A Comparison of Accuracy Using Administrative Data between National Smartphone Web and CAPI Surveys in the Age of Mobile Technology and COVID-19

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A Comparison of Accuracy Using Administrative Data between National Smartphone Web and CAPI Surveys in the Age of Mobile Technology and COVID-19

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Abstract
Kim and Couper (2021) demonstrated that a national random-digit-dialing (RDD) smartphone web survey using invitations by SMS (short message service) text messages, which has various advantages such as convenience and low cost, is feasible to collect data for the general population. But they did not address the accuracy of data collected from such an attractive survey mode, although it can get asked the most from survey researchers and practitioners. We conducted a similar RDD smartphone web survey using enhanced sampling methods and SMS invitations, focusing on the accuracy of responses to the factual survey item that the general population may have a special interest in: "Have you ever been quarantined or hospitalized for COVID-19?" Benchmarking governmental administrative data on the COVID-19 number of confirmed cases, we compared the accuracy of the smartphone web survey's estimated percentage for a rare population who has ever been quarantined or hospitalized for COVID-19 against the estimated percentage from a large-scale national face-to-face survey (CAPI). The two surveys were conducted during the COVID pandemic in the second half of 2020. Despite a relatively very small number of respondents, based on better results in unequal weighting effects, demographic representation of respondents, and design effects, the smartphone web survey was more accurate than the large-scale CAPI survey. This finding shows the high potential of the RDD smartphone web survey in conducting research requiring accuracy.

Keywords
smartphone web survey, SMS, single frame random-digit-dialing design, CAPI survey, stratified two-stage cluster sampling, unequal weighting effects, response rates, demographic representation, design effects, accuracy

Introduction

Although a great variety of procedures for selecting, locating, and measuring populations have been developed for centuries, the pace at which new and more efficient communication technology-based procedures are established and adopted as a primary one is slow. As representative evidence, despite the widespread availability of data collection by telephone or the web, owing to rapid advances in wireless communication technologies that enable the use of smartphones or mobile devices, the most important national surveys with household members in many countries, including South Korea, are still conducted by traditional face-to-face interviewing such as computer-assisted personal interviewing (CAPI) and paper and pencil personal interviewing (PAPI). These methods are very labor-intensive, yet they are often perceived as the 'gold standard' in collecting high-quality data about opinions, attitudes, experiences, and behaviors of the general population for creating official statistics or public policymaking.

Face-to-face interviewing can be favored due to the fact that in theory and in practice, since the interviewer and the selected person are present at the same location, it is easier for the interviewer to convince a person to participate in a survey, resulting in higher response rates than other data collection methods (see Bethlehem, Cobben, & Schouten, 2011¸ p93). Nevertheless, face-to-face surveys have faced threats to data quality from decreasing response rates and rising costs of in-person visits in recent years (e.g., see Groves & Harris-Kojetin, 2017, pp. 23-27). One of the underlying causes is the increase of housing units having access impediments (controlled access situations) such as locked central entrances to apartment buildings and gated communities with guards. Though this issue has not been well addressed as a research topic, it is of great concern to researchers. The presence of physical impediments can make it difficult or impossible for an interviewer to contact a person, which often consequently requires more calls. For example, the rate of impediments to access encountered in the U.S. was nearly 40% of housing units (see Lepkowski et al., 2013, p10). In South Korea, as people have become increasingly sensitive to home security and privacy, the proportion of housing units with access impediments has increased substantially. About 50% of all households live in high-rise apartment buildings with security-locked central entrances or gatekeepers, or both (Kim et al., 2015). Interviewers are finding it increasingly difficult to overcome these impediments by themselves before making face-to-face contact with households.

In the midst of this, the COVID-19 pandemic, declared by the World Health Organization (WHO) on March 11, 2020, has exacerbated the difficulty of conducting face-to-face interviews worldwide, due to the public health risk posed by the virus and associated mobility restrictions taking place. In response, survey organizations have either suspended fieldwork or shifted to alternate means of collecting data. One alternative was telephone surveys (e.g., see Moynihan & Letterman, 2020). However, even telephone interviews have already encountered serious data collection difficulties for the same reasons (decreasing response rates and rising costs) as face-to-face interviews (e.g., see AAPOR, 2019; Groves & Harris-Kojetin, 2017, pp. 23-27).

