BTS Guideline for diagnosing and monitoring paediatric sleep disordered breathing

Online Appendix 2 Question 2 Evidence Review and Protocol

Q2 For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Contents

Question Evidence Review

Q2 For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Background

Current tests in the UK for diagnosing or detecting sleep disordered breathing (SDB) in children are pulse oximetry, cardiorespiratory sleep study (CRSS) and polysomnography (PSG). When choosing which test to perform, considerations include which tests are accessible to the entire UK paediatric population, which tests are cost effective and which tests can accurately identify SDB. In the UK there is a desire to use simple investigations to detect SDB wherever possible, so this review evaluates the diagnostic accuracy of pulse oximetry and CRSS to diagnose SDB in children with suspected SDB.

Outcomes

Diagnostic accuracy of pulse oximetry and CRSS to diagnose SDB in children

Evidence Review

The initial literature search identified 229 papers, but only nine were deemed suitable for the review.[1-9] All studies that were not truly reflective of standard UK pulse oximetry or CRSS clinical practice were excluded. All included studies used PSG as a gold standard, but due to the limited number of relevant studies, there was heterogeneity in the pulse oximetry and CRSS parameters used across the studies (Table 2a). Please note that due to the lack of supporting evidence, some of the included studies had a mixed population within their study group (i.e. children with and without comorbidities)[1,2,7,8], or information on the inclusion of children with obesity, or lesser comorbidities was not provided[4,5,9].

Pulse oximetry

Fifteen analyses from seven studies investigated the diagnostic accuracy of pulse oximetry in the diagnosis of SDB in children, with the pooled estimates showing a sensitivity and specificity of 0.82 [0.76-0.87] and 0.75 [0.60-0.85] respectively [95% confidence intervals] (Figure 2a).[1-7]

Pulse oximetry (AHI ≥1)

Sub-analysis of the diagnostic accuracy of pulse oximetry to diagnose an apnoea-hypopnea index (AHI) ≥1 in children with suspected SDB gave a pooled estimate sensitivity of 0.81 [0.69-0.89] and specificity of 0.83 [0.58-0.94] [95% confidence intervals] (Figure 2b).[1,2,4-7]

Pulse oximetry (AHI ≥5)

For diagnosing moderate-to-severe SDB in children (AHI ≥5) using pulse oximetry, the pooled estimate sensitivity and specificity were 0.81 [0.74-0.87] and 0.62 [0.43, 0.78] respectively [95% confidence intervals] (Figure 2c).[1,3-5,7]

Pulse oximetry (AHI ≥10)

Finally, for diagnosing severe SDB in children (AHI ≥10) using pulse oximetry, the pooled estimate sensitivity and specificity were 0.95 [0.44-1.00] and 0.72 [0.31, 0.94] respectively [95% confidence intervals] (Figure 2d).[1,4,5]

Pulse oximetry – children without comorbidities

Only two studies focused on children without comorbidities[3,6], with one study using a cut-off value of AHI ≥1[6] and the other AHI >5[3]. Despite the inconsistency in the AHI cut-off values, a meta-analysis was performed (Figure 2e) and a summary of the results is shown in Table 2b.

CRSS (all)

Five analyses (from two studies) evaluated the diagnostic accuracy of CRSS for diagnosing SDB in children. Meta-analysis of the results showed a pooled sensitivity of 0.76 [0.68, 0.85] and pooled specificity of 0.96 [0.84, 0.99] [95% confidence intervals] (Figure 2f).[8,9]

CRSS (AHI ≥1)

Two studies specifically investigated the diagnostic accuracy of CRSS for diagnosing AHI ≥1, reporting a sensitivity and specificity of 0.84 [0.76, 0.89] and 0.81 [0.67, 0.90] respectively [95% confidence intervals] (Figure 2g).[8,9] Due to the lack of supporting evidence, one dataset with a cut-off value of AHI ≥1.5 was included in the CRSS (AHI ≥1) analysis.[8]

CRSS (AHI ≥5)

Finally, two studies reported on the diagnostic accuracy of CRSS for diagnosing AHI ≥5, giving a pooled estimate sensitivity of 0.65 [0.52, 0.76] and specificity of 0.98 [0.89, 1.00] [95% confidence intervals] (Figure 2h).[8,9]

A summary of all pulse oximetry and CRSS meta-analyses results is shown in Table 2c.

Table 2a: Pulse oximetry and CRSS parameters

Study	**PSG cut-off**	**Oximetry/CRSS variable(s) measured/cut-off**
Pulse oximetry		
Ehsan 2020[1]	AHI>1	ODI_4 >3
	AHI≥5	ODI_4 >3
	AHI≥10	ODI_4 >3
Jonas 2020[2]	AHI≥1	McGill scores 1-4
Kirk 2003[3]	AHI >5	DI >5
Ma 2018[4]	AHI >1	ODI_4 (corresponding cut-offs not specified)
	AHI >5	
	AHI >10	
	AHI >20	
Tsai 2013[5]	AHI ≥1	DI cut off 2.05*
	AHI ≥5	DI cut off 3.50*
	AHI ≥10	DI cut off 4.15*
Velasco Suarez 2013[6]	AHI ≥1	≥2 desaturation clusters, with at least one cluster < 90%
Wiebracht 2018[7]	AHI ≥1	ODI >1.19*
	AHI ≥5	ODI >2.40*
CRSS		
Masoud 2019[8]	AHI ≥1.5	AHI ≥1.5
	AHI ≥5	AHI ≥5
	AHI ≥10	AHI ≥10
Tan 2014[9]	AHI ≥1	AHI ≥1
	AHI ≥5	AHI ≥5

* Desaturation Index cut offs generated by receiver operator curve analysis

AHI – apnoea hypopnoea index; DI – desaturation index; ODI – oxygen desaturation index; ODI_4 – 4% oxygen desaturation index

Table 2b: Diagnostic accuracy of pulse oximetry for diagnosing sleep disordered breathing in children without comorbidities

Included data	No. datasets	No. subjects	Sensitivity [95% CI]	Specificity [95% CI]
Pulse oximetry (all)	2	224	0.77 [0.59, 0.90]	0.92 [0.36, 1.00]
Pulse oximetry (AHI ≥1)	1	167	0.87 [0.77, 0.93]	0.99 [0.94, 1.00]
Pulse oximetry (AHI ≥5)	1	57	0.67 [0.46, 0.83]	0.60 [0.41, 0.77]

