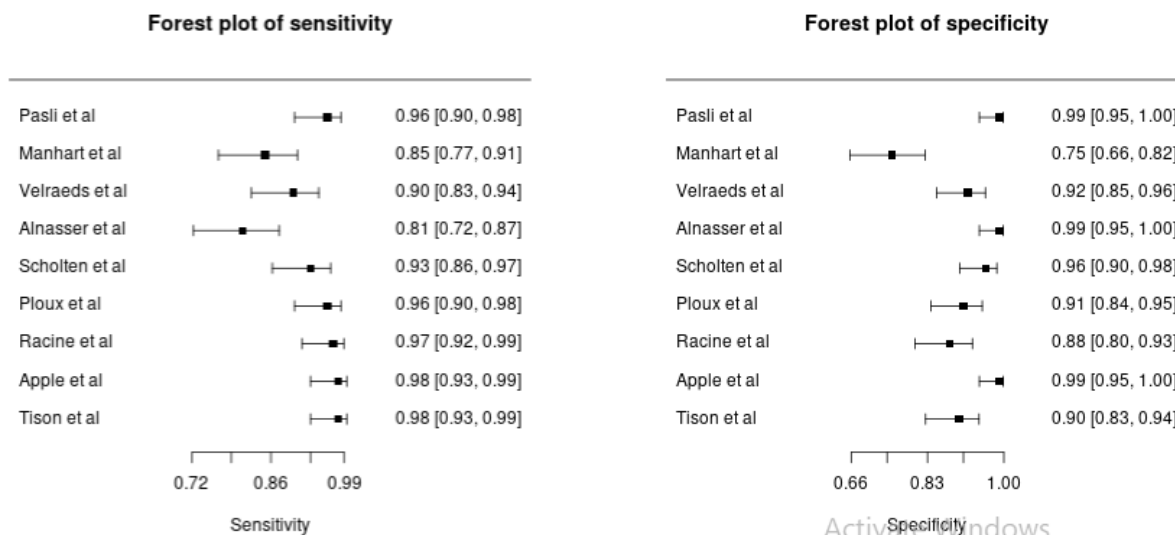


Figure S11. Forest plots of diagnostic accuracy showing the sensitivity and specificity estimates with 95% confidence intervals for Apple Watch Dedicated Subset.

