Accuracy of self-monitoring heart rate, respiratory rate and oxygen saturation in patients with symptoms suggestive of COVID infection.

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Research Questions

1. What is the accuracy of self-monitoring of heart-rate, respiratory rate and oxygen saturation in patients with symptoms suggestive of COVID infection?
2. What is the optimal method for self-monitoring each of these?

Verdict

We found very few studies that addressed our question of interest. The limited evidence suggests that smartphone apps can accurately measure heart rate, although there is variation across apps. Those that use contact photoplethysmography to measure heart rate appear to have better accuracy than those that use non-contact photoplethysmography. The most accurate apps for measuring heart rate appear to be the "Heart Fitness" app (version 2.0.3; Senscare SAS, France) and the "Samsung Health Application". Samsung Health Application was also found to be accurate for measuring oxygen saturation for patient with saturation levels in the normal range but performed less well among those with hypoxia. The scientific basis for the use of smartphone apps for this purpose is questionable and so we would not recommend their use for measuring oxygen saturation. These findings should be interpreted with caution due to the very small number of studies available. There was no evidence on home monitoring of respiratory rate.

What does the evidence say?

Number of included studies/reviews (number of participants)

We identified one systematic review of 14 studies (n=381)[1] and three additional studies (n=108, 101 and 30) of heart rate monitoring using smartphone apps.[2-4] Two of these also assessed oxygen saturation measurement using smartphone apps (n=101, n=15).[2 4] We also identified a very recent rapid review by the Oxford COVID-19 Evidence Service Team.[5] We did not find any studies of remote monitoring of respiratory rate. Studies were done in various patient populations, none were conducted in patients with symptoms of acute respiratory infection.

Main findings

Heart Rate

There was generally high correlation between heart rate measured by photoplethysmography using a smartphone/table and heart rate measured by electrocardiogram (ECG) or vital signs monitor. The systematic review reported a summary correlation co-efficient of 0.951 (95% CI 0.91, 0.98) between measurement of heart rate conducted with the photo camera of a smartphone by photoplethysmography (PPG) with measurements made at a finger, toe, or earlobe.[1] There were no clear differences between different apps or sites used to measure heart rate.

The three primary studies also reported good agreement. One compared four different smartphone apps, all assessed using an iPhone 4 or 5, and standard pulse oximetry with ECG.[3] The apps that used contact photoplethysmography were found to be more reliable (mean difference in beats per minutes ranged from 2.0 to 4.5 and correlation from 0.83 to 0.96) than those that used non-contact photoplethysmography (mean difference ranged from 7.1 to 8.1 and correlation from 0.60 to 0.62). Agreement between pulse oximetry and ECG was similar to the best performing App (mean difference 2.0; r=0.92). The most reliable app was the "Heart Fitness" app. The other two studies each assessed single apps. One assessed the Samsung Health Application using a Samsung Galaxy S8 smartphone and reported very high correlation with heart rate measured by a vital signs monitor (0.99, 95% CI 0.99, 0.99).[2] The other assessed the Kenek O_2oximeter with probe using iPhone, iPad or iPod Touch.[4] HR measurements in the patients with chronic lung disease were above the predetermined thresholds of 5 bpm and LoA ±10 bpm.

Oxygen saturation

Both studies reported good correlation between oxygen saturation measured using smartphone apps and arterial blood gas devices. The study that assessed the Samsung Health application using a Samsung Galaxy S8 smartphone reported very high correlation with measured obtained from arterial blood gas (0.97 (95% CI=0.95–0.98).[2] However, it performed less well in patients with hypoxia. The study that assessed the Kenek O_2oximeter found that SpO2measurements were valid at rest in patients with chronic lung disease, with mean bias of 1% and LoA ±4%, but not during exercise (ie the smartphone oximeter had values above the acceptable threshold measures).[4] The Oxford rapid evidence synthesis also incorporated expert opinion from Professor Tarassenko who suggested that "it is not physically possible to measure SpO2 using current smartphone technology".[5]

Strength of the evidence

The systematic review was judged as high risk of bias due to limitations in the search which mean that relevant studies may have been missed. All primary studies were judged at low risk of bias and so their findings are considered likely to be reliable.

