

The completeness, accuracy and impact on alerts, of wearable vital signs monitoring in hospitalised patients

Supplementary Digital Content

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Appendix 1

The following table summarises completeness of data capture by each wearable sensor according to the duration of wear defined by the researchers (sensor log) and the wearable itself. This serves for comparison with other studies where completeness of data capture is variably defined and provides a check of the robustness of the completeness measurements reported.

A: Completeness from sensor log maintained by research team

Wearable	n	Overall % completeness	Completeness (%, per participant)
HR/RR	48	82.1	86.0 [64.4 – 95.9]
Temp	48	90.7	96.9 [80.7 – 99.3]
SpO ₂	48	63.0	62.5 [44.8-74.7]
BP	33	32.9	22.0 [15.0 – 45.0]

B: Completeness from data recorded by each wearable

Wearable	n	Overall % completeness	Completeness (%, per participant)
HR/RR	48	81.2	83.8 [64.1 – 95.7]
Temp	48	92.1	97.7 [79.7 – 99.8]
SpO ₂	48	68.6	72.3 [61.7 – 87.2]
BP	30	38.4	35.8 [16.3 – 47.6]

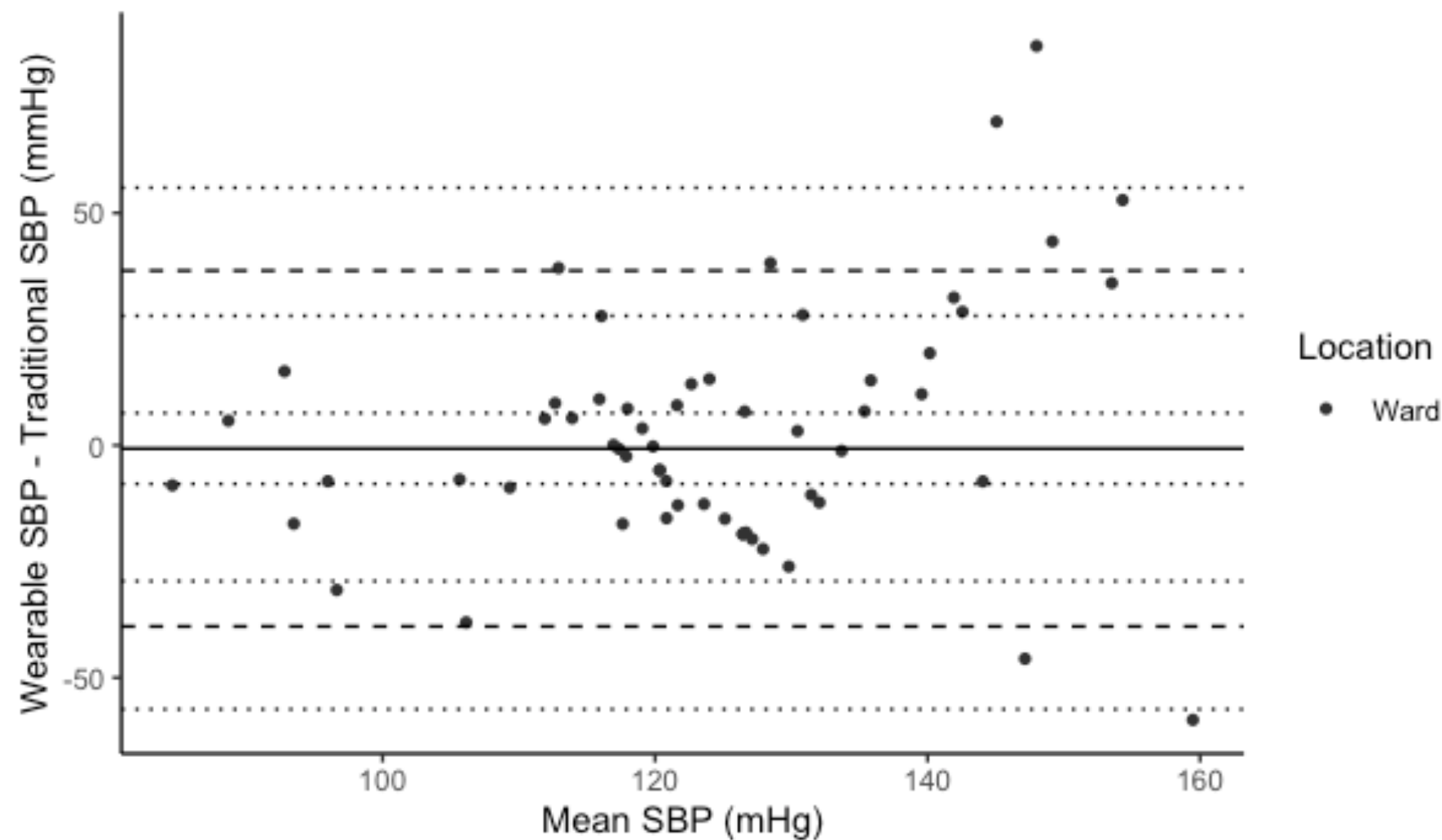
Appendix 1: percentage completeness of data capture for each of the four wearable vital sign sensors worn in the study. The numerator is the total number of minutes for which any vital sign is recorded by the wearable. In A the denominator is the total duration of device wear in minutes determined from the sensor log maintained by the research team. In B the denominator is the total duration of device wear defined as the difference in minutes between the first and last vital sign recorded by the device. HR/RR = heart rate/respiratory rate, Temp = temperature, SpO₂ = oxygen saturations, BP = blood pressure

