Early Identification of COVID-19 using Remote Cardiorespiratory Monitoring: Three Case Reports

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Table of Contents

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Abstract

Remote patient monitoring (RPM) is an emerging clinical tool which collects physiologic data electronically from outside the clinical setting. The adoption of RPM into routine medical care requires an increased understanding of how the physiologic changes predict disease and what proactive interventions will improve outcomes. In this series we present 3 cases of physiologic changes occurring prior to COVID-19 diagnosis in patients with chronic respiratory disease. The cases demonstrate opportunities for earlier diagnosis, treatment, and isolation. Ongoing research leading to improved protocols are necessary to optimize the benefits of RPM in clinical practice.

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Early Identification of COVID-19 using Remote Cardiorespiratory Monitoring: Three Case Reports

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Abstract
Background: The adoption of remote patient monitoring (RPM) into routine medical care requires an increased understanding of how the physiologic changes accompanying disease development and what proactive interventions will improve outcomes.
Objectives: We present three case reports which highlight the capability of RPM to allow for early identification of viral infection with COVID-19 in chronic respiratory disease patients.
Methods: Patients at a large pulmonary practice were identified who were enrolled in a respiratory RPM program and who had contracted COVID-19. The physiologic data was retrospectively reviewed and three instances were identified where the RPM system had notified clinicians of physiologic deviation due to the viral infection.
Results: Physiologic deviations from respective patient baselines occurred during infection onset and, despite the infection manifesting differently in each case, had been identified by the RPM system. In one case, the patient was symptomatic, in another the patient was pre-symptomatic, and in the final the patient varied from asymptomatic to mildly symptomatic.
Conclusions: RPM systems meant for long-term use and which utilize patient-specific baselines can highlight physiologic changes early in the course of acute disease, such as COVID-19 infection. The cases demonstrate opportunities for earlier diagnosis, treatment, and isolation. This supports the need for further research into how RPM can be effectively integrated into clinical practice.

Keywords: COVID-19; remote patient monitoring; respiration; wearable sensors; pre-identification;

Introduction

Early identification of acute clinical deterioration can lead to proactive intervention and a reduction in morbidity in patients with or without chronic disease [1-3]. There are a number of reason why patients may receive delayed medical care [4]. For example, patients may not recognize a change in their symptoms or may avoid contacting their provider so as not to burden themselves or the practice. The COVID-19 pandemic also appears to exacerbate patient reluctance to seek care [5].

Early diagnosis of COVID-19, the disease resulting from SARS-CoV-2 infection, can lead to proactive management such as increased monitoring [6], daily prone positioning [7], as well as early patient isolation. To be effective, the novel monoclonal antibodies therapy appears to require use before the patient develops severe illness [8].

Studies using data from consumer activity trackers have been reported to identify signs of COVID-19 infections before symptoms develop [9-11]. Despite the promise of medical-grade remote patient monitoring (RPM), physicians and healthcare organizations can be slow to adopt it. Valid reasons for this lag in acceptance include limited clinical data [12] and discomfort with unfamiliar technology [13]. Deployment of new technology can also be delayed due to a lack of technological infrastructure and integration into clinical workflow [14]. This report motivates study into how to effectively integrate RPM into clinical practice by describing three cases of COVID-19 patients where physiologic changes were identified on RPM prior to their presentation to the medical practice.

Methods

The RPM system studied, designed and validated for long-term use with chronic respiratory disease patients [15,16], contains three components: (1) Health Tags (SpireHealth.com), undergarment waistband-adhered physiologic monitors which require no patient management and include a sensor of respiratory rate, (2) an app on an in-home, stationary internet-connected device (a Nokia smartphone) configured to automatically collects and uploads sensor data to the cloud, and (3) a web dashboard (SpireHealth.com) monitored 7

days/week by respiratory therapists (RTs) who proactively engage patients by phone in the event of significant changes in adherence, respiratory rate, pulse rate, or activity level. The dashboard notifies RTs of significant patient-specific deviations in respiratory metrics, pulse rate, and activity. The notifications compare each patient's current metrics with their respective historical baseline. The system was designed to identify deviations associated with exacerbation of chronic respiratory disease.