Summary of searches

We first searched for relevant systematic reviews using the KSR evidence database. We only found one systematic review of heart rate monitoring and this had only searched to 2016. We therefore carried out additional searches for primary studies using the MEDLINE (Ovid) database. We searched for studies of home-monitoring of heart rate published since 2016 and home monitoring of oxygen saturation or respiratory rate published at any time.

We included studies that evaluated monitoring of heart rate, respiratory rate, and oxygen saturation that could be done at home, conducted in any adult population. Studies had to report information on accuracy or agreement with an accepted measurement method. We excluded studies carried out in healthy volunteers and those that evaluated novel techniques not routinely available in practice.

Date question received: 31/3/2020
Date searches conducted: 1/4/2020
Date answer completed: 2/4/2020

References

1. De Ridder B, Van Rompaey B, Kampen JK, et al. Smartphone apps using photoplethysmography for heart rate monitoring: meta-analysis. *JMIR Cardio* 2018;2(1):e4.
2. Tayfur I, Afacan MA. Reliability of smartphone measurements of vital parameters: A prospective study using a reference method. *American Journal of Emergency Medicine* 2019;37(8):1527-30. doi: https://dx.doi.org/10.1016/j.ajem.2019.03.021
3. Coppetti T, Brauchlin A, Muggler S, et al. Accuracy of smartphone apps for heart rate measurement. *European Journal of Preventive Cardiology* 2017;24(12):1287-93. doi: https://dx.doi.org/10.1177/2047487317702044
4. Chan C, Inskip JA, Kirkham AR, et al. A smartphone oximeter with a fingertip probe for use during exercise training: usability, validity and reliability in individuals with chronic lung disease and healthy controls. *Physiotherapy* 2019;105(3):297-306. doi: https://dx.doi.org/10.1016/j.physio.2018.07.015
5. Tarassenko, Greenhalgh T. Question: Should smartphone apps be used as oximeters? Answer: No. 1/2/2020. Available from: https://www.cebm.net/covid-19/question-should-smartphone-apps-be-used-as-oximeters-answer-no/

Disclaimer

This report has not been peer-reviewed; it should not replace individual clinical judgement and the sources cited should be checked. The views expressed in this report represent the views of the authors and not necessarily those of the University of Bristol, the NHS, the NIHR, or the Department of Health and Social Care. The views are not a substitute for professional medical advice.

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Systematic Reviews

Author (year)	Search Date	Inclusion criteria	Number of included studies	Summary of results	Risk of bias
De Ridder (2018)[1]	December 2016	Population: Any Index test: Measurement of heart rate conducted with the photo camera of a smartphone by photoplethysmography (PPG); the measurements were made at a finger, toe, or earlobe. Reference standard: electrocardiogram (ECG), a pulse oximeter, or another validated method to determine heart rate. Exclusion criteria: measurement conducted with a mobile sensor or medical device connected to a smartphone; the paper did not have heart rate as one of the outcomes; no abstract or full text was available.	14 studies (n=381)	No difference between heart rate measurements with smartphone and validated method (MD =-0.32, 95% CI -1.24, 0.60; p=0.37) In adults, the Pearson correlation coefficient of the relation between heart rate measurement with a smartphone and a validated method was always ≥.90 (summary CC 0.951, 95% CI 0.91, 0.98) In children, the results varied depending on measuring point and heart rate.	High; potential for missing studies due to restricted search and language restrictions