Appendix 2

Event of interest	Parameter	Wearable sensor			
		HR/RR (LifeTouch)	SpO ₂ (Nonin PulseOx)	Temp (LifeTemp)	BP (A&D TM2441)
Any data loss	Median survival (hrs)	22.3 (5.4 to 38.5)	1.7 (1.1 to 2.3)	47.9 (43.5 to 67.4)	-
	24hr survival (%)	42.4 (30.2 to 59.4)	0	74.7 (62.7 to 88.9)	-
Data loss >15mins	Median survival (hrs)	46.7 (24.1 to 87.8)	9.3 (6.1 to 19.8)	142 (72.4 to ND)	-
	24hr survival (%)	63.5 (50.7 to 79.7)	20.5 (11.2 to 37.6)	88.4 (79.4 to 98.6)	-
Data loss >1hr	Median survival (hrs)	49.8 (37.9 to 108.0)	25.4 (17.6 to 45.1)	165.2 (142 to ND)	-
	24hr survival (%)	72.0 (59.7 to 86.9)	51.8 (38.3 to 70.2)	97.5 (92.8 to 100)	-
Data loss >4hrs	Median survival (hrs)	95.3 (76.1 to ND)	61.5 (42.9 to 88.5)	189.1 (189.1 to ND)	28.6 (20.1 to 70.7)
	24hr survival (%)	87.9 (78.5 to 98.4)	81.5 (70.0 to 94.9)	97.5 (92.8 to 100)	65.5 (47.7 to 89.9)

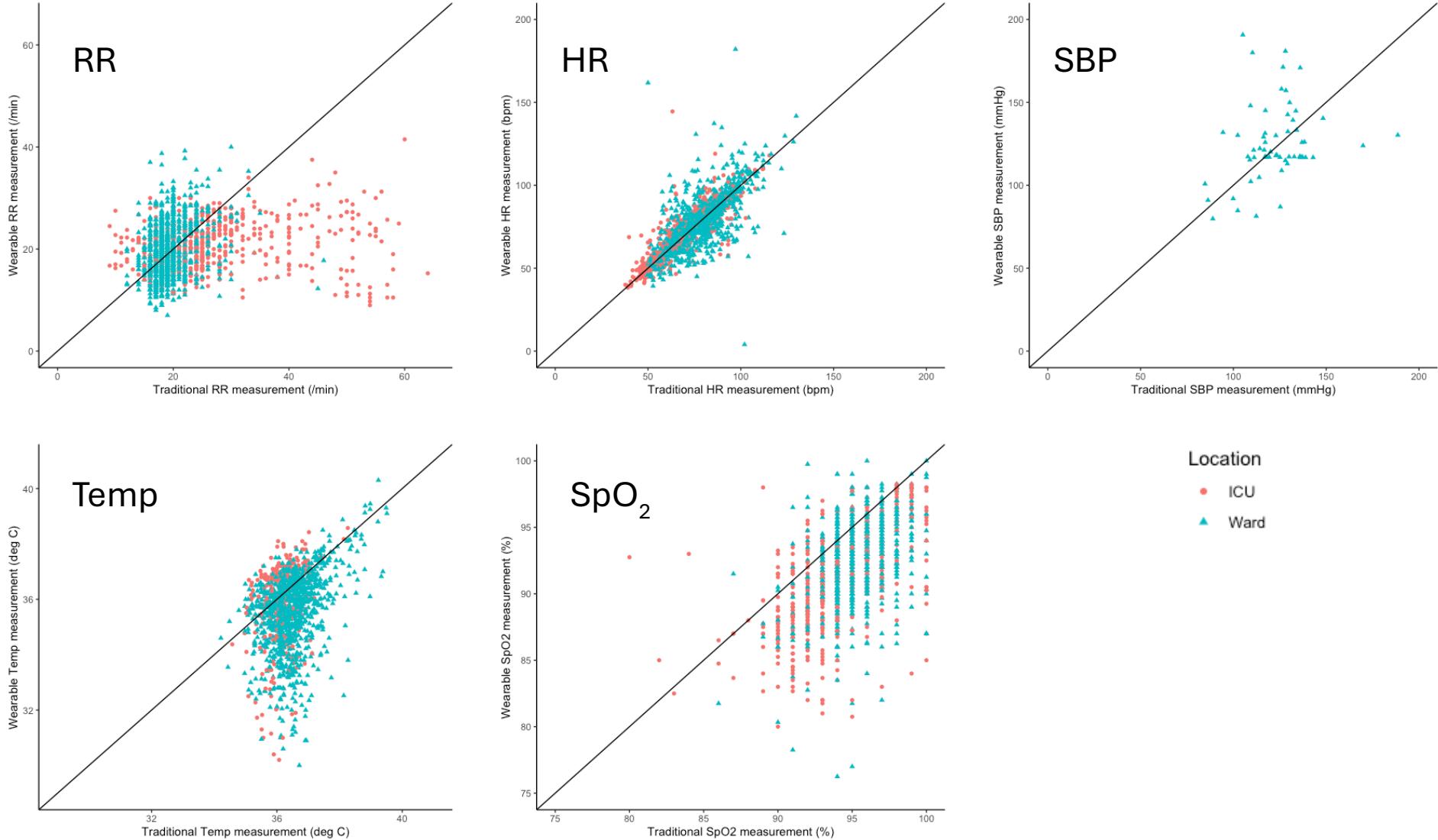
Appendix 2: Median and 24-hour survival times until the event of interest (see methods). HR/RR = heart rate/respiratory rate, Temp = temperature, SpO₂ = oxygen saturations, BP = blood pressure