Given these conditions, one might consider web data collection self-administered for the general population as a viable and attractive alternative to interviewer-administered modes (telephone or face-to-face interviews). But in reality, there are many inherent methodological problems. Since the first published papers on web surveys appeared in 1996, the methodological attention that web surveys have received has exceeded other modes in a similar time period (Couper, 2008). Web surveys have become very popular over two decades because of their low costs and ease of implementation, especially when using nonprobability or selfselected samples in the commercial sectors. If data quality is important, however, using the web-only mode to collect data for cross-sectional or panel surveys of the general population can be problematic. It is because while an area- or address- or population register-based probability sampling is available to select households in each country, there has not yet been found a cost-effective method for contacting or inviting, (via postal mail, email, phone call, or in-person visit) and then persuading people to go online and complete a questionnaire without potential errors arising from methodological challenges such as undercoverage or low response rates. (e.g., for Belgium see Braekman et al., 2022; for the UK see Nicolaas, Calderwood, Lynn, & Roberts, 2014). To obtain a better balance of costs and quality than would be possible with a single-mode design, web-interviewer mixed-surveys or mixed-mode push-to-web surveys using an area- or address-based probability sample can be also considered, but research knowledge is sparse on such issues as how best to frame the initial invitation, how best to incentivize sample members to participate online rather than in an interviewer-administered mode, and how best to target different modes at different sample subpopulations as well as how best to analyze data collected from different modes (Lynn, 2020). Thus, substantial further development and testing, implementation success being heavily dependent on the Internet environment in each country, is required before web mode can become the primary data collection mode for high-quality surveys of the general population.

Smartphones may offer opportunities for a single mode, not a mixed mode suffering from the complexity of both data collection and analysis. Some researchers have made some progress in smartphone web-only mode data collection for the general population from a random-digit-dialing (RDD) sample, traditionally widely used in telephone surveys. Kim & Couper (2021) demonstrated the potential of a national RDD smartphone web survey using invitations by SMS (short message service) text messages, which combines telephone sampling and mobile technology, as a stand-alone or primary mode of data collection, by comparing results to an RDD cell phone CATI survey. Their study in South Korea encourages researchers to explore the RDD smartphone web mode using SMS invitations in different contexts or environments and go one step further by comparing it with various interviewer-administered modes in the general population surveys.

Following their study (smartphone web versus cell phone CATI) conducted before the COVID pandemic, this research seeks to answer the following questions: Could an RDD smartphone web survey provide accurate data on the experiences or behaviors of the public, especially during the COVID pandemic? Are the estimates in an RDD smartphone web survey different from those in face-to-face surveys? Are there any advantages of using RDD smartphone web mode concerning methodological aspects and quality?

To answer these questions, we designed a national RDD smartphone web survey to compare with a large-scale national face-to-face survey called the Korea Community Health Survey (KCHS), evaluating the accuracy of responses to the factual survey item that the general population may have a special interest in: "Have you ever been quarantined or hospitalized for COVID-19?", as well as other indicators of data quality such as sample representativeness or design effects. The KCHS is sponsored by the Korea Centers for Disease Control and Prevention, involves numerous people working as interviewers, coordinators, or data managers, and is conducted solely using CAPI. Common demographic questions and other questions, including the key question "Have you ever been quarantined or hospitalized for COVID-19?" were carefully chosen within the KCHS questionnaire to make a direct comparison of responses between the smartphone web and CAPI modes. The smartphone web and CAPI surveys were conducted during the COVID pandemic in the second half of 2020.

Critical Factors for Smartphone Web Survey

Since an invitation to a national RDD smartphone web survey is sent to smartphone users via SMS text message with a link to a web survey, there are three critical factors influencing data quality: smartphone ownership, the popularity of text messaging, and the mobile Internet environment. South Korea is one of the few countries with all three factors simultaneously high.

First, according to Pew Research Center (2019), 95% of adults in South Korea owned a smartphone in 2018, compared to a median of 76% across 18 advanced economies (e.g., Israel 88%, Netherlands 87%, Sweden 86%, U.S. 81%, Germany 78%, UK 76%, Canada 66% et al.). Therefore, it is expected that a larger proportion of Korean adults will be able to fill out web questionnaires with their smartphones.

Second, Smith (2015) reports that among the four prominent smartphone features (text messaging, voice, and video calling, using email, and using the internet) text messaging was most widely used in the U.S., and more than 90% of smartphone owners in all age groups use text messaging (100% among ages 18-29, 98% among ages 30-49, 92% among those 50 or older). Likewise, the National Information Society Agency (2021) reports text messaging as the most popular feature in South Korea. In 2020, 97.0% of South Koreans used text messaging via smartphone or tablet, and except for the age group 70 or above, more than 96% of mobile device users in all age groups used it (20s 99.7%, 30s 99.6%, 40s 99.1%, 50s 98.6%, 60s 96.5%, 70 or above 87.8%). Accordingly, most Koreans with a smartphone can receive an invitation sent via SMS text message with a link to a web survey. Andreadis (2020) pointed out that although using text messages to invite individuals to smartphone-friendly web surveys seems to be a method with great potential, findings could differ across countries depending on whether the receiver or the sender pays for the SMS transmission cost. In South Korea, the cost of SMS is only paid by the sender, so there is no burden of payment borne by the receiver.

Third, a stable and fast mobile Internet connection is especially important for the seamless conduction of smartphone web surveys. Slow speeds and unreliable connections may frustrate respondents and often result in incomplete questionnaires. South Korea is well-known for having one of the fastest and most stable internet networks in the world (Opensignal, 2017). This Internet environment would have a low likelihood of nonresponse due to mobile Internet connection issues.