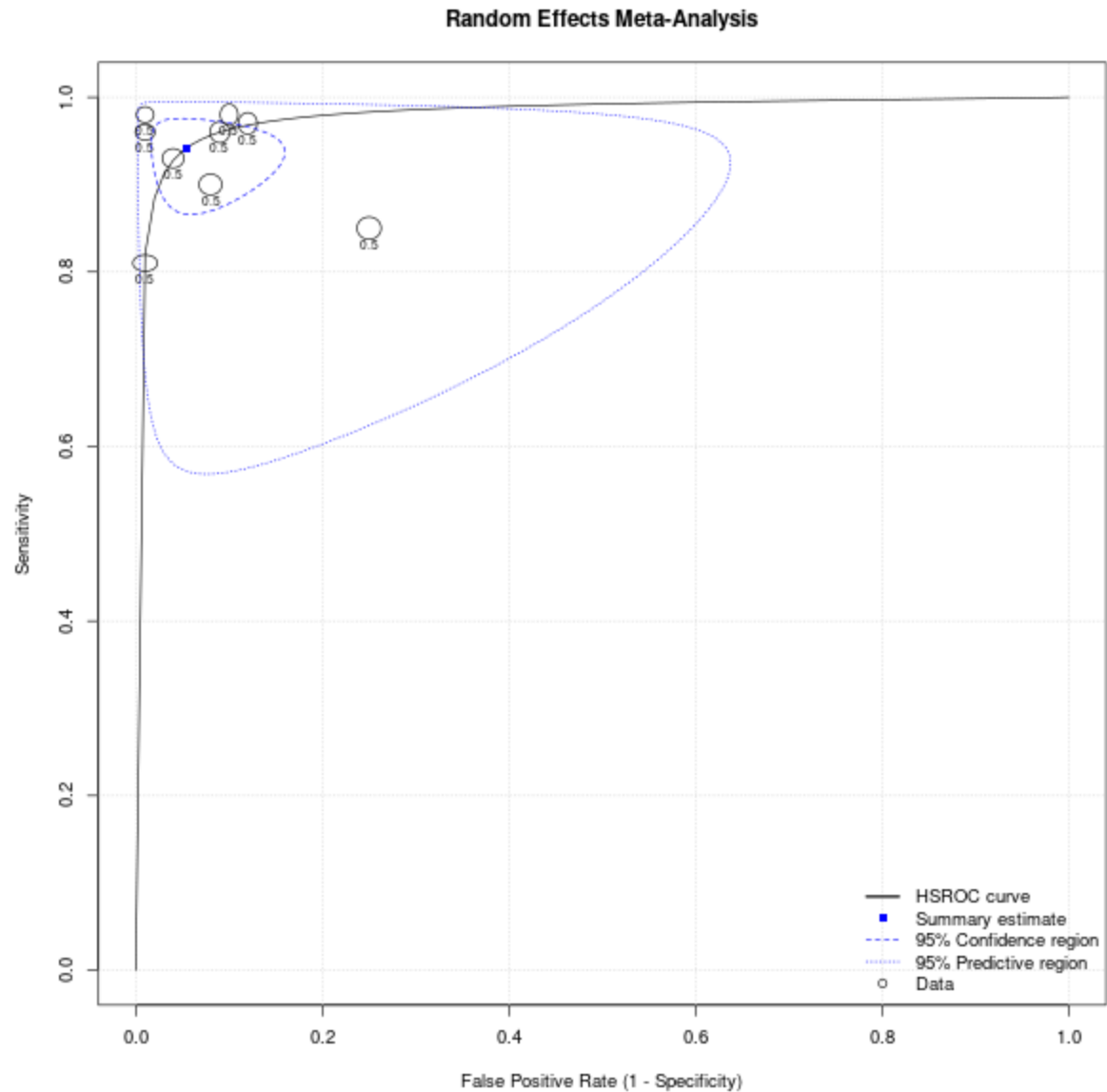


Figure S12. SROC curve for Apple Watch Dedicated Subset, demonstrating the hierarchical SROC (HSROC) curve with the pooled sensitivity and specificity estimate, along with the 95% confidence region and 95% prediction region for the included studies.