Table 2c: Diagnostic accuracies of pulse oximetry and cardiorespiratory sleep study for diagnosing sleep disordered breathing in children

Included data	No. datasets	No. subjects	Sensitivity [95% CI]	Specificity [95% CI]
Pulse oximetry (all)	15	1704	0.82 [0.76, 0.87]	0.75 [0.60, 0.85]
Pulse oximetry (AHI ≥1)	6	894	0.81 [0.69, 0.89]	0.83 [0.58, 0.94]
Pulse oximetry (AHI ≥5)	5	617	0.81 [0.74, 0.87]	0.62 [0.43, 0.78]
Pulse oximetry (AHI ≥10)	3	218	0.95 [0.44, 1.00]	0.72 [0.31, 0.94]
CRSS (all)	5	410	0.76 [0.68, 0.85]	0.96 [0.84, 0.99]
CRSS (AHI ≥1)*	2	170	0.84 [0.76, 0.89]	0.81 [0.67, 0.90]
CRSS (AHI ≥5)	2	170	0.65 [0.52, 0.76]	0.98 [0.89, 1.00]

CI – confidence intervals; CRSS – cardiorespiratory sleep study

* Due to the lack of supporting evidence, one dataset with a cut-off value of AHI ≥1.5 was included in the CRSS (AHI ≥1) analysis

Evidence statements

Pulse oximetry appears to have a high sensitivity and moderate specificity for diagnosing sleep disordered breathing in children (**Very low**)

Pulse oximetry also appears to have a high sensitivity and low specificity for diagnosing moderate-to-severe sleep disordered breathing (**Very low**) and a very high sensitivity and moderate specificity for diagnosing severe sleep disordered breathing in children (**Very low**)

Based on very limited evidence, cardiorespiratory sleep studies appear to have a moderate sensitivity and a very high specificity for diagnosing sleep disordered breathing in children (**Low**)

Recommendation

➢ For children with suspected sleep disordered breathing pulse oximetry can be considered as a first line diagnostic test for sleep disordered breathing. If a test result is normal, this does not exclude mild-to-moderate sleep disordered breathing and a clinical review should be undertaken to decide if a higher level of investigation is needed such as a cardiorespiratory sleep study (CRSS) (**Conditional**)

Good Practice Points

✓ If pulse oximetry is normal, but there is suspicion of sleep disordered breathing, a cardiorespiratory sleep study (CRSS) may be useful to identify mild OSA. Sleep video recording may also be considered to give a clearer picture

✓ If pulse oximetry is abnormal, cardiorespiratory sleep studies (CRSS) are more specific and can discriminate between central and obstructive events

✓ When analysing and interpreting paediatric pulse oximetry traces, a 4% oxygen desaturation index (ODI4) cut-off of >4/hr and/or a 3% oxygen desaturation index (ODI3) cut-off of >7/hr are suggestive of an abnormality in children over two years of age. Baseline mean oxygen saturation (SpO2) of <95%; desaturations to <90% and clustering and depth of desaturation events should also be considered in pulse oximetry interpretation.[10,11] If one pulse oximetry parameter is considered abnormal when the other parameters are considered normal, a cardiorespiratory sleep study should be considered

- ✓ While pulse oximetry is non-discriminatory at all ages particular caution is required in using oximetry to diagnose obstructive sleep apnoea in children under two years of age as children in this age group are predisposed to central sleep apnoea (as a result of developmental immaturity) and oxygen desaturations cannot discriminate between obstructive and central events
- ✓ If a child is unable to tolerate cardiorespiratory sleep study (CRSS) equipment, for example children with autistic spectrum disorder, consideration should be given to utilising play therapy techniques to facilitate data acquisition. Consideration should also be given to undertaking CRSS in the home (please see Supplementary Online Appendix 8)
- ✓ If a CRSS test result does not fit the clinical picture, polysomnography (PSG) should be considered. An exception to this is when CRSS rules out a diagnosis of SDB and a diagnostic pathway for narcolepsy should be considered (please see Supplementary Online Appendix 10)
- ✓ Clinicians are cautioned from using AHI alone to guide decision making
- ✓ If hypoventilation is suspected, guideline users should refer to Supplementary Online Appendix 3

Research Recommendations

- Further research is needed into determining how pulse oximetry can be combined with other information, such as history, or video or carbon dioxide recordings, to diagnose sleep disordered breathing in children
- As polysomnography provides a positive diagnosis of sleep disordered breathing in more children than cardiorespiratory sleep studies, research is needed on how cardiorespiratory sleep studies and polysomnography relate to clinical outcomes
- A UK standard for paediatric oximetry interpretation is required, particularly focusing on determining oxygen desaturation index (ODI) values that relate to different severities of obstructive sleep apnoea/sleep disordered breathing in children

Meta-analyses

Diagnostic accuracy table contents and summary receiver operating characteristic (SROC) curve legend

<u>*Table contents*</u>

Pooled sensitivity [95% confidence intervals]

Pooled specificity [95% confidence intervals]

Likelihood ratio of a positive test result (LR+) [95% confidence intervals]

Likelihood ratio of a negative test result (LR-) [95% confidence intervals]

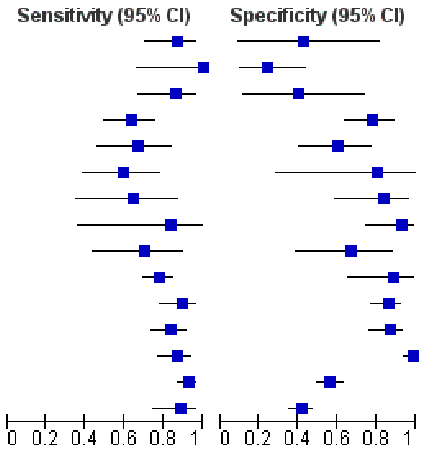
Diagnostic odds ratio (DOR, an indicator of the likelihood of a positive test result) [95% confidence intervals]