A U.S.-based pulmonology practice offered RPM to chronic respiratory disease patients and had not yet defined a clinical workflow for using RPM with COVID-19 patients. At the time of review, from approximately 1000 patients enrolled, 9 were confirmed to have contracted COVID-19. The RPM data of these 9 patients was retrospectively reviewed and evaluated based on whether the RPM had notified clinicians of physiologic deviation around infection onset. No evaluation of the RPM's predictive performance was done. Three case reports which demonstrated differentiated clinical cases and these patients gave consent to use of their data.

Results

Case 1: Symptomatic

Patient 1 is a 70 year-old female with moderate COPD who had been receiving routine follow-up care. For the first 3 months of monitoring, she demonstrated stable parameters in her respiratory rate and heart rate as well as typical variations in her activity levels. Approximately 3 months prior to her next scheduled office visit, the patient was noted to have an acute increase in her respiratory rate accompanied by reduced step counts (see Figure 1). These physiologic changes triggered a notification in the monitoring system leading to a phone contact of the patient. The patient reported feeling generally poor and attributed her symptoms to back pain. Further query by the RT call center staff did elicit increased shortness of breath (SOB) and cough. While the patient declined a pulmonary clinic visit, she was encouraged to monitor her symptoms and contact her doctor or ER if not improving. Five days after the initial notification, her respiratory rate remained elevated and the patient presented to the ER. She was diagnosed with COVID-19 and spent 17 days in the hospital before recovering to near baseline and returning home. 20 days later, her respiratory physiologic parameters returned to baseline. Step counts were noted to return to baseline approximately a month after hospital discharge.