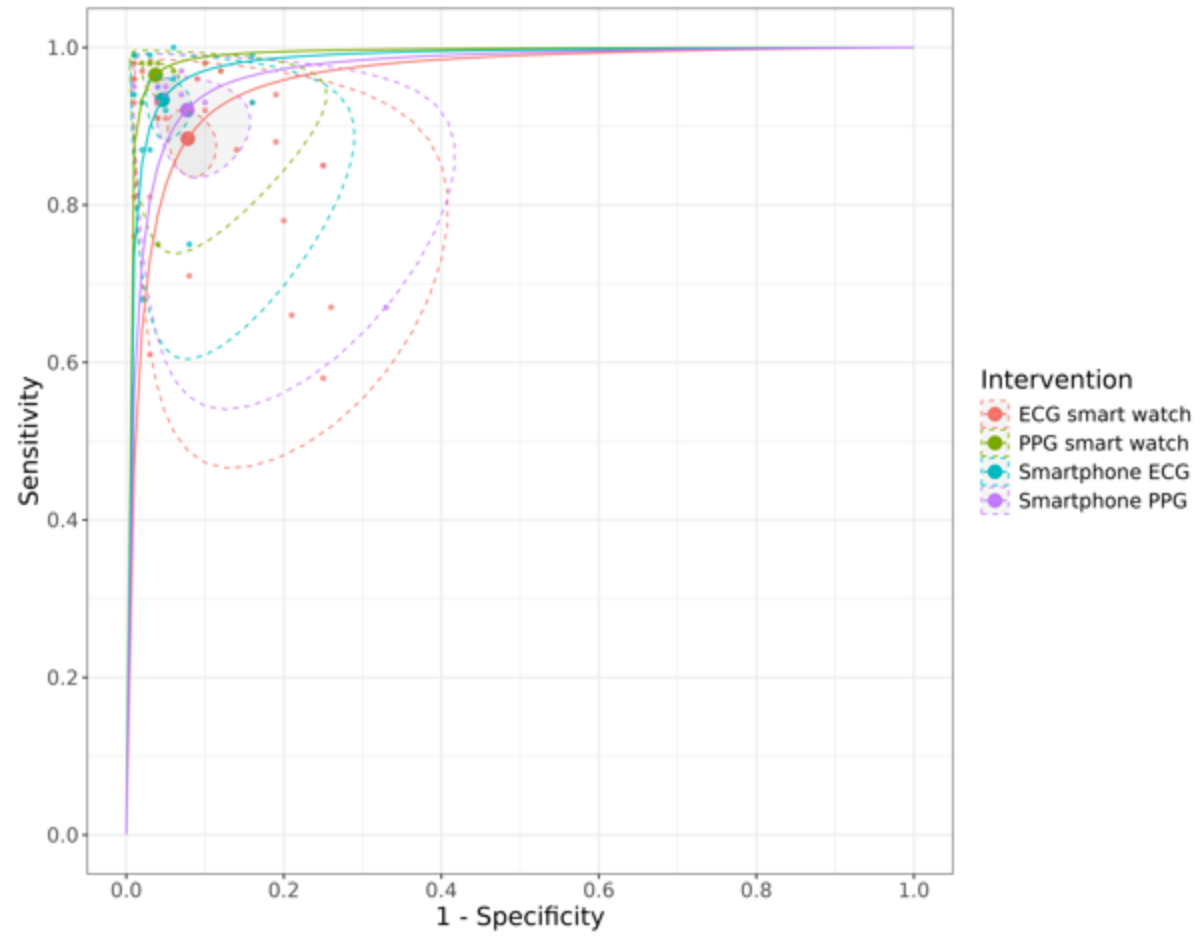


Figure S13. Regression analysis

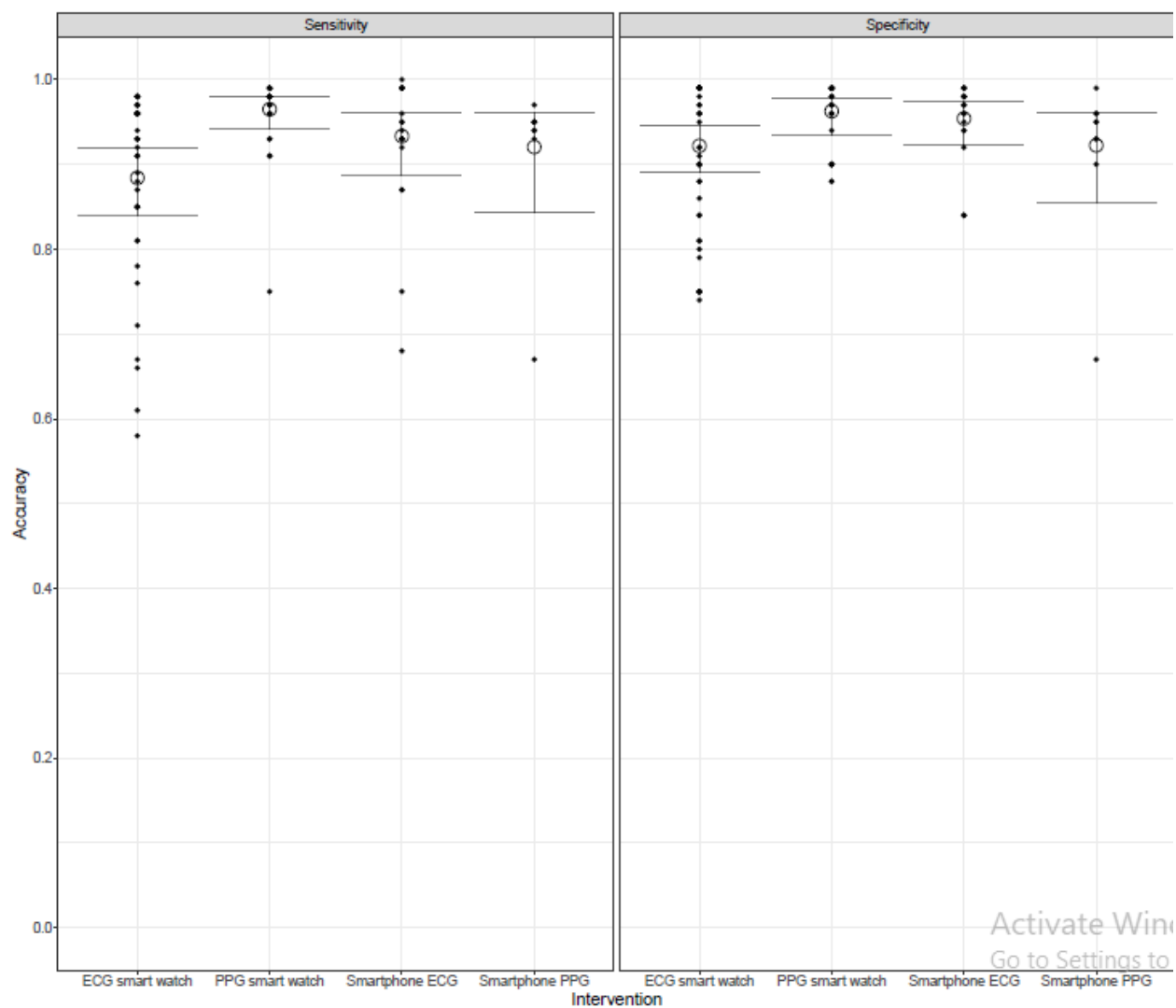