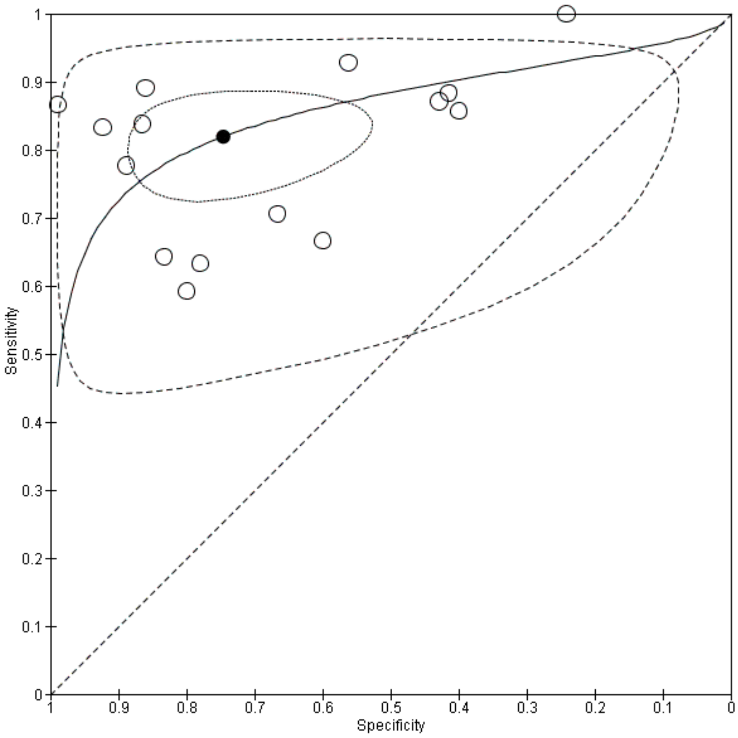
<u>*Summary receiver operating characteristic (SROC) curve legend*</u>

—	SROC
○	Study estimate
●	Summary point
········	95% confidence region
- - -	95% prediction region

Figure 2a Pulse oximetry (all data)

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Ehsan 2020 AHI1	27	4	4	3	0.87 [0.70, 0.96]	0.43 [0.10, 0.82]
Ehsan 2020 AHI10	9	22	0	7	1.00 [0.66, 1.00]	0.24 [0.10, 0.44]
Ehsan 2020 AHI5	24	6	4	4	0.86 [0.67, 0.96]	0.40 [0.12, 0.74]
Jonas 2020 AHI1	38	11	22	39	0.63 [0.50, 0.75]	0.78 [0.64, 0.88]
Kirk 2003 AHI5	18	12	9	18	0.67 [0.46, 0.83]	0.60 [0.41, 0.77]
Ma 2018 AHI1	16	1	11	4	0.59 [0.39, 0.78]	0.80 [0.28, 0.99]
Ma 2018 AHI10	9	3	5	15	0.64 [0.35, 0.87]	0.83 [0.59, 0.96]
Ma 2018 AHI20	5	2	1	24	0.83 [0.36, 1.00]	0.92 [0.75, 0.99]
Ma 2018 AHI5	12	5	5	10	0.71 [0.44, 0.90]	0.67 [0.38, 0.88]
Tsai 2013 AHI1	101	2	29	16	0.78 [0.70, 0.85]	0.89 [0.65, 0.99]
Tsai 2013 AHI10	49	13	6	80	0.89 [0.78, 0.96]	0.86 [0.77, 0.92]
Tsai 2013 AHI5	62	10	12	64	0.84 [0.73, 0.91]	0.86 [0.77, 0.93]
Velasco Suarez 2013 AHI1	65	1	10	91	0.87 [0.77, 0.93]	0.99 [0.94, 1.00]
Wiebracht 2018 AHI1	116	95	9	122	0.93 [0.87, 0.97]	0.56 [0.49, 0.63]
Wiebracht 2018 AHI5	38	175	5	124	0.88 [0.75, 0.96]	0.41 [0.36, 0.47]

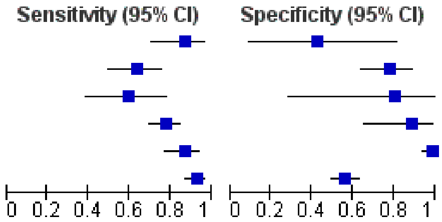


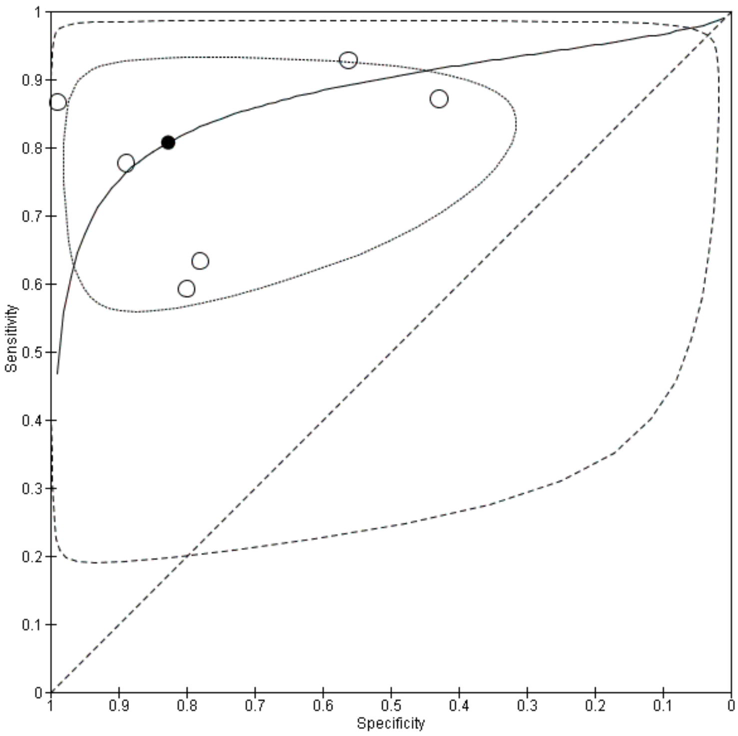


Pooled Sensitivity	0.819	[0.755, 0.870]
Pooled Specificity	0.746	[0.596, 0.854]
LR+	3.224	[1.948, 5.335]
LR-	0.242	[0.175, 0.336]
DOR	13.305	[6.514, 27.177]