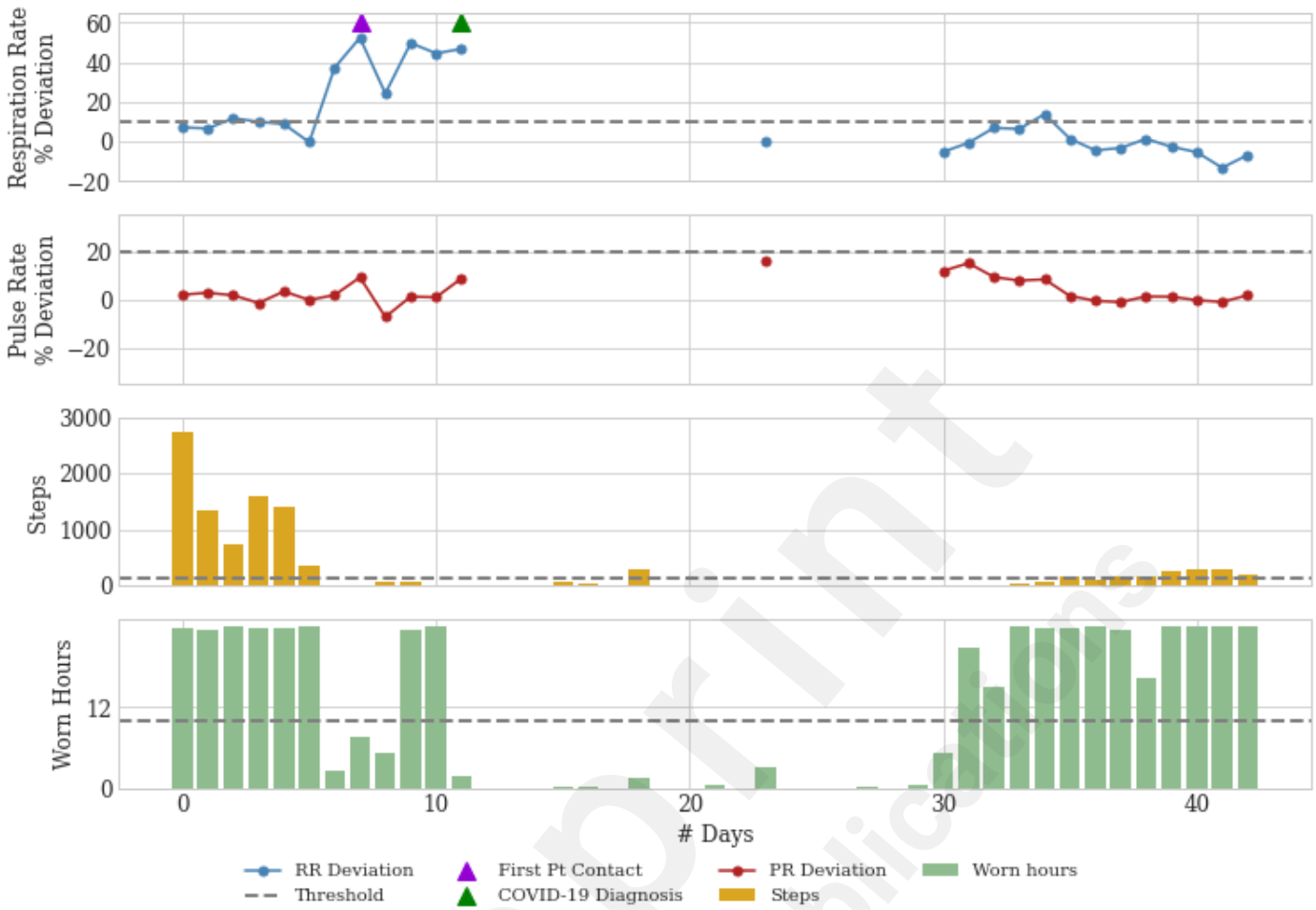

Figure 1. Daily physiology, activity, and adherence metrics. Patient was hospitalized for COVID-19-related symptoms 5 days after patient was contacted by the RT call center. Physiology shows return to baseline after discharge 17 days later. Each point for respiration and pulse rate represents the percent difference between that day's median value and that patient's lifetime median baseline value. The thresholds are clinician-configurable points at which notifications are triggered. Default threshold values (for all three cases): Worn Hours <11 hours, RR % Deviation: >10%, PR % Deviation: >20%, and Steps: <150 steps.

Case 2: Pre-symptomatic

Patient 2 is a 72 year-old male with a history of idiopathic pulmonary fibrosis (IPF). After 6 months of stable physiologic parameters, the RPM triggered a notification of a respiratory rate increase 24% above baseline (see Figure 2). The patient was reached by phone within 48 hours of the notification and he reported no concerning symptoms. He declined further clinical evaluation at that time. Five days after the initial notification, the patient developed body aches and a general feeling of being unwell. That day, a COVID-19 test performed by the patient's primary care physician was positive. The patient's physiology returned to baseline 15 days after infection onset.