On the other hand, there could be legal restrictions on sending SMS text messages inviting individuals to a smartphone web survey. Some countries have laws regulating unsolicited text messages. For example, under the Telephone Consumer Protection Act (TCPA) in the U.S., sending any text messages without the user's prior expressed consent is illegal (see Marlar & Hoover, 2019). As Andreadis (2020) described, this legislation is not as strict in the EU if the contact is made for purposes other than advertising, whereas sending commercial ads via SMS without prior consent is not permitted. According to the General Data Protection Regulation (GDPR), an organization that has collected data on the basis of legitimate interest, a contract, or vital interests, can use the data for statistics or for scientific research, even if this was not among the original purposes of data collection (see European Commission, 2022). In South Korea, unsolicited text messages without prior consent are proscribed by the Information and Communication Network Act to prevent illegal spamming. But this law only applies to advertising information for commercial use. Text messages for non-commercial use by public offices or non-profit organizations are exempt from the restriction law (see Korea Communications Commission, 2020). With such critical factors in place, we conducted a national RDD smartphone web survey to compare with a face-to-face CAPI survey (KCHS).

South Korea's COVID-19 Situation and Face-to-Face Data Collection

South Korea recorded its first coronavirus disease case on January 20, 2020, and had a slow spread of COVID-19 throughout 2020. There were 979, 1,334, 5,642, 2,714, and 26,564 monthly new confirmed cases in April, June, August, October, and December, respectively (Statistics Korea, 2021). For reference, on December 31, 2020, there were 231,024 new reported cases in the United States (The New York Times, 2022).

South Korea endured devastating early outbreaks and flattened the coronavirus curve without paralyzing the national health and economic systems by rapidly adopting comprehensive approaches such as the world's first drive-through screening centers, walk-through screening stations, self-diagnosis applications, and community treatment centers (You, 2020). Mobility restrictions were not implemented, and most face-to-face surveys, including the KCHS, were conducted on or behind schedule with rigorous COVID-19 safety protocols (e.g., PCR-testing before fieldwork, measuring body temperature, washing hands, wearing masks, and social distancing) to protect both interviewers and respondents. Despite this, there were a lot of concerns about lower response rates and poor data quality compared to the years before the COVID-19 pandemic, unlike non-face-to-face interviews (web surveys).

Study Design, Implementation, and Data Analysis

When we planned and designed this study (smartphone web versus CAPI) targeting the adult population, there are several reasons why we chose the KCHS as a comparison target among many face-to-face household surveys conducted by statistical agencies, universities, and survey firms in 2020. One was the field period during which data are gathered from respondents. Since our national RDD smartphone web survey was supposed to be implemented in the fourth quarter, we chose a survey to be conducted in a similar period of time, if possible. The second was to choose a comparable CAPI that used a laptop rather than PAPI since smartphone web mode is computer-assisted. The third was to choose a survey asking questions on health issues that were of great interest to ordinary people. The fourth was to choose a large-scale household survey with a high response rate sponsored by a government agency. The last one was to choose a survey with well-documented and transparent data collection. The KCHS was a face-to-face household survey fully satisfying these conditions. (for the details, see Korea Centers for Disease Control and Prevention, 2020; Korea Centers for Disease Control and Prevention, 2021).

The national RDD Smartphone web survey for this study, which was named the 2020 National Survey of Life and Health (NSLH), was conducted by the Survey and Health Policy Research Center (SHPRC) at Dongguk University. There are many differences between the RDD smartphone web survey methodology in this study and that by Kim & Couper (2021) in sample design, implementation, and data analysis, as well as questionnaire design, as described below.

Sample Design in NSLH

Single cell phone RDD frame. After Kim & Lepkowski (2002) reported the rise of cell phone-only households and the decline of landlines across countries including South Korea, the SHPRC established its own dual frame (landline and cell phone RDD) and has used it for various studies on national telephone surveys (see, e.g., Lepkowski, Kim, & Steeh, 2005; Kim, Lee, Hong, & Park, 2012; Park, Lee, Kim, & Lee, 2012; Kim, Traugott, Kwak, Choi, & Lee, 2014; Kim, Woo, & Kim, 2017). Since 2018, the SHPRC dropped the landline RDD frame and started using a cell phone RDD frame only. There were two major causes of this transition. First, the study by Kim, Woo, & Kim (2017) discovered that only 3 percent of Korean adults were landline-only, and almost all adults (97%) owned a cell phone (smartphone 91%, feature phone 6%; cell phone-only 50%, both cell phone and landline 47%), and thus, cell phone RDD samples were much more demographically representative than landline RDD samples. Based on this study, the SPHRC concluded that there has been a significant transition from landlines to mobile phones in most households, diminishing the dual frame's coverage improvements. The other was survey cost. The interviewing and supervision costs in landline RDD surveys were three times more expensive than those in cell phone RDD surveys due to a large difference between the numbers of completed interviews per hour (0.65 cases per hour for landlines versus 1.83 cases per hour for cell phones in 2017). Unlike in South Korea, the costs of cell phone RDD surveys in the U.S. are substantially greater than those of landline RDD surveys (see AAPOR, 2010). As for the studies or actual telephone surveys using a single cell phone frame instead of a dual frame in the U.S., see Peytchev and Neely (2013), Kennedy et al. (2018), National Immunization Surveys sponsored by the Centers for Diseases Control and Prevention (2022), and Surveys of Consumers conducted by the Survey Research Center at the University of Michigan (2022).