Figure 2b Pulse oximetry (AHI ≥1)

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Ehsan 2020	27	4	4	3	0.87 [0.70, 0.96]	0.43 [0.10, 0.82]
Jonas 2020	38	11	22	39	0.63 [0.50, 0.75]	0.78 [0.64, 0.88]
Ma 2018	16	1	11	4	0.59 [0.39, 0.78]	0.80 [0.28, 0.99]
Tsai 2013	101	2	29	16	0.78 [0.70, 0.85]	0.89 [0.65, 0.99]
Velasco Suarez 2013	65	1	10	91	0.87 [0.77, 0.93]	0.99 [0.94, 1.00]
Wiebracht 2018	116	95	9	122	0.93 [0.87, 0.97]	0.56 [0.49, 0.63]

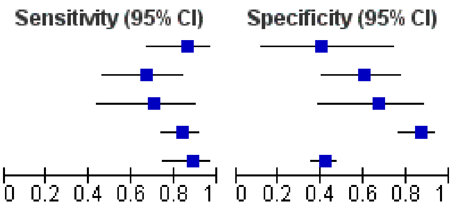


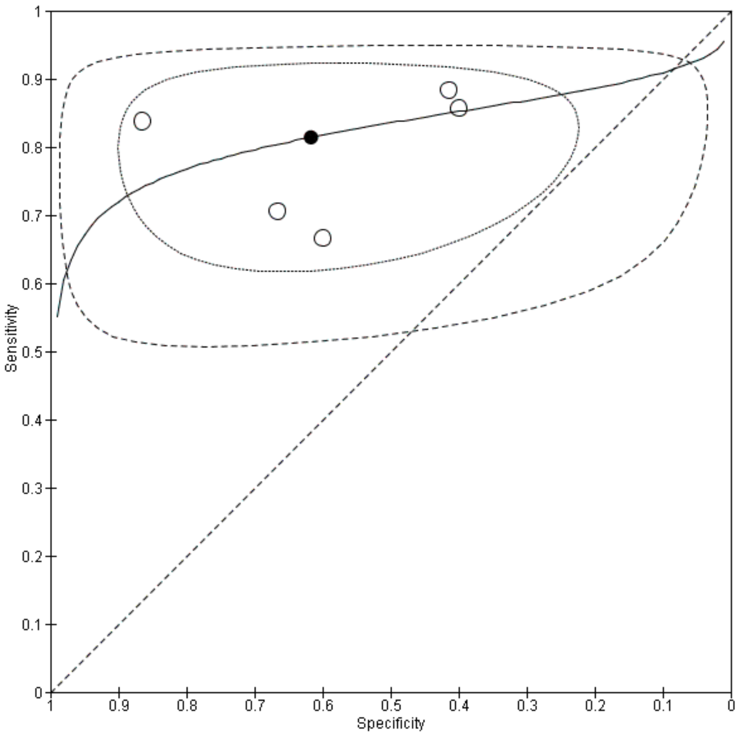


Pooled Sensitivity	0.807	[0.690, 0.887]
Pooled Specificity	0.827	[0.582, 0.942]
LR+	4.659	[1.706, 12.726]
LR-	0.233	[0.139, 0.392]
DOR	19.972	[5.501, 72.514]

Figure 2c Pulse oximetry (AHI ≥5)

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Ehsan 2020	24	6	4	4	0.86 [0.67, 0.96]	0.40 [0.12, 0.74]
Kirk 2003	18	12	9	18	0.67 [0.46, 0.83]	0.60 [0.41, 0.77]
Ma 2018	12	5	5	10	0.71 [0.44, 0.90]	0.67 [0.38, 0.88]
Tsai 2013	62	10	12	64	0.84 [0.73, 0.91]	0.86 [0.77, 0.93]
Wiebracht 2018	38	175	5	124	0.88 [0.75, 0.96]	0.41 [0.36, 0.47]

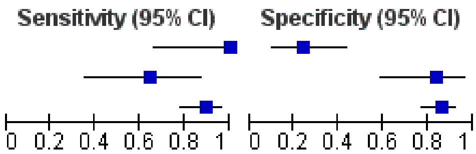




Pooled Sensitivity	0.814	[0.737, 0.873]
Pooled Specificity	0.617	[0.426, 0.778]
LR+	2.126	[1.319, 3.426]
LR-	0.301	[0.193, 0.471]
DOR	7.054	[2.999, 16.592]

Figure 2d Pulse oximetry (AHI ≥10)

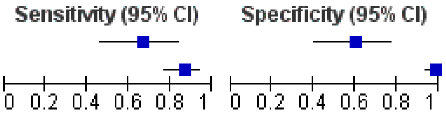
Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Ehsan 2020	9	22	0	7	1.00 [0.66, 1.00]	0.24 [0.10, 0.44]
Ma 2018	9	3	5	15	0.64 [0.35, 0.87]	0.83 [0.59, 0.96]
Tsai 2013	49	13	6	80	0.89 [0.78, 0.96]	0.86 [0.77, 0.92]



Pooled Sensitivity	0.946	[0.441, 0.997]
Pooled Specificity	0.723	[0.317, 0.937]
LR+	3.422	[1.099, 10.652]
LR-	0.074	[0.005, 1.007]
DOR	46.158	[5.196, 410.034]

Figure 2e Pulse oximetry (all data) – children without comorbidities

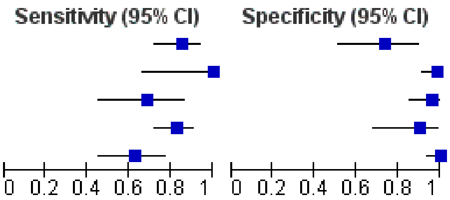
Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Kirk 2003	18	12	9	18	0.67 [0.46, 0.83]	0.60 [0.41, 0.77]
Velasco Suarez 2013	65	1	10	91	0.87 [0.77, 0.93]	0.99 [0.94, 1.00]