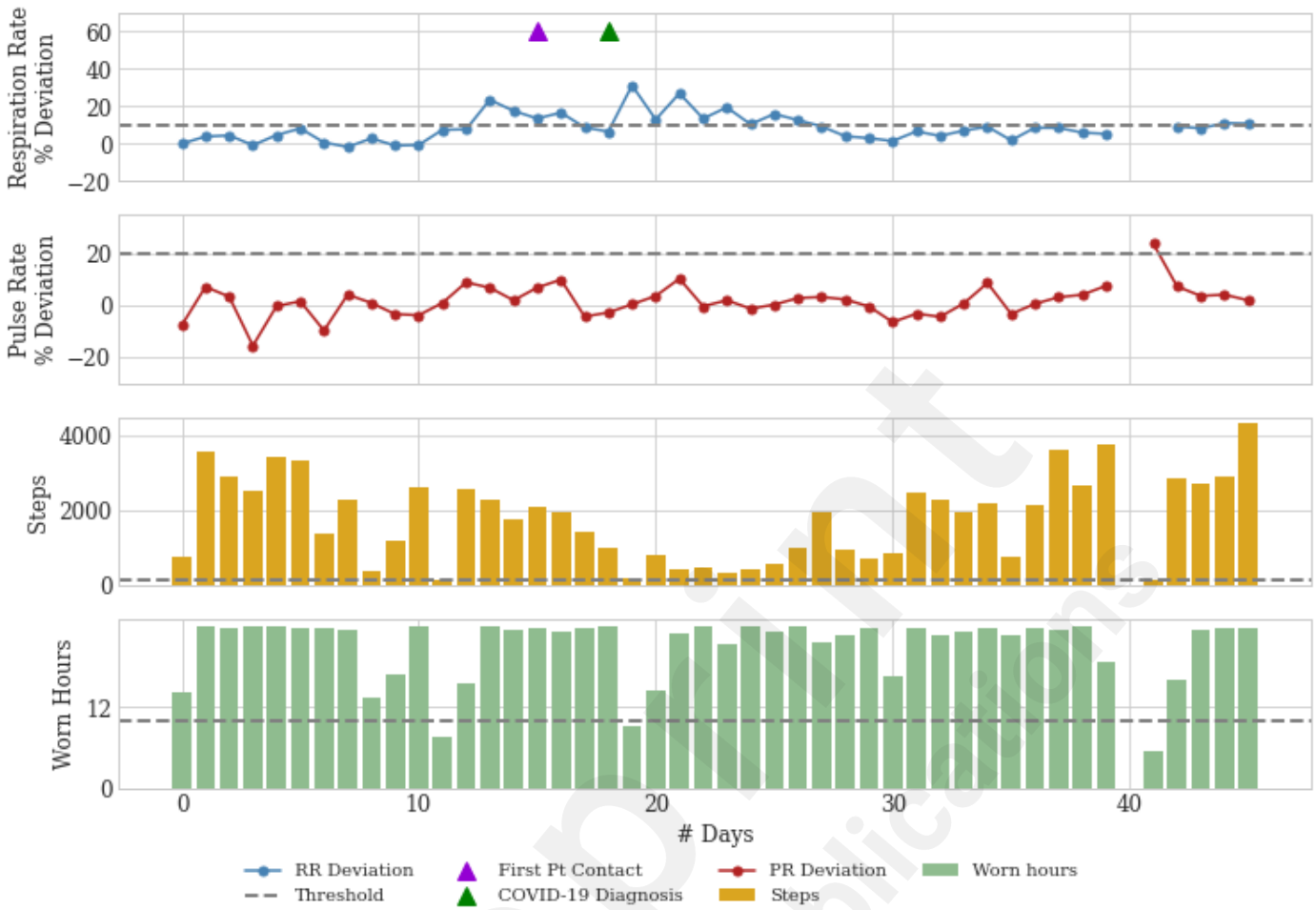

Figure 2. Timeline for Case 2. COVID-19 diagnosis was confirmed 3 days after the patient was contacted and 5 days after initial RPM notification.

Case 3: Asymptomatic to mildly symptomatic

Case 3 is an 80 year-old male with moderate COPD who had started in the practice's remote monitoring program about one month prior to the first notification, which reported a 24% increase in the patient's respiratory rate. The patient was reached by phone the next day and reported mild allergic type symptoms. He opted for over the counter symptomatic treatment and also declined a clinic visit as he was seen in clinic only 8 days prior. Seven days after the initial notification his respiratory symptoms remained mild but he was hospitalized for an unrelated reason. As part of hospital routine during the viral pandemic, he was tested and found to be positive for COVID-19 (see Figure 3). The patient's physiology returned to baseline 14 days after infection onset.

