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Analytical validation of an ultra low-cost mobile phone microplate reader for infectious disease testing

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ABSTRACT

Most mobile health (mHealth) diagnostic devices for laboratory tests only analyze one sample at a time, which is not suitable for large volume serology testing, especially in low-resource settings with shortage of health professionals. In this study, we developed an ultra-low-cost clinically-accurate mobile phone microplate reader (mReader), and clinically validated this optical device for 12 infectious disease tests. The mReader optically reads 96 samples on a microplate at one time. 771 de-identified patient samples were tested for 12 serology assays for bacterial/viral infections. The mReader and the clinical instrument blindly read and analyzed all tests in parallel. The analytical accuracy and the diagnostic performance of the mReader were evaluated across the clinical reportable categories by comparison with clinical laboratorial testing results. The mReader exhibited 97.59–99.90% analytical accuracy and < 5% coefficient of variation (CV). The positive percent agreement (PPA) in all 12 tests achieved 100%, negative percent agreement (NPA) was higher than 83% except for one test (42.86%), and overall percent agreement (OPA) ranged 89.33–100%. We envision the mReader can benefit underserved areas/populations and low-resource settings in rural clinics/hospitals at a low cost (~$50 USD) with clinical-level analytical quality. It has the potential to improve health access, speed up healthcare delivery, and reduce health disparities and education disparities by providing access to a low-cost spectrophotometer.

1. Introduction

Every year, millions of serology tests are performed in well-equipped central laboratories in the United States, especially for the infectious disease diagnosis in high burden areas. The relatively long turnaround time may delay timely infection control, especially in rural underserved areas and densely populated cities [1]. Decentralizing infectious disease serology testing, rapid tests on site and immediate sharing of data through servers in the cloud have the promise to control and prevent infection transmission [2–4].

To meet the multifunctional needs of analytical sensing and digital health management, mobile health (mHealth) technology supported by mobile devices is rapidly developing, including using mobile communication devices for health information, data collection and diagnostics [5–7]. Currently, there are two major streams in mHealth. One is the mHealth applications (Apps) and the other is the mHealth diagnostic/monitoring devices [8,9]. The number of mHealth applications (apps) is increasing rapidly [10,11]. Until 2016, mHealth apps listed on major app stores have grown to 259,000 to help people improve health conditions, such as weight/diet management, sleep quality improvement, emergency first aid/treatment guide, or vital signs monitoring (blood pressure, heart rate, etc.) [12–14]. However, few studies clinically validated mHealth diagnostic devices for further clinical translation [15]. One challenge is to tailor the design of mHealth diagnostic devices to the complex diagnostic needs of various diseases and achieve high-throughput testing at the same time. Strong clinical, medical translation and engineering capabilities are needed to research, develop, and deploy mHealth diagnostic devices. Due to these challenges, most reported mHealth diagnostic devices remain at academic development stage. Very few mHealth devices proceed to the clinical translation stage [16].

In this study, we developed and clinically validated an ultra-low-cost mobile phone microplate reader (mReader) using12 human infectious disease serology tests. The detection modality of this mReader is colorimetrically designed to achieve one-time optical sensing of 96 samples in the microtiter plate. The major technological challenge is unmatched field-of-view (FOV) between the mobile phone camera and the 96-well plates. To address these obstacles, we invented a unique

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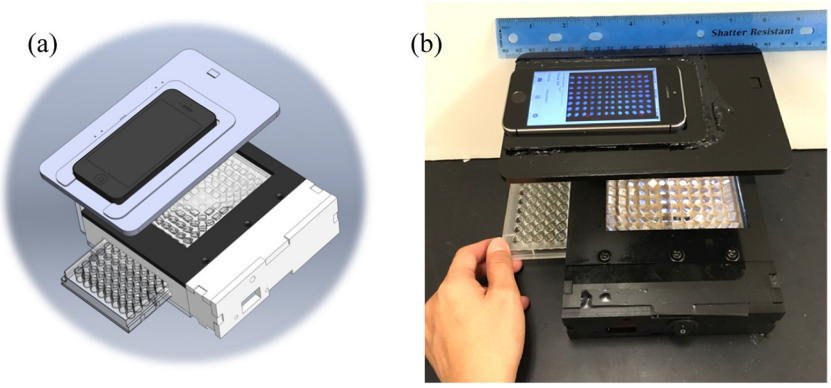

Fig. 1. (a) The 3D model and (b) the assembled setup of the mReader.