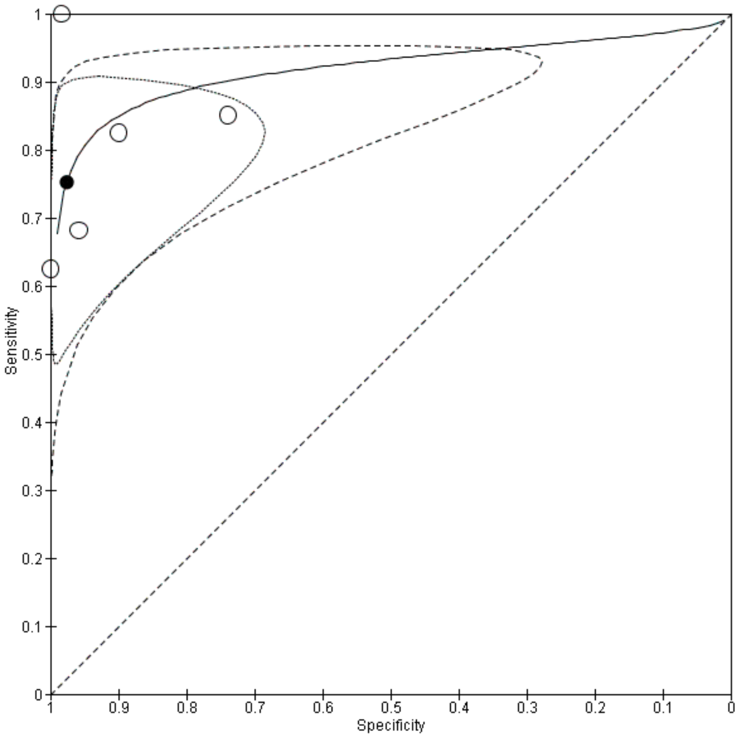


Pooled Sensitivity	0.786	[0.588, 0.904]
Pooled Specificity	0.920	[0.363, 0.996]
LR+	9.773	[0.528, 180.897]
LR-	0.233	[0.091, 0.597]
DOR	41.920	[0.954, 1842.531]

Figure 2f CRSS (all data)

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Masoud 2019 AHI1.5	40	6	7	17	0.85 [0.72, 0.94]	0.74 [0.52, 0.90]
Masoud 2019 AHI10	9	1	0	60	1.00 [0.66, 1.00]	0.98 [0.91, 1.00]
Masoud 2019 AHI5	15	2	7	46	0.68 [0.45, 0.86]	0.96 [0.86, 0.99]
Tan 2014 AHI1	66	2	14	18	0.82 [0.72, 0.90]	0.90 [0.68, 0.99]
Tan 2014 AHI5	25	0	15	60	0.63 [0.46, 0.77]	1.00 [0.94, 1.00]

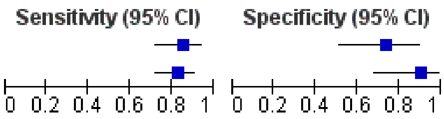




Pooled Sensitivity	0.755	[0.677, 0.850]
Pooled Specificity	0.961	[0.841, 0.991]
LR+	19.787	[4.802, 81.531]
LR-	0.234	[0.164, 0.334]
DOR	84.397	[22.342, 318.810]

Figure 2g CRSS (AHI ≥1)

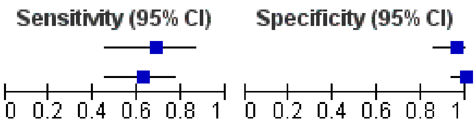
Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Masoud 2019 AHI1.5	40	6	7	17	0.85 [0.72, 0.94]	0.74 [0.52, 0.90]
Tan 2014 AHI1	66	2	14	18	0.82 [0.72, 0.90]	0.90 [0.68, 0.99]



Pooled Sensitivity	0.835	[0.760, 0.890]
Pooled Specificity	0.814	[0.670, 0.904]
LR+	4.486	[2.389, 8.423]
LR-	0.203	[0.134, 0.308]
DOR	22.083	[8.983, 54.289]

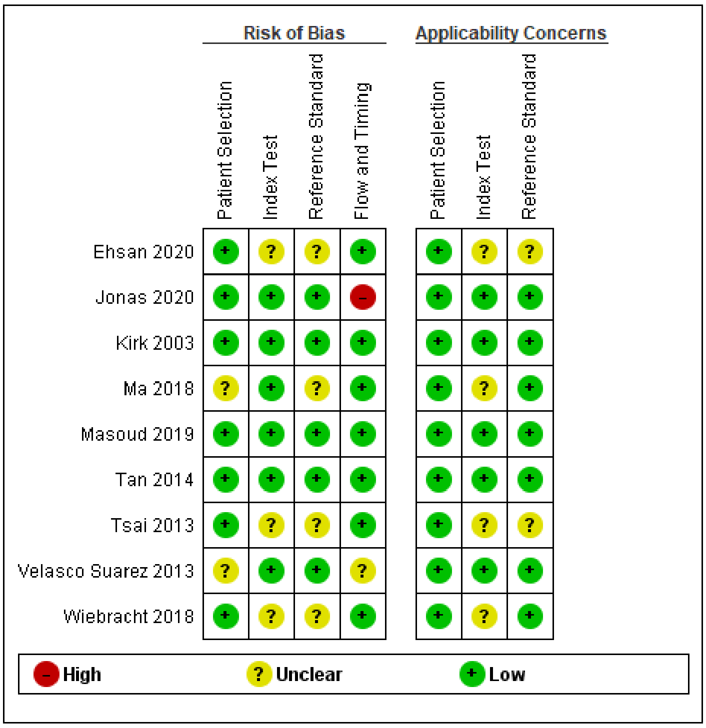
Figure 2h CRSS (AHI ≥5)

Study	TP	FP	FN	TN	Sensitivity (95% CI)	Specificity (95% CI)
Masoud 2019	15	2	7	46	0.68 [0.45, 0.86]	0.96 [0.86, 0.99]
Tan 2014	25	0	15	60	0.63 [0.46, 0.77]	1.00 [0.94, 1.00]



Pooled Sensitivity	0.648	[0.517, 0.759]
Pooled Specificity	0.984	[0.885, 0.998]
LR+	41.374	[5.244, 326.406]
LR-	0.358	[0.252, 0.508]
DOR	115.573	[13.506, 988.945]

Risk of bias summary



GRADE analyses

Pulse oximetry (all data)

For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Patient or population: Children (<17 years) with suspected sleep disordered breathing