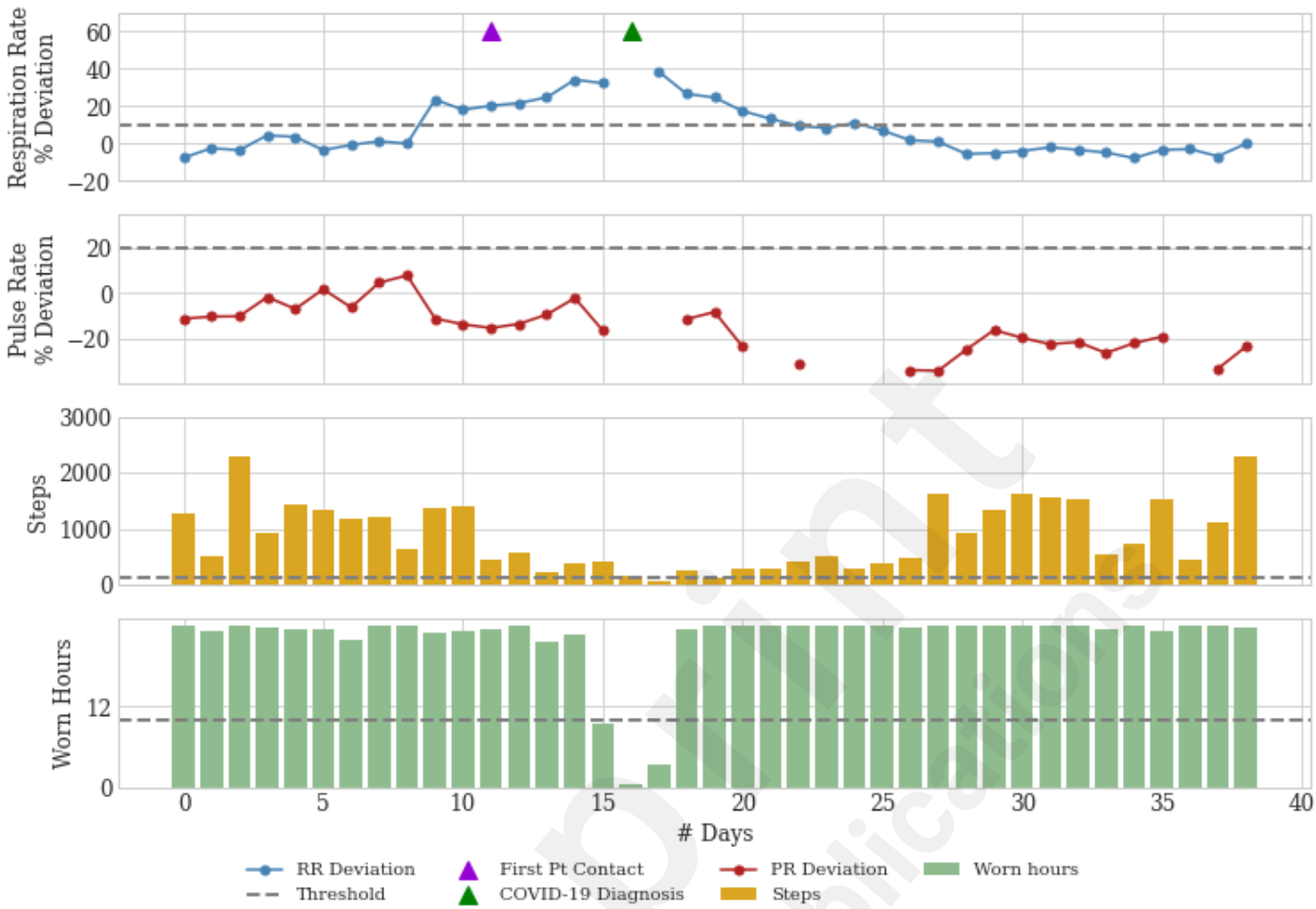

Figure 3. Timeline for Case 3. Initial patient outreach based on RPM notification was at 4 days before COVID-19 diagnosis.