Primary studies

Author (year)	Inclusion criteria	Number	Summary of results	Risk of bias
Tayfur (2019) [2]	*Population:* patients presenting at the emergency service that required an arterial blood gas (ABG) evaluation due to chronic obstructive pulmonary disease, congestive heart failure, acute dyspnea, pneumonia, and multiple trauma. *Index test:* Samsung Health application (model code SM-G950F and version 6.1.0.047) using a Samsung Galaxy S8 smartphone. *Reference standard:* vital signs monitor (VSM) and an arterial blood gas (ABG) device	101	High correlation between HR measured by smartphone and HR measured by VSM [0.99 (95% CI=0.99–0.99)]. SaO2 values obtained by smartphone were highly correlated with those by ABG [0.97 (95% CI=0.95–0.98)].	Low risk of bias
Coppetti (2017) [3]	*Population:* adults requiring heart rate monitoring on the chest pain unit or the emergency room; patients in critical medical condition excluded. *Index tests:* Pulse oximetry derived heart rate Apps using iPhone 4 and iPhone 5: Contact Photoplethysmography: 'Instant Heart Rate' (IHR) 'Heart Fitness' (HF) Non-contact photoplethysmography: 'Whats My Heart Rate' (WMH) 'Cardiio Version' (CAR) *Reference standard:* Electrocardiogram (ECG)	108	Accuracy of app-measured heart rate compared to electrocardiogram, reported as mean absolute error (in bpm, standard error) and correlation with ECG: Pulse oximetry: 2.0(0.35); r=0.92 IHR: 4.5 (1.1); r=0.83 HF: 2.0 (0.5); r=0.96 WMH: 7.1 (1.4); r=0.62 CAR: 8.1 (1.4); r=0.60	Low risk of bias
Chan (2019) [4]	*Population:* chronic lung disease *Index tests:* Kenek O2oximeter with fingertip monitor using iPhone, iPad or iPod Touch *Reference standard:* Pulse oximeter for SpO2 measurements and 12-lead electrocardiogram for heart rate measurements. *Inclusion criteria:* patients awaiting or undergoing pulmonary rehabilitation (PR), or who had completed PR within the preceding 2 years. *Exclusion criteria:* respiratory infection or change in their respiratory medications in the 4 weeks prior to testing, had been diagnosed with dementia, had a hand injury or impairment, used a wheelchair for regular mobility, or required oxygen therapy to complete activities of daily living.	15 patients and 15 healthy controls; results reported for patients only at rest.	*Oxygen:* SpO2measurements were also valid at rest in the patients with chronic lung disease, with mean bias of 1% and LoA ±4%, but not during exercise (ie the smartphone oximeter had values above the acceptable threshold measures). *Heart rate:* HR measurements in the patients with chronic lung disease were above the predetermined thresholds of 5 bpm and LoA ±10 bpm, although the HR measurements during both the cycle ergometer test and the treadmill test were reliable.	Low risk of bias

Search details

Initial project screen:

Source	Link	Relevant Evidence Identified
CEBM, University of Oxford	https://www.cebm.net/covid-19/	1: https://www.cebm.net/covid-19/question-should-smartphone-apps-be-used-as-oximeters-answer-no/
Evidence aid	https://www.evidenceaid.org/coronavirus-resources/	-
Cochrane Methodology Review Group	Infection control and prevention: https://www.cochranelibrary.com/collections/doi/SC000040/full Evidence relative to critical care: https://www.cochranelibrary.com/collections/doi/SC000039/full	-
Department of Health and Social Care Reviews Facility	http://eppi.ioe.ac.uk/COVID19_MAP/covid_map_v3.html	-
UCSF COVID19 papers	https://ucsf.app.box.com/s/2laxq0v00zg2ope9jppsqtnv1mtxd52z	-
PHE Knowledge and Library Services	https://phelibrary.koha-ptfs.co.uk/coronavirusinformation/	-
WHO Global Research COVID19 database	https://www.who.int/emergencies/diseases/novel-coronavirus-2019/global-research-on-novel-coronavirus-2019-ncov	-
CDC COVID19 guidance	https://www.cdc.gov/coronavirus/2019-ncov/hcp/index.html	-

Search for SRs and Primary studies

Source	Search strategy	Number of Hits	Relevant evidence identified
KSR Evidence	"Heart rate" in title	159	1 SR
	"Saturation" in title	18	-
	Pulse oxim*	53	-
	Respiratory rate in title	2	-
Medline	Respiratory rate.mp. or Respiratory Rate/ AND Telemedicine/ or Monitoring, Ambulatory/ or home monitoring.mp.	105	-
	"Oxygen Saturation.mp OR pulse oxim*.mp" AND Telemedicine/ or Monitoring, Ambulatory/ or home monitoring.mp.	260	1
	heart rate.mp. or Heart Rate/ AND Telemedicine/ or Monitoring, Ambulatory/ or home monitoring.mp. Limit 2016	206	2
Rayyan "COVID-19 Open Research Dataset"	COVID-19 AND (home OR self OR telemedicine OR "heart rate" OR "oxygen saturation" OR "respiratory rate" OR app OR application OR smartphone OR mobile OR remote)	114	-