New test: Pulse oximetry

Pooled sensitivity: 0.82 (95% CI: 0.76 to 0.87) | **Pooled specificity**: 0.75 (95% CI: 0.60 to 0.85)

Test result	Number of results per 1,000 patients tested (95% CI)	Number of participants (studies)	Certainty of the Evidence (GRADE)
	Prevalence 40%* Typically seen in		
True positives	**328** (302 to 348)	721 (15)	⊕◯◯◯ **VERY LOW** [a,b]
False negatives	**72** (52 to 98)		
True negatives	**448** (358 to 512)	983 (15)	⊕◯◯◯ **VERY LOW** [a,b]
False positives	**152** (88 to 242)		
	Prevalence 60%* Typically seen in		
True positives	**491** (453 to 522)	721 (15)	⊕◯◯◯ **VERY LOW** [a,b]
False negatives	**109** (78 to 147)		
True negatives	**298** (238 to 342)	983 (15)	⊕◯◯◯ **VERY LOW** [a,b]
False positives	**102** (58 to 162)		
	Prevalence 80%* Typically seen in		
True positives	**655** (604 to 696)	721 (15)	⊕◯◯◯ **VERY LOW** [a,b]
False negatives	**145** (104 to 196)		
True negatives	**149** (119 to 171)	983 (15)	⊕◯◯◯ **VERY LOW** [a,b]
False positives	**51** (29 to 81)		

CI: Confidence interval

Explanations

a. High risk of bias across studies
b. Specificity inconsistency across the studies
c. Specificity imprecision across the studies and variation in confidence intervals

* 40% typically seen in district general hospitals; 60% typically seen in general respiratory clinics; 80% typically seen in sleep clinics

Pulse oximetry (AHI ≥1)

For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Patient or population: Children (<17 years) with suspected sleep disordered breathing

New test: Pulse oximetry (AHI ≥1)

Pooled sensitivity: 0.81 (95% CI: 0.69 to 0.89) | **Pooled specificity**: 0.83 (95% CI: 0.58 to 0.94)

Test result	Number of results per 1,000 patients tested (95% CI)	Number of participants (studies)	Certainty of the Evidence (GRADE)
	Prevalence 40%* Typically seen in		
True positives	**323** (276 to 355)	448 (6)	⨁◯◯◯ **VERY LOW** [a,b,c]
False negatives	**77** (45 to 124)		
True negatives	**496** (349 to 565)	389 (6)	⨁◯◯◯ **VERY LOW** [a,b,c]
False positives	**104** (35 to 251)		
	Prevalence 60%* Typically seen in		
True positives	**484** (414 to 532)	448 (6)	⨁◯◯◯ **VERY LOW** [a,b,c]
False negatives	**116** (68 to 186)		
True negatives	**331** (233 to 377)	389 (6)	⨁◯◯◯ **VERY LOW** [a,b,c]
False positives	**69** (23 to 167)		
	Prevalence 80%* Typically seen in		
True positives	**646** (552 to 710)	448 (6)	⨁◯◯◯ **VERY LOW** [a,b,c]
False negatives	**154** (90 to 248)		
True negatives	**165** (116 to 188)	389 (6)	⨁◯◯◯ **VERY LOW** [a,b,c]
False positives	**35** (12 to 84)		

CI: Confidence interval

Explanations

a. High risk of bias across studies
b. Some inconsistency in specificity
c. Large specificity confidence intervals in some datasets

* 40% typically seen in district general hospitals; 60% typically seen in general respiratory clinics; 80% typically seen in sleep clinics

Pulse oximetry (AHI ≥5)

For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Patient or population: Children (<17 years) with suspected sleep disordered breathing

New test: Pulse oximetry (AHI ≥5)

Pooled sensitivity: 0.81 (95% CI: 0.74 to 0.87) | **Pooled specificity**: 0.62 (95% CI: 0.43 to 0.78)

Test result	Number of results per 1,000 patients tested (95% CI)	Number of participants (studies)	Certainty of the Evidence (GRADE)
	Prevalence 40%* Typically seen in		
True positives	**326** (295 to 349)	189 (5)	⨁◯◯◯ **VERY LOW** [a,b,c]
False negatives	**74** (51 to 105)		
True negatives	**370** (256 to 467)	428 (5)	⨁◯◯◯ **VERY LOW** [a,b,c]
False positives	**230** (133 to 344)		
	Prevalence 60%* Typically seen in		
True positives	**488** (442 to 524)	189 (5)	⨁◯◯◯ **VERY LOW** [a,b,c]
False negatives	**112** (76 to 158)		
True negatives	**247** (170 to 311)	428 (5)	⨁◯◯◯ **VERY LOW** [a,b,c]
False positives	**153** (89 to 230)		
	Prevalence 80%* Typically seen in		
True positives	**651** (590 to 698)	189 (5)	⨁◯◯◯ **VERY LOW** [a,b,c]
False negatives	**149** (102 to 210)		
True negatives	**123** (85 to 156)	428 (5)	⨁◯◯◯ **VERY LOW** [a,b,c]
False positives	**77** (44 to 115)		

CI: Confidence interval

Explanations

a. High risk of bias across studies
b. Specificity inconsistency across the studies
c. Moderate specificity confidence intervals in some datasets

* 40% typically seen in district general hospitals; 60% typically seen in general respiratory clinics; 80% typically seen in sleep clinics

Pulse oximetry (AHI ≥10)

For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Patient or population: Children (<17 years) with suspected sleep disordered breathing

New test: Pulse oximetry (AHI ≥10)

Pooled sensitivity: 0.95 (95% CI: 0.44 to 1.00) | **Pooled specificity**: 0.72 (95% CI: 0.32 to 0.94)

Test result	Number of results per 1,000 patients tested (95% CI)	Number of participants (studies)	Certainty of the Evidence (GRADE)
	Prevalence 40%* Typically seen in		
True positives	**378** (176 to 399)	78 (3)	⨁◯◯◯ VERY LOW [a,b,c]
False negatives	**22** (1 to 224)		
True negatives	**434** (190 to 562)	140 (3)	⨁◯◯◯ VERY LOW [a,b,c]
False positives	**166** (38 to 410)		
	Prevalence 60%* Typically seen in		
True positives	**568** (265 to 598)	78 (3)	⨁◯◯◯ VERY LOW [a,b,c]
False negatives	**32** (2 to 335)		
True negatives	**289** (127 to 375)	140 (3)	⨁◯◯◯ VERY LOW [a,b,c]
False positives	**111** (25 to 273)		
	Prevalence 80%* Typically seen in		
True positives	**757** (353 to 798)	78 (3)	⨁◯◯◯ VERY LOW [a,b,c]
False negatives	**43** (2 to 447)		
True negatives	**145** (63 to 187)	140 (3)	⨁◯◯◯ VERY LOW [a,b,c]
False positives	**55** (13 to 137)		

CI: Confidence interval

Explanations

a. High risk of bias across studies
b. Serious inconsistency across the studies
c. Moderate sensitivity confidence intervals

* 40% typically seen in district general hospitals; 60% typically seen in general respiratory clinics; 80% typically seen in sleep clinics

CRSS (all data)

For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies?