Discussion

Case 1 demonstrates the capability to identify and engage patients earlier in the course of acute disease than would otherwise be able without remote monitoring. While the patient declined seeing her provider at the time of the phone call, she was notified of the physiologic changes and encouraged to seek early evaluation. Delayed care in COVID-19 leads to worse outcomes and this is particularly relevant for patients with comorbid conditions [17,18].

Unlike case 1, the second patient had denied symptoms at the time of initial notification. For this reason, he declined further evaluation. It is known that physiologic changes can occur prior to patient reported symptoms and recognition in COVID-19. Understanding the potential significance of physiologic changes, particularly during a viral pandemic, can lead to earlier diagnosis. Home and rapid COVID-19 testing should be deployed liberally during a pandemic to allow for early identification and patient isolation [19]. As with case 1, this patient is over 65 years old and with comorbidities. These patients require increased monitoring when diagnosed with COVID-19 and current evidence supports the consideration of monoclonal antibody therapy prior to needing hospital level of care [8].

Case 3 demonstrates a patient with mild symptoms who was incidentally found to be positive for COVID-19. It is possible he would have recovered without knowing he had been infected with COVID-19. Similar to the prior cases, significant time passed between physiologic identification and confirmed COVID-19 diagnosis. The exact burden of asymptomatic and pre-symptomatic spread of COVID-19 is uncertain but is felt to be significant [20]. Even if this patient makes a full recovery, the exposure to others prior to diagnosis has implications on pandemic control. During a viral pandemic, a high index of suspicion for infection must exist in patients who demonstrate signs of infection even in the absence of significant symptoms or complaints.

In all three instances, COVID-19 was diagnosed 5-7 days after the initial notifications. Optimally, the physiologic notifications and high suspicion of COVID-19 related to the RPM findings would prompt earlier diagnostic testing. However, patients' rationalization of symptoms and hesitancy to be evaluated factor into the delay[4]. Likewise, physicians may be less apt to intervene in cases where patient symptoms are minimal. Though these cases were selected by the authors, we suspect this delay in diagnosis is typical in most medical practices for the stated reasons.

One of the primary potential benefits of RPM is to treat deterioration earlier and more effectively. To increase RPM acceptance, data demonstrating improved patient outcomes is necessary. The success of RPM in providing these benefits is dependent on 3 requirements: the physiologic data is accurate, notifications are set at clinically significant levels, medical interventions are effective and instituted in a timely manner. Continuous physiological monitoring has shown itself to be accurate in patients with and without chronic disease [15,16]. There is emerging evidence regarding what physiologic changes from patient specific baselines on RPM are significant for various diseases, including COVID-19 [11].

Optimization and the timing of medical interventions is less clear. With the expanded role of telemedicine, we propose a standardized short term clinical assessment after RPM notification, performed from the patient's home with a low threshold to test for COVID-19. Further research is necessary to determine if this protocol alone would be enough to result in the desired clinical benefit.

Conclusion

This report suggests a blueprint in the approach to using RPM on chronic respiratory disease patients during a viral pandemic. In these 3 cases, early physiologic changes secondary to COVID-19 infection detected using RPM were readily identified and patients were proactively engaged. Further research refining RPM use in clinical practice may lead to earlier diagnosis, isolation, and treatment.

Disclosures

Dr. Polsky is a paid consultant to Spire Health, was the lead author, and was responsible for primary selection and description of the patients. Dr. Moraveji is an employee of Spire Health and was responsible for data extraction, figure generation, and supporting research activities.