Figure S14. Accuracy plot for each intervention

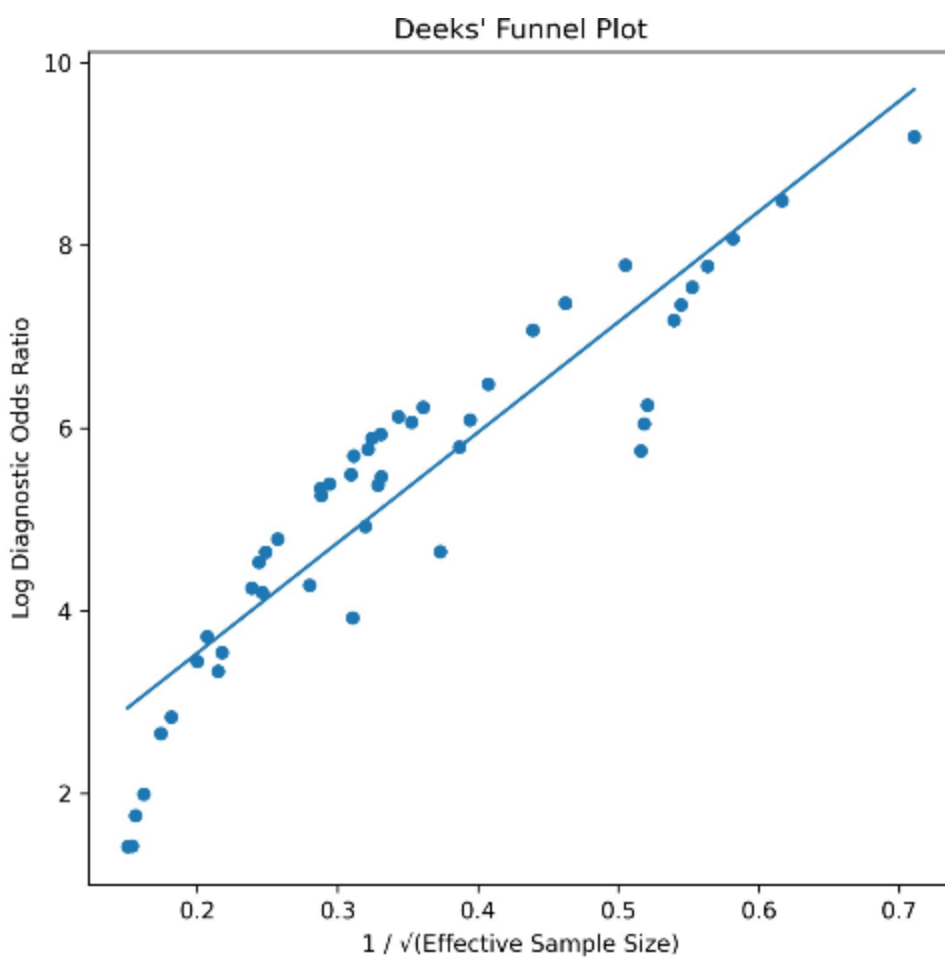


Figure S15. Publication bias plot