Appendix 3



Appendix 3: Bland Altman analysis of systolic BP measurement pairs from traditional and wearable vitals

Appendix 4



	Vital sign				
	RR	HR	SBP	Temp	SpO ₂
Repeated measures correlation coefficient	0.15	0.63	0.39	0.26	0.36
(r _{rm})	(0.10 to 0.20)	(0.57 to 0.69)	(0.17 to 0.57)	(0.20 to 0.31)	(0.30 to 0.41)

Appendix 4: Correlation plots between repeated wearable and traditional vital signs measurements. The black line is a line of unity not a line of best fit. HR = heart rate, RR = respiratory rate, Temp = temperature, SpO₂ = oxygen saturations, SBP = systolic blood pressure. The table provides repeated measures correlation coefficients between each traditional and wearable vital sign pair.

Appendix 5

Median NEWS2 (traditional) = 2 [IQR: 1 – 4]

Median NEWS2 (wearable) = 5 [IQR: 3 – 7]

		NEWS2 5+ (5 vitals, traditional)		NEWS2 7+ (5 vitals, traditional)	
		Positive	Negative	Positive	Negative
NEWS2 5+ (5 vitals, wearable)	Positive	5 + 0*	12		
	Negative	2	12		
NEWS2 7+ (5 vitals, wearable)	Positive			0 + 0\$	10
	Negative			21	0