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Supplementary Files

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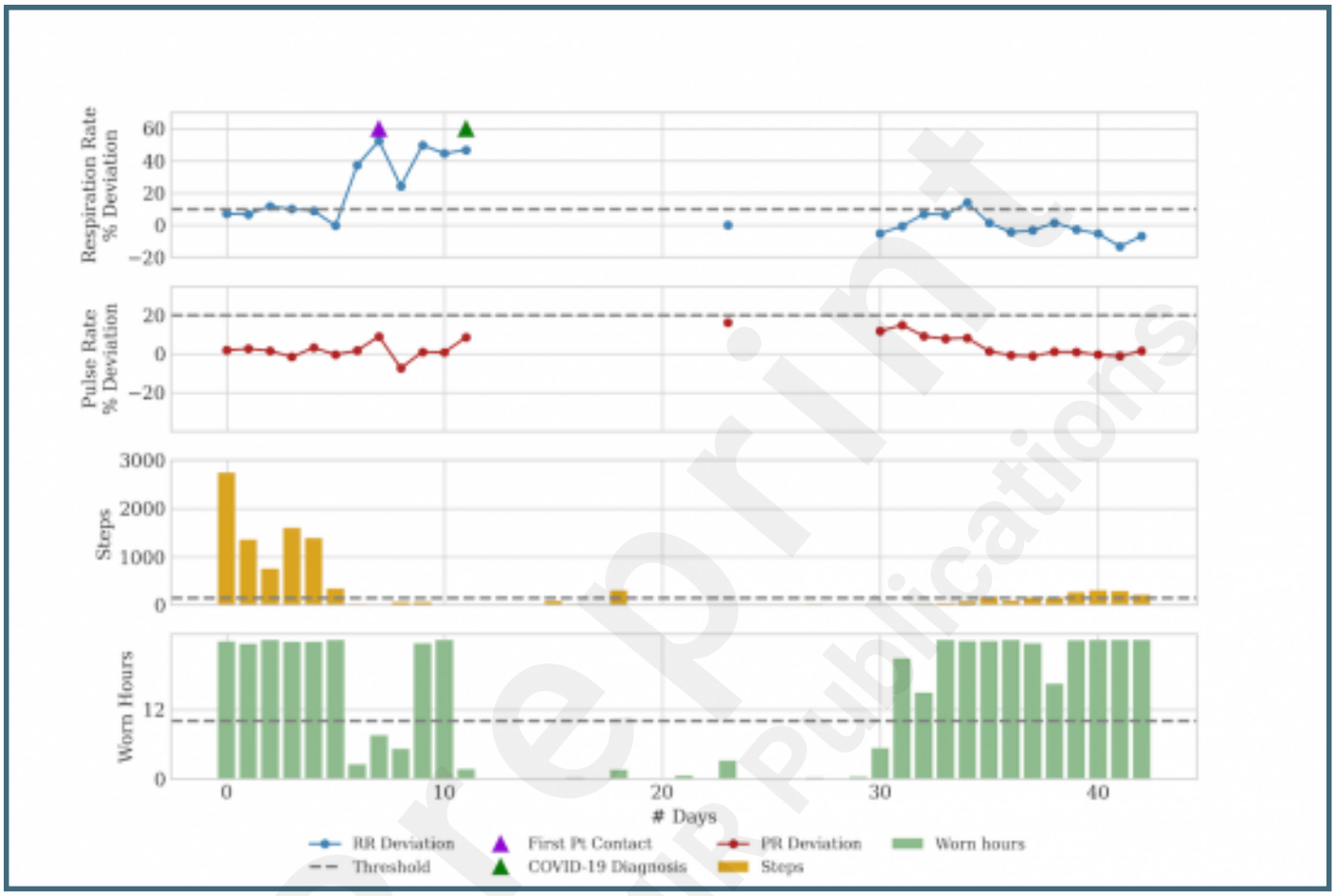
Figures



