Application Notes:  
APD Handwash Android App – A tool for evaluating the effectiveness of handwashing  
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ABSTRACT  
Handwashing is a basic infection control practice that needs to be performed correctly to be effective. In the ongoing COVID-19 pandemic, its correct practice is emphasized by public health institutions. However, turning a practice into a habit requires acceptance for adoption of the twenty-second proper procedure to which difficulty remains. To promote and convince the average user, we developed the “APD Handwash app” as a home-use demonstration/education tool to the pitfalls and need of proper handwashing practices through the detection of assigned clean or dirty areas on the hand in a quantitative manner to provide a gauge to the effectiveness of washing when used before and after washing.

INTRODUCTION  
The importance of handwashing as a basic infection control practice is made evident during the COVID19 pandemic given the possible contact transmission of microorganisms (Edmonds-Wilson et al., 2015). Effective handwashing practices can reduce the spread of antibiotic resistant infections within hospitals (Larson et al., 2000), decrease community risk to diarrhea (Curtis & Cairncross, 2003), and reduce absenteeism rates due to infectious illness in elementary schools (Nandrup-Bus, 2009). In times of infectious disease outbreak, handwashing is an individual’s first line of defense against contagions (CDC, 2020), and is especially important for healthcare workers (Alzyood et al., 2020). Public health campaigns encourage frequent handwashing before and after most high-risk activities, proposing a minimum duration of at least 20 seconds while utilizing a set of handwashing techniques. Yet, convincing individuals to adopt these handwashing habits, while a simple lifesaving action (Doronina et al., 2017), is difficult due to its time-consuming nature, seemingly complex procedure and supposed lack of scientific validation (Pittet, 2001).

To encourage effective handwashing practices, short videos and memes were disseminated through both social media and mainstream media e.g. television, radio and print advertisements (Alzyood et al., 2020). With the disruptive ubiquitous use of smartphones as the main screen that people use today, where there are apps for almost everything, apps can also be harnessed and used in promoting effective handwashing habits. A brief survey of currently available handwash applications in the market revealed four key functions: 1) Assisting in timing handwashing: “Handwashtimer (Nani Innovations, 2020)” and “CleanerHands (Generation 28, 2020)”, where some even have music accompaniment: “LatherApp Hand Wash Timer” (Think Tap Work, 2021); 2) There are those that remind individuals to wash their hands by location change triggers: “Sanitizer Hand (Zdravkin, 2021)”, by set time: “Wash Your Hands Reminder (Dev Tools, 2020)” and time intervals: “Let’s wash (Seolgi, 2020)”; 3) There are also apps that serve to educate hand hygiene through games for children: “Ella’s Hand Washing Adventure (Essity AB, 2020)” and “Wash germs away (Miryana’s World, 2020)” as well as training packages for adults: “Tork VR Clean Hands Training (Essity, 2020)”; Last but not least, 4) Apps that check and monitor handwashing: “SpeedyAudit Hand Hygiene Audit (HandyMetrics Corporation, 2021)”.  

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To address the unmet need of detecting the effectiveness of handwashing as a new category, “APD Handwash app (APD Lab, 2020)” was developed as an evaluation tool to fill the gaps in the pool of available handwashing apps. With features to detect discolorations as dirt, the effectiveness of the cleanliness before and after a handwash can be reasonably approximated from comparisons of before and after washing. Building on previous areametric/volumetric apps that utilize image processing (Chew et al., 2021; Sim et al., 2019; Wong et al., 2019; Wu et al., 2019; Budianto & Gan, 2017), the area of detected dirt on the auto-cropping of hands is calculated and displayed. With possible home-use or to complement hand hygiene education, the visualization is expected to aid in convincing individuals to adopt better practices and provide quantitative feedback to the effectiveness of their handwashing procedure to make necessary improvements as required.

DEVELOPMENT AND METHODOLOGY
The APD Handwash App was developed using Android Studio version 4.1.1 and OpenCV library 3.4.0.

Image thresholding and blurring is first applied as an image pre-processing procedure. The contour area function. Thereafter, contour detection is applied, where the biggest contour area is deemed as the hand area.

Upon identifying the hand, ‘SkinMasking’, a procedure to detect skin in images, highlights specific skin colors within the lower and upper range of skin colors in the HSV (Hue, Saturation, Value) color format. This continues with another round of image thresholding and blurring to enhance the masking procedure. The area of germs on the hand is calculated by removing skin colors from the ‘SkinMask’. With the presence of hand and germs area, the percentage can thus be calculated.

FEATURES
The APD Handwash App allows users to load an image of their hand on the app via direct image capture or image upload prior a handwash (Figure 1b). For best detection, the image of the hand is best placed before a black background such that only areas representing the hand are accurately auto detected for an accurate measurement of the area of dirt, that is designated as areas with “germs” on the hand (Figure 1c). The app processes the user’s request to generate an estimated area of “germs” displaying the percentage of the detected area of the hand. This is performed by the in-built algorithm that calculates RGB values, classifying parts of the hand image with germs and parts without, transiting into a calculation of the percentage of the hand containing germs (Figure 1f). The app then prompts for a new image after a handwash and repeats the generation of the estimated area of germs on the hand. For privacy, APD Handwash app does not store camera captured images.

Figure 1: Step by step usage process (a) Initiation screen (b) A list of actionable functions to allow image input (c) Image selection of a hand prior to a handwash placed against a black background (d) Confirmation of selected image to scan (e) Detection and result generation of dirty areas (f) Display of results with instruction to proceed to the next image input screen.
detailed process of using the app is illustrated in Figure 1.

APPLICATION
The APD Handwash app evaluates hand cleanliness where discolored areas are designated as areas with “germs”. There is potential for the app to be used with citizen science for data collection and analysis from the masses or in science classes, where students can generate and test hypothesis on hand washing practices (Donley & Jarem, n.d.) While built specifically for hands, the app can also analyze other regions of the body, best performed over a black background.

CONCLUSION
The APD Handwash App is an Android application that estimates the area that may have germs on an individual’s hand before and after a handwash procedure. The in-built algorithm identifies the hand, classifying parts of the image with germs and without, which are then calculated and displayed as a percentage of the hand containing the germs.

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AVAILABILITY
The APD Handwash App can be downloaded from the Google Play Store. A full video demonstration is found on www.youtube.com/watch?v=Iss1KQyuA1w.

CONFLICTING INTERESTS
This article was handled by an independent member of the editorial team.

AUTHOR CONTRIBUTIONS
WWL developed the mobile application while ZHSL drafted the manuscript. SKEG supervised the overall project.

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