A landline RDD frame at the SHPRC is based on 100-banks with one or more listed numbers, whereas a cell phone RDD frame at the same institution is constructed using active seven-digit cell phone 10,000-banks. All 10,000 possible suffixes, from 0000 to 9999, are appended to the seven-digit codes to generate eleven-digit cell phone numbers. The seven-digit codes for a business or public purpose were identified and removed by using various sources released to the public. The cell phone RDD frame size was 69,720,000 numbers in 2020. Considering that among cell phone subscribers in general, there were 55,857,980 individuals (Ministry of Science and ICT, 2020), 80 percent of phone numbers in the cell phone RDD frame can be considered to be used by the general population. A random sample of eleven-digit numbers selected from this cell phone RDD frame was directly used in the NSLH, the smartphone web survey for this study.

Sample size. The final sample size, which is the number of completed interviews, is one of the key elements we would like to examine in an RDD smartphone web survey. We aimed to achieve about 1,000 completed interviews as a final sample size, typically required for nationwide polls or social research often reported in newspapers, broadcasting, etc. In order to achieve such a sample size, based on a previous study by Kim & Couper (2021), which obtained a total of 537 completed interviews from a smartphone web survey using an initial sample of 15,900 RDD cell phone numbers, we decided to select an initial sample of 30,000 numbers, almost doubled. A reserve sample was not considered.

Sampling method. By using an unstratified and unclustered single-stage equal probability of selection method (EPSEM), we selected an initial sample of 30,000 eleven-digit numbers from the cell phone RDD frame at the SHPRC. In South Korea, geographical stratification for eleven-digit cell phone numbers by area codes that match administrative divisions is not possible because they share a single mobile prefix '010' instead of area codes, followed by a four-digit prefix and four-digit suffix. The single-stage EPSEM provides exactly equal probabilities of selection for all cell phone numbers in the frame, and hence the sample is self-weighted, that is, the reciprocal of the probability of selection of each cell phone number in the sample is the same. Self-weighting samples are often preferred for many surveys because they possess considerable advantages including reduced variance, simplicity, and robustness (see

Kish, 1992, pp. 194-195).

Sample Design in KCHS

Begun in 2008, the KCHS is a community (municipality)-based large annual survey covering the adult population in households for the purpose of gathering information that could be used to plan, implement, monitor, and evaluate community health promotion and disease prevention programs. This survey is jointly conducted by 255 community health centers located in cities and counties across the country, in cooperation with universities within the communities. A sample of households was selected by stratified two-stage cluster sampling in each community. In the first stage, stratified small administrative units in a city or a county were selected as the primary sampling units (PSU), and in the second stage, the households were randomly selected within each sample PSU. All adults, not one adult, were selected (interviewed) within each sample household. A similar number of adults (about 900) were interviewed in each community, and about 230,000 adults nationally.

Data Collection in NSLH

To efficiently manage and monitor data collection in the NSLH, we used four sample replicates, each made up of randomly assigned 7,500 of the initial 30,000 sample numbers. Data collection with three follow-up reminders per sample replicate lasted for a total of 7 weeks, from October 12 to November 28.

Using a text messaging service in NSLH. In South Korea, many commercial SMS text messaging services can assist in sending out invitations and reminders to sample numbers simultaneously in a batch process. We chose one of the popular commercial services, 'Aligo' (see https://smartsms.aligo.in/). It costs only a few cents per SMS message and provides real-time information on the delivery status and reasons for delivery failures when a message is either queued, sent, delivered successfully, or not delivered by the carrier. We did not screen the initial sample of 30,000 cell phone numbers with trained operators or automatic systems to remove nonworking numbers. Conversely, Kim & Couper (2021) used a screening process by trained operators.

Data Collection in KCHS

The KCHS ran for 11 weeks, from August 16 to October 31, which partially overlapped with the NSLH (October 12 to November 28). A one-page official pre-notification letter from the director of the community health center was sent via mail with a survey brochure to each sampled household to foster trust among participants (Korea Centers for Disease Control and Prevention, 2020, p29). The basic guidelines were a minimum of three callbacks (attempts) to reach members of the sample household. But field workers actually made more than three callbacks to reduce non-contacts or refusals as much as possible (Korea Centers for Disease Control and Prevention, 2020, pp. 40-41).

Questionnaires

The NSLH questionnaire consisted of 50 questions divided into five sections. The first section asked respondents screener questions (e.g., age to determine if an adult) to determine if they were eligible to participate in the survey. The second section asked a mix of factual and subjective questions about essential health topics. This section included a sensitive question "Have you ever been quarantined or hospitalized for COVID-19?" which was the key question in this study. The KCHS questionnaire, which consisted of 142 common questions and additional questions (23 on average) that vary by community, also included this question. The third section asked about the devices used to respond to the web survey. The fourth section asked about daily life. The fifth section asked standard demographic questions.

Survey Software

For the NSLH, we used SurveyMonkey (see https://ko.surveymonkey.com), which is one of the most well-known online survey software and questionnaire tools all over the world. SHPRC has used it for various web surveys. It is available in the Korean language and web surveys automatically adjust to screen sizes available from most smartphone brands. For the KCHS, CAPI software developed by a company in South Korea was used.

Data Analysis Methods

Several things must be considered for a comparative analysis of data from the NSLH (smartphone web mode) and the KCHS (CAPI mode). Each of the 255 community health centers releases a separate report on the KCHS. For users and researchers, reports and microdata (in the form of SAS files) can be downloaded by a request from the KCHS website (https://chs.kdca.go.kr/chs/main.do) in Korean. While the KCHS microdata allows a direct comparison of the differences in health issues among 255 communities, appropriate survey weights for calculating national estimates of population parameters are not available. The results of national-level analyses in the KCHS have officially been reported as a simple median of 255 community-based weighted estimates instead of a single national-weighted estimate. Thus, separate national-level survey weights for the KCHS are required for accurate comparison with the NSLH. Besides, selecting (or interviewing) all adults from each sample household in the KCHS is adopted on the grounds of saving time and cost as well as convenience. If the purpose is not to aggregate measures from individual reports in the household, or if inter-household dynamics are not of interest, however, selecting one person per household can be more statistically efficient than selecting all people in a household even when it is operationally feasible. Also, collecting data on more people in the same household would be perceived as more burdensome for the respondents, especially when asking sensitive questions. Moreover, selecting all people in a household for additional interviews tends to increase the within-household correlation (a measure of how similar values are for different people in the same household) and sampling variance, while not adding much additional information (see Clark & Steel, 2007).

Accordingly, as a prior procedure for producing separate national-level survey weights, which increase the accuracy and precision of national estimates in the KCHS, we randomly subsampled one person per each surveyed household on the microdata. There were 229,269 respondents on the microdata and the total number of subsampled individuals was 125,585, which is 55 percent of the whole respondents. This subsampling method can be a suitable strategy to fairly compare the two modes (smartphone web versus CAPI) since a smartphone is a personal device, not a household device like a landline.

The survey weights for the subsampled individuals in the microdata were adjusted to obtain national weighted estimates as follows. The base weight, which is the inverse of the selection probability of the household in the sample, was multiplied by the number of adults in the household to get back to a sample of persons (not households). Poststratification was also used for reducing sampling variance, the biases of nonresponse, and noncoverage at the national level (see Kish, 1992, p187). For poststratification, the base weights were adjusted so that the weighted totals within each of 170 post-strata divided by the domains (17 administrative divisions of 8 cities and 9 provinces, 2 gender groups, and 5 age groups) equaled the population totals in the 2020 Census. These adjusted weights were used as the final weights to analyze survey results.

In contrast to the KCHS, the final weights in the NSLH were calculated through a different procedure. As mentioned above, the RDD sample of cell phone numbers was selected by using a single-stage EPSEM. Since the EPSEM sample is self-weighted, the base weight is the same for all cell phone numbers in the sample. Subsampling within a household is not necessary because a smartphone is a personal device. But we used the same poststratification as the KCHS. However, since the number of respondents is relatively much smaller than that in the KCHS, some post-strata were collapsed with neighboring ones by systematic rules to meet minimum size requirements in calculating the variance of the survey estimates (see Kim, Li, & Valliant, 2007, p. 145).

Results

Completed Interviews and Completion Times

The number of completed interviews, or the final sample size, was one of the most important results we wanted to examine through this promising smartphone web mode. A total of 1,532 adults completed the survey, which started from the initial sample of 30,000 RDD cell phone numbers. While such a final sample size is acceptable for most nationwide polls or social research, it is valuable to assess the overall length of time respondents took to complete the questionnaires, since the completion time is a potentially important indicator of data quality. Also, we need to see if the elderly did well in the web survey like other age groups.

The questionnaire for the smartphone web survey (NSLH) consisted of 50 questions. We allowed respondents to stop filling out the survey whenever they liked and resume it later simply by clicking the survey link again. They would be automatically brought back to the last page they were filling out. Because of this feature, some respondents may have taken longer to complete the survey than expected. 38 (2.5%) of 1,532 (100.0%) respondents took longer than an hour. Excluding these respondents, 1,494 (97.5%) have taken an average of 10.7 minutes (the first quartile of 6.2, the median of 8.2, and the third quartile of 12.0) to complete the survey. There were 123 (8.2%) upper outliers, who have taken longer than 21 minutes (outside 1.5 times the interquartile range above the third quartile), and there were no lower outliers. Of these outliers, 35 (28%) were aged 60 years or over, and this corresponds to one-fourth (24%) of all respondents in that age group (147 of 1,532). The highest age group, which can take the longest to complete, does not account for a high proportion of outliers.