Patient or population: Children (<17 years) with suspected sleep disordered breathing

New test: CRSS

Pooled sensitivity: 0.76 (95% CI: 0.68 to 0.85) | **Pooled specificity**: 0.96 (95% CI: 0.84 to 0.99)

Test result	Number of results per 1,000 patients tested (95% CI)	Number of participants (studies)	Certainty of the Evidence (GRADE)
	Prevalence 40%* Typically seen in		
True positives	**302** (271 to 340)	198 (5)	⨁⨁◯◯ **LOW** a,b
False negatives	**98** (60 to 129)		
True negatives	**577** (505 to 595)	212 (5)	⨁⨁◯◯ **LOW** a,b
False positives	**23** (5 to 95)		
	Prevalence 60%* Typically seen in		
True positives	**453** (406 to 510)	198 (5)	⨁⨁◯◯ **LOW** a,b
False negatives	**147** (90 to 194)		
True negatives	**384** (336 to 396)	212 (5)	⨁⨁◯◯ **LOW** a,b
False positives	**16** (4 to 64)		
	Prevalence 80%* Typically seen in		
True positives	**604** (542 to 680)	198 (5)	⨁⨁◯◯ **LOW** a,b
False negatives	**196** (120 to 258)		
True negatives	**192** (168 to 198)	212 (5)	⨁⨁◯◯ **LOW** a,b
False positives	**8** (2 to 32)		

CI: Confidence interval

Explanations

a. Some sensitivity inconsistency across the studies
b. Moderate sensitivity confidence intervals in some datasets

* 40% typically seen in district general hospitals; 60% typically seen in general respiratory clinics; 80% typically seen in sleep clinics

Recommendation Tables

Question Details

POPULATION:	Children (<17 years) with suspected sleep disordered breathing
INDEX TESTS:	Pulse oximetry and cardiorespiratory sleep study (CRSS)
GOLD STANDARD:	Polysomnography (PSG)
OUTCOME:	Diagnostic accuracy of pulse oximetry or CRSS for diagnosing sleep disordered breathing in children

Pulse oximetry

SUMMARY OF JUDGEMENTS

	JUDGEMENT						
PROBLEM	No	Probably no	Probably yes	**Yes**		Varies	Don't know
TEST ACCURACY	Very inaccurate	Inaccurate	**Accurate**	Very accurate		Varies	Don't know
DESIRABLE EFFECTS	Trivial	Small	Moderate	**Large**		Varies	Don't know
UNDESIRABLE EFFECTS	Large	Moderate	**Small**	Trivial		Varies	Don't know
CERTAINTY OF EVIDENCE	**Very low**	Low	Moderate	High			No included studies
BALANCE OF EFFECTS	Favours the comparison	Probably favours the comparison	Does not favour the intervention or the comparison	**Probably favours the intervention**	Favours the intervention	Varies	Don't know

TYPE OF RECOMMENDATION

Strong recommendation against the intervention	Conditional recommendation against the intervention	Conditional recommendation for either the intervention or the comparison	**Conditional recommendation for the intervention**	Strong recommendation for the intervention
☐	☐	☐	☒	☐

CONCLUSIONS

Recommendation

For children with suspected sleep disordered breathing, pulse oximetry can be considered as a first line screening test for diagnosing sleep disordered breathing

Justification

Pulse oximetry appears to have a high sensitivity and moderate specificity for diagnosing sleep disordered breathing in children (Very low), a high sensitivity and low specificity for diagnosing moderate-to-severe sleep disordered breathing (Very low) and a very high sensitivity and moderate specificity for diagnosing severe sleep disordered breathing in children (Very low)

Subgroup considerations

There were not enough data for subgroup consideration (typically developing children <2 years and typically developing children 2-16 years)

Research priorities

Further research is needed into determining how pulse oximetry can be combined with other information, such as history, or video or carbon dioxide recordings, to diagnose sleep disordered breathing in children

CRSS

SUMMARY OF JUDGEMENTS

	JUDGEMENT						
PROBLEM	No	Probably no	Probably yes	**Yes**		Varies	Don't know
TEST ACCURACY	Very inaccurate	Inaccurate	**Accurate**	Very accurate		Varies	Don't know
DESIRABLE EFFECTS	Trivial	Small	Moderate	**Large**		Varies	Don't know
UNDESIRABLE EFFECTS	Large	Moderate	**Small**	Trivial		Varies	Don't know
CERTAINTY OF EVIDENCE	Very low	Low	**Moderate**	High			No included studies
BALANCE OF EFFECTS	Favours the comparison	Probably favours the comparison	Does not favour the intervention or the comparison	**Probably favours the intervention**	Favours the intervention	Varies	Don't know

TYPE OF RECOMMENDATION

Strong recommendation against the intervention	Conditional recommendation against the intervention	Conditional recommendation for either the intervention or the comparison	Conditional recommendation for the intervention	**Strong recommendation for the intervention**
☐	☐	☐	☐	☒

CONCLUSIONS

Recommendation

For children with suspected sleep disordered breathing, CRSS is recommended for diagnosis when pulse oximetry results are negative

Justification

CRSS appear to have a moderate sensitivity and a very high specificity for diagnosing sleep disordered breathing in children (Low)

Subgroup considerations

There were not enough data for subgroup consideration (typically developing children <2 years and typically developing children 2-16 years)