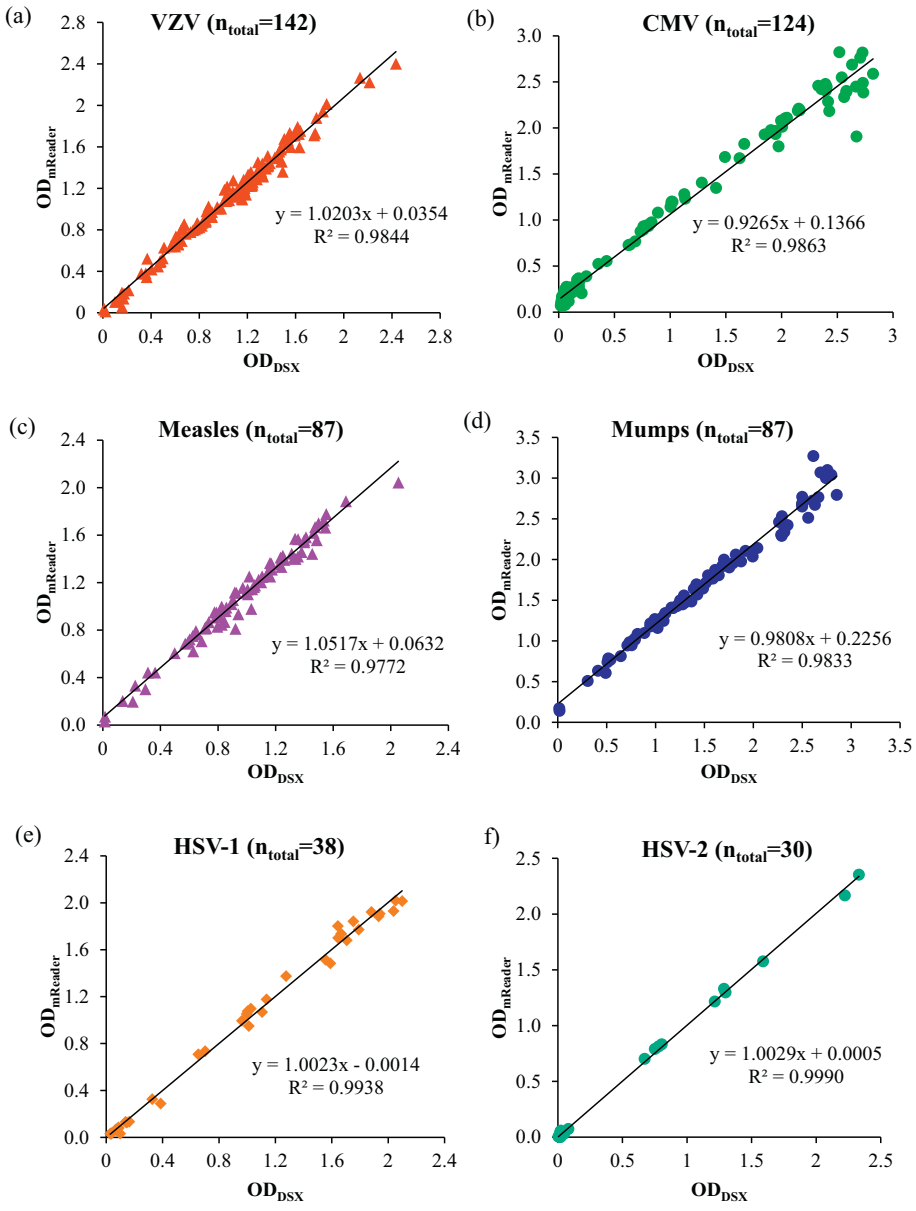

Fig. 2. The linear correlation between O.D. readings by the mReader and the DSX instrument for viral infections: (a) Varicella-zoster virus (VZV) with 142 samples, (b) Cytomegalovirus (CMV) with 124 samples, (c) Measles virus with 87 samples, (d) Mumps virus with 87 samples, (e) Herpes simplex virus type 1 (HSV-1) with 38 samples, and (f) Herpes simplex virus type 2 (HSV-2) with 30 samples, all including kit-derived and in-house controls across clinical reportable ranges.