The questionnaire at the community level for the CAPI survey (KCHS) consisted of 142 common questions and additional questions (23 on average) that vary by community. The completion time was 28 minutes on average at the national level (Korea Centers for Disease Control and Prevention, 2020).

Unequal Weighting Effects

The design effects due to unequal weighting (Kish, 1992), simply unequal weighting effects, which means a factor of increase in the variance of the survey estimates resulting from final weights, were 1.74 and 2.23 in the NSLH (smartphone web mode) and the KCHS (CAPI mode), respectively. Owing to a single-stage EPSEM sampling, the unequal weighting effects were slightly lower for the NSLH than for the KCHS.

Advantages and Efficiency of Screening RDD Sample by SMS

There is a critical positive aspect of using the SMS messaging/reporting system (Aligo), simply SMS. Using the real-time delivery report of SMS eliminates the need to screen the initial sample of 30,000 RDD cell phone numbers by trained operators (or automatic systems) for pre-removing nonworking numbers. 68.4 percent (20,529 of 30,000) of SMS messages were successfully delivered in the invitation. This percentage can be viewed as a working number rate in a typical RDD smartphone web survey. It is slightly lower than the working number rate of 75.4 percent (=11,991/15,900) in a smartphone web survey in the study of Kim & Couper (2021, p1223), which screened the initial sample of 15,900 numbers with trained operators using conventional methods to remove nonworking numbers to increase the hit rate (the proportion of numbers in an RDD sample that is working numbers) in telephone surveys at the SHPRC (a similar screening process, which identifies inactive numbers within a cell phone RDD sample and can reduce data collection costs by 20% or more, is used for telephone surveys in the United States; see Marketing Systems Group, 2022) and produced 11,991 working numbers. It should be noted that despite the difference in the cell phone RDD frame sizes (69,720,000 in this study and 77,000,000 in the study of Kim & Couper), subtracting certain percentages from 75.4 percent in their study gives an almost identical percentage to 68.4 percent in this study. Specifically, subtracting 3.8 percent (600 of 15,900, cases where a trained operator gets a voice message, “The customer cannot answer the phone. Please call back later,” indicating that the call is either refused or blocked) and 3.3 percent (517 of 15,900, cases getting a voice message, “The phone is switched off.”) from 75.4 percent gives 68.3 percent, which is almost the same as 68.4 percent (20,529 of 30,000). Although these two subtracted percentages were originally regarded in the study of Kim & Couper (2021) as those of working numbers that require re-contact as in telephone surveys, it now seems appropriate to regard them as the percentages of nonworking numbers that eventually fail to receive SMS invitation messages. This becomes even more obvious when we consider the fact that SMS is a store-and-forward messaging protocol; when a number cannot be reached, instead of terminating, it is queued up to resend usually for several days (three days for Aligo) and keeps trying until this time elapses. This suggests that the SMS used in this study could efficiently remove nonworking cell phone numbers at a rate of about 32 percent (100 % minus 68.4%) effectively substituting for a screening process via person or a machine. Using SMS, which does not charge for non-delivered SMS messages in South Korea, can help in reducing time, effort, and costs for smartphone web data collection at the SHPRC.

Response Rates

The response rate is one of the fundamental indicators of survey quality. The AAPOR (2016)'s Standard Definitions describe six standardized response rates. For web surveys, response rates can be calculated by using the AAPOR Response Rate Calculator V4.1 (2000) written in Microsoft Excel. Response rate 1 (RR1) was 7.6%, which was slightly higher than 5.3% (RR1) in an RDD smartphone web survey by Kim & Couper (2021). Response rate 3 (RR3) was 30.8%. It is worth noting that this 30.8% (RR3) was at least three times higher than 9% in 2016, 7% in 2017, and 6% in 2018 (RR3) for the recent RDD telephone surveys in the U.S. that Keeter, Hatley, Kennedy, & Lau (2017) and Kennedy & Hartig (2019) reported as RR3.