Research priorities

As polysomnography provides a positive diagnosis of sleep disordered breathing in more children than cardiorespiratory sleep studies, research is needed on how cardiorespiratory sleep studies and polysomnography relate to clinical outcomes

References

1. Ehsan Z, He S, Huang G, Hossain MM, Simakajornboon N. Can overnight portable pulse oximetry be used to stratify obstructive sleep apnea risk in infants? A correlation analysis. *Pediatric Pulmonology.* 2020;55:2082-2088.
2. Jonas C, Thavagnanam S, Blecher G, Thambipillay G, Teng AY. Comparison of nocturnal pulse oximetry with polysomnography in children with sleep disordered breathing. *Sleep Breath.* 2020;24:703-707.
3. Kirk VG, Bohn SG, Flemons WW, Remmers JE. Comparison of home oximetry monitoring with laboratory polysomnography in children. *Chest.* 2003;124:1702-1708.
4. Ma JR, Huang JJ, Chen Q, Wu HT, Xiao KL, Zhang YT. Value of pulse oximetry watch for diagnosing pediatric obstructive sleep apnea/hypopnea syndrome. *Acta Otolaryngol (Stockh).* 2018;138:175-179.
5. Tsai CM, Kang CH, Su MC, et al. Usefulness of desaturation index for the assessment of obstructive sleep apnea syndrome in children. *International Journal of Pediatric Otorhinolaryngology.* 2013;77:1286-1290.
6. Velasco Suarez CT, Figueroa Turienzo JM, Len F, Mansilla E. Pulse oximetry recording in children with adenotonsillar hypertrophy: usefulness in the diagnostic of obstructive sleep apnea syndrome. *Archivos Argentinos de Pediatria.* 2013;111:196-201.
7. Wiebracht ND, He S, Cotton C, et al. Polysomnographic oxygen saturation findings for preteen children versus adolescents. *Otolaryngol Head Neck Surg.* 2018;158:187-193.
8. Masoud AI, Patwari PP, Adavadkar PA, Arantes H, Park C, Carley DW. Validation of the MediByte portable monitor for the diagnosis of sleep apnea in pediatric patients. *Journal of Clinical Sleep Medicine.* 2019; 15:733-742.
9. Tan HL, Gozal D, Ramirez HM, Bandla HP, Kheirandish-Gozal L. Overnight polysomnography versus respiratory polygraphy in the diagnosis of pediatric obstructive sleep apnea. *Sleep.* 2014;37:255-260.
10. Ong JWY, Williams D, Gavlak JC, Liddle N, Lowe P, Evans HJ. Observational study to define reference ranges for the 3% oxygen desaturation index during sleep in healthy children under 12 years using oximetry motion-resistant technology. *Archives of Disease in Childhood.* 2021;106:583-586. [Available online 20 October 2020]
11. Urschitz MS, Wolff J, Von Einem V, Urschitz-Duprat, PM, Schlaud M, Poets CF. Reference values for nocturnal home pulse oximetry during sleep in primary school children. *Chest.* 2003;123:96-101.

Question Protocol

Field	Content
Review Question	For children with suspected sleep disordered breathing, what is the diagnostic accuracy of pulse oximetry and cardiorespiratory sleep studies (CRSS)?
Type of review question	Diagnostic accuracy
Objective of the review	The aim of this question is to identify investigative tools relevant to the NHS (UK) that can accurately detect OSA; and: • Are accessible to the entire paediatric population, • Are cost-effective; and • Are able to accurately identify OSA so that children with this condition can be appropriately managed.
Eligibility criteria – population / disease / condition / issue / domain	Children (<17 years) with suspected sleep disordered breathing
Eligibility criteria – index test(s)	Pulse oximetry CRSS
Eligibility criteria – gold standard	Polysomnography
Outcomes and prioritisation	Diagnostic accuracy
Eligibility criteria – study design	Meta-analyses Randomised controlled trials – oximetry versus cardiorespiratory sleep studies Prospective Cohort Studies Retrospective Case Note Reviews
Other inclusion /exclusion criteria	Non-English language excluded unless full English translation Conference abstracts, Cochrane reviews, reviews Cochrane reviews and systematic reviews can be referenced in the text, but **DO NOT** use in a meta-analysis

Proposed sensitivity / subgroup analysis, or meta-regression	Typically developing children <2 years Typically developing children 2-16 years Children with co-morbidities <2 years Children with co-morbidities 2-16 years
Selection process – duplicate screening / selection / analysis	Agreement should be reached between Guideline members who are working on the question. If no agreement can be reached, a decision should be made by the Guideline co-chairs. If there is still no decision, the matter should be brought to the Guideline group and a decision will be made by consensus
Data management (software)	RevMan5 Meta-analysis data input. Evidence review/considered judgement. Storing Guideline text, tables, figures, etc. MetaDTA Data meta-analyses Gradepro Quality of evidence assessment / Recommendations
Information sources – databases and dates	MEDLINE, Embase, PubMED, Central Register of Controlled Trials and Cochrane Database of Systematic Reviews No date restrictions
Methods for assessing bias at outcome / study level	RevMan5 diagnostic accuracy full review template (based on QUADAS2) (follow instructions in '*BTS Guideline Process Handbook - Diagnostic Accuracy*')
Methods for quantitative analysis – combining studies and exploring (in)consistency	If 3 or more relevant studies: RevMan5 for forest plots, summary ROC plot MetaDTA to combine studies (pooled specificity, sensitivity, likelihood ratios, diagnostic odds ratio and confidence intervals) and calculate RevMan parameters for summary ROC plot (follow instructions in '*BTS Guideline Process Handbook - Diagnostic Accuracy*')
Meta-bias assessment – publication bias, selective reporting bias	GRADEpro Diagnostic accuracy quality of evidence assessment for each index test (follow instructions in '*BTS Guideline Process Handbook - Diagnostic Accuracy*')
Rationale / context – what is known	In the NHS there is a desire to use simple investigations to detect OSA wherever possible. Previous studies investigating oximetry parameters have demonstrated there is a tendency to underestimate OSA especially mild OSA. Accuracy is better for children with moderate OSA and in adult studies correlation is good for predicting OSA when the AHI is >10 (severe OSA). Cardiorespiratory sleep studies are known to underestimate AHI as

	determined by PSG. The clinical relevance of this under-estimation is uncertain.