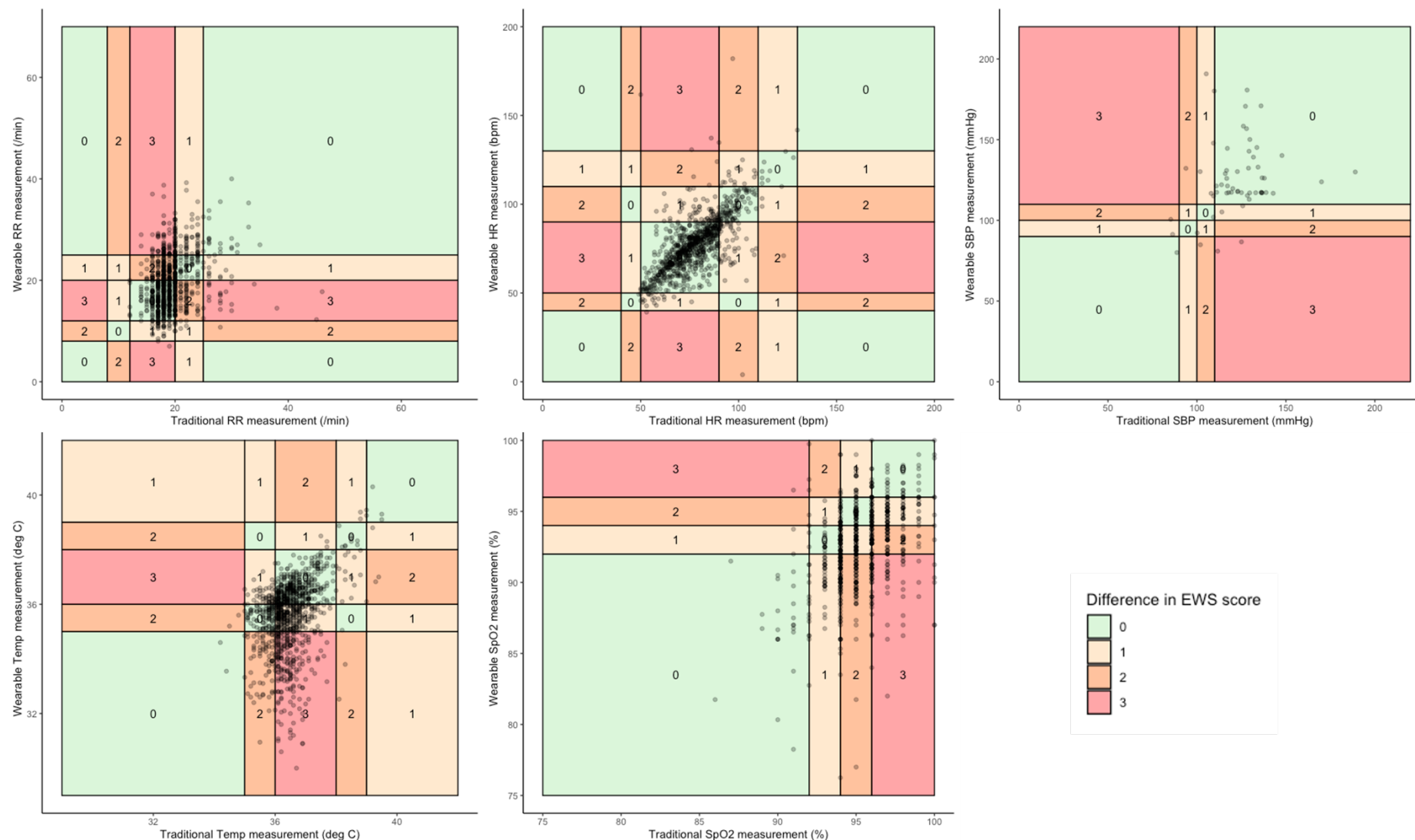
Appendix 5: confusion matrix for NEWS2 scores calculated from 5 vital signs (heart rate, respiratory rate, temperature, SpO₂ and systolic blood pressure) using paired traditional and wearable vital signs recorded on the ward. A positive NEWS2 score is considered a score of 5+ or 7+ respectively. *On 0 occasions, vitals from wearable sensors identified a 5+ NEWS2 event at the same time as traditional measurements but also identified a 5+ NEWS2 event in the preceding 12 hours which was not detected by traditional measurements. We considered this to represent early detection of deterioration and therefore a true positive. \$Similarly there were 0 instances of early detection of a 7+ NEWS2 event. NEWS2 = national early warning score 2.

Appendix 6

Vital sign (number of measurement pairs)						
	NEWS2 component difference	RR (N=941)	HR (N=942)	SpO ₂ (N=760)	Temp (N=1050)	SBP (N=59)
W↓	-3	21 (2.2)	-	1 (0.1)	1 (0.1)	-
	-2	61 (6.5)	1 (0.0)	5 (0.7)	6 (0.6)	2 (3.4)
	-1	13 (1.4)	45 (4.8)	51 (6.7)	60 (5.7)	7 (11.9)
W↔	0	496 (52.7)	785 (83.3)	217 (28.6)	455 (43.3)	45 (76.3)
W↑	1	75 (8.0)	101 (10.7)	251 (33.0)	245 (23.3)	2 (3.4)
	2	159 (16.9)	6 (0.6)	183 (24.1)	78 (7.4)	1 (1.7)
	3	116 (12.3)	4 (0.4)	52 (6.8)	205 (19.5)	2 (3.4)

Appendix 6: differences in the early warning score components generated by pairs of wearable and traditional vital sign measurements recorded on the ward (wearable - traditional). NEWS2 = national early warning score 2, HR = heart rate, RR = respiratory rate, SpO₂ = oxygen saturation, SBP = systolic blood pressure, Temp = temperature, W↓ = wearable returns lower NEWS2 component than traditional measurement, W↑ = wearable returns higher NEWS2 component than traditional measurement, W↔ = wearable and traditional return the same NEWS2 component score. SpO₂ NEWS2 component scale 1 was used to evaluate all SpO₂ measurement pairs.

Appendix 7



Appendix 7: modified Clark Error grid displaying the difference in NEWS2 component scores for paired wearable and traditional vitals recorded on the ward. NEWS2 = national early warning score 2, HR = heart rate, RR = respiratory rate, SpO₂ = oxygen saturations, SBP = systolic blood pressure, Temp = temperature.