As mentioned above, in the CAPI survey (KCHS) all adults, not one adult, are selected (interviewed) within each sample household. Thus, some outcome rates at the household level are reported. One of them is the sample household replacement rate, which can be expressed as '(R+NC+O)/(I+P+R+NC+O)' according to the notation given in the AAPOR (2016)'s Standard Definitions. The reason for reporting this rate instead of the response rate is that each of the 255 community health centers has a maximum goal of minimizing the sample household replacement due to refusals (R), non-contacts (NC), and others (O) for eligible cases as well as of maximizing I (completion interviews) and P (partial interviews) through various efforts. Since this rate can be re-expressed as '1-(I+P)/(I+P+R+NC+O)=1-RR6' by using Response Rate 6 (RR6), which is the maximum response rate out of six response rates in AAPOR (2016), RR6 can be easily calculated. The sample household replacement rate at the national level is officially reported as an average and median of 255 community-based rates. In the 2020 KCHS, each (1-RR6) was 7.5% and 5.6% (see the 2020 KCHS Progress and Quality Management Report Section, Korea Centers for Disease Control and Prevention, 2021). Accordingly, RR6 at the national level was 92.5% (average) and 94.4% (median) with very high rates. For the RDD smartphone web survey, RR6 cannot be calculated because there are no cases of refusals, non-contacts, and others. The direct comparison of different response rates (e.g., RR1 versus RR6 or RR3 versus RR6) between the two surveys (NSLH and KCHS) is not appropriate, but both can be said to have high response rates, despite a lot of concerns about lower response rates due to the COVID-19 pandemic.

Demographic Representation of Respondents

Even if the response rate for the smartphone web survey (NSLH) is comparatively high, as described above, surveys errors due to undercoverage, sampling, and nonresponse are inevitable and moreover, the number of respondents (1,532) is only 0.0035 percent of the adult population size of 43,526,824 in 2020. To ensure the survey quality, we need to examine how well the respondents are representative of (or similar to) the population by comparing the demographic distributions of respondents to the corresponding distribution from the population. For this, we chose three key demographic variables: administrative division (area of residence), gender, and age. For the first variable, we especially asked respondents a screener question with a list of 17 first-level administrative divisions (8 cities and 9 provinces) made up of response items because as mentioned in the sampling method above, area codes that match those administrative divisions like landline numbers are not available for cell phone numbers as they share a single mobile prefix '010' instead of area codes. Since there is no area code in the cell phone number, a sample design based on not only geographical stratification of cell phone numbers but also a proportional allocation of a sample size to each area was impossible. This situation was expected to make it difficult to achieve the percentage of respondents accurately proportional to the different sizes of the adult population of each administrative division, although maintaining the geographic representation of administrative divisions of respondents is most important concerning survey quality. Kim, Woo, & Kim (2017) discussed the same issue in RDD telephone surveys in South Korea.

The table shows the unweighted percentages of the respondent and adult population percentages for the three demographic variables in the smartphone web survey (NSLH) and CAPI survey (KCHS), and the p-values in Pearson's chi-square tests for the differences in the respondent percentages between the two surveys. Since adult population percentages were obtained from the Census conducted by Statistic Korea in a similar period to the two surveys, a more accurate comparison is possible.

Table. Demographic Comparison between Respondents and Adult Population Distributions

Variables	Respondents' Distributions % (Signed Difference)		p Value[a]	Adult Population %[c]
	Smartphone Web Survey (NSLH)	CAPI (KCHS)		
Administrative Divisions[b]			0.000***	
8 Cities (Abbreviation)				
SU	22.9 (3.7)	9.6 (-9.6)		19.2
PS	5.2 (-1.5)	6.5 (-0.2)		6.7
IC	5.4 (-0.3)	4.0 (-1.7)		5.7
DG	4.2 (-0.5)	3.0 (-1.7)		4.7
DJ	3.3 (0.5)	2.0 (-0.8)		2.8
GJ	3.5 (0.8)	1.9 (-0.8)		2.7
US	2.2 (0.0)	1.9 (-0.3)		2.2
SJ	0.7 (0.1)	0.4 (-0.2)		0.6
9 Provinces (Abbreviation)				
GG	27.3 (2.0)	16.8 (-8.5)		25.3
GN	5.2 (-1.2)	8.0 (1.6)		6.4
GB	4.4 (-0.8)	10.2 (5.0)		5.2
CN	4.3 (0.3)	6.2 (2.2)		4.0
JN	2.2 (-1.4),	9.0 (5.4),		3.6
JB	3.1 (-0.4)	5.6 (2.1)		3.5
CB	2.5 (-0.6),	5.7 (2.6),		3.1,
GW	2.8 (-0.2)	7.0 (4.0)		3.0
JJ	0.8 (-0.5)	2.2 (0.9)		1.3
Gender			0.000***	
Male	50.9 (1.3)	43.3 (-6.3)		49.6
Female	49.1 (-1.3)	56.7 (6.3)		50.4
Age groups			0.000***	
19 – 29	33.7 (16.7)	9.0 (-8.0)		17.0
30 – 39	23.9 (7.9)	10.8 (-5.2)		16.0
40 – 49	19.2 (0.1)	15.3 (-3.8)		19.1
50 – 59	13.6 (-6.3)	18.0 (-1.9)		19.9
60 or older	9.6 (-18.4)	46.9 (18.9)		28.0

Note. There was no item nonresponse in the two surveys for three demographic variables. CAPI = computer-assisted personal interviewing.

[a]p Values in Pearson's chi-square tests for differences of the unweighted estimates between surveys.

[b]South Korea is made up of 17 first-level administrative divisions (8 cities and 9 provinces). The adult population (19 years of age or older) size was 43,526,824 (100.0%) in the 2020 Census. SU (Seoul) is the capital city, and its adult population was 8,378,491 (19.2%). The largest province is GG (Gyeonggi-do), and its adult population was 11,009,537 (25.3%). The smallest city and provinces are SJ (Sejong) and JJ (Jeju), respectively, and their adult populations were 261,332 (0.6%) and 547,925 (1.3%), respectively. The adult population sizes are provided by the Korean Statistical Information Service (http://kosis.kr/index/index.do).

*** p value < 0.01.

As presented in the table, for administrative divisions, in the smartphone web survey with a very small number of respondents (1,532), contrary to great concerns about geographic representation, 12 of 17 administrative divisions (71 percent) had signed differences between the respondent and population percentages within ±1%. 5 other administrative divisions had signed differences of less than ±4%. Thus, it would be enough to say that the percentage of respondents is almost proportional to the adult population size of each administrative division. In contrast, the signed differences between the respondent and population percentages in the CAPI survey were overall much larger than in the smartphone web survey, and only 5 of 17 administrative divisions (29 percent) had signed differences less than ±1%, in spite of a very large number of respondents (125,585). This result was partially attributable to the fact that an almost identical number of adults (about 900), not proportional to the size of the adult population in each community, were interviewed in each of the 255 communities. Accordingly, there was a highly significant difference in the respondent percentages between the two surveys ($p<.01$).

Regarding gender, while the respondent percentages in the smartphone web mode were very close to the population percentages (difference of ±1.3%), those in the CAPI mode had larger differences with the population percentages (difference of ±6.3%). As expected, the difference between the two modes was highly significant ($p<.01$).

For age, the smartphone web mode was very overrepresented (+16.7%) in the youngest age group (19-29) and seriously underrepresented (-18.4%) in the oldest group (60+), whereas the CAPI mode was moderately underrepresented (-8.0%) the youngest age group (19-29) and seriously overrepresented (+18.9%) the older group (60+). The differences across the age groups were highly significant between modes ($p<.01$).

Taking these points into account, in summary, although it is not for an age, despite the relatively small number of respondents, the smartphone web mode was highly representative of the adult population, either geographically or by gender, relative to the large-scale CAPI mode.

Design Effects

The (estimated) design effect, which is widely used as a routine item in reporting survey results, is the ratio of an actual variance of a weighted estimate calculated from a sample selected by a given sample design to the variance of an unweighted estimate calculated when assuming that sample was selected by simple random sampling. If a design effect is 2, it indicates that an original sample of 1,000 adults is as good as a simple random sample of 500 adults, which is called the effective sample size. The larger the design effect, the more sample required to obtain the same variance of an estimate as would have been obtained in simple random sampling (See Kish, 1995, pp257-259).

The question asking whether the respondent had ever been quarantined or hospitalized for COVID-19 (Yes, No) had a design effect of 1.05 in the smartphone web survey using a sample selected by a single-stage RDD sampling. The design effect of the same question was 3.01 in the CAPI survey using a sample selected by stratified multi-stage cluster sampling. This indicates that the sample size in a smartphone web survey would be only one-third of that in the CAPI survey required to obtain the same variance of an estimate in simple random sampling.

Comparing Accuracy for a Rare Population

As described above, the smartphone web mode had better results for unequal weighting effects, demographic representation of respondents, and design effects than the CAPI mode. Could these overall results be reflected in the accuracy of the smartphone web mode? Survey accuracy can be defined as the extent to which results deviate from the true values of the characteristics in the target population. Assessing accuracy is important to the development of survey methodology including data collection methods. Despite this importance, it is often difficult to gauge survey measurement accuracy since neither a true value nor an accuracy benchmark is readily available in general. Thus, the benchmarks obtained from large government surveys with high response rates are used instead (e.g., see Yeager et al., 2011). But fortunately, one administrative data that has been of great interest during the COVID-19 pandemic can be used as a benchmark to judge the estimation accuracy between the two modes in this study. It is the number of confirmed COVID-19 cases quarantined or hospitalized from governmental administrative data.

The key question in this study is: Have you ever been quarantined or hospitalized for COVID-19? (Yes, No). Before comparing the accuracy of the estimates for the proportion of 'Yes' to this question between the two modes, we must consider two technicalities. First, the number of confirmed COVID-19 cases quarantined or hospitalized can be used as an accuracy benchmark. But since those who were in contact with patients with confirmed or suspected infection, as well as asymptomatic or mild confirmed cases, were quarantined at home or a designated facility for 14 days according to the policy of the Korean government, it is very a reasonable assumption that the actual number ever being quarantined or hospitalized would be moderately higher than the number of confirmed cases. Second, as mentioned above, South Korea had a slow spread of Covid-19 throughout 2020 due to adopting comprehensive approaches such as the world's first drive-through screening centers, walk-through screening stations, self-diagnosis applications, and community treatment centers. Given this, the true proportion of 'Yes' to this question would be very small among adults, so the accuracy of the estimates must be compared accommodating for a rare population