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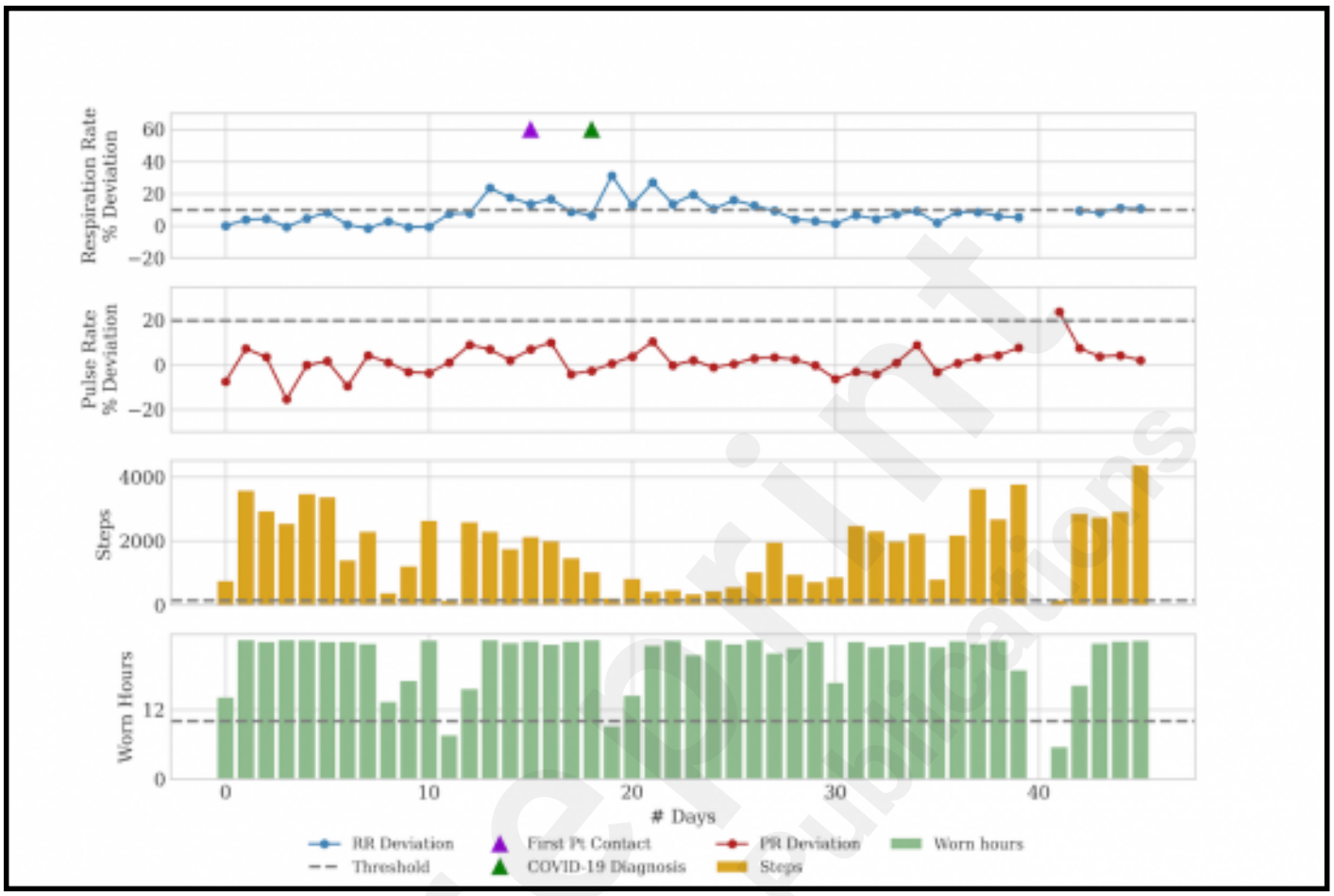

Timeline for Case 3. Initial patient outreach based on RPM notification was at 4 days before COVID-19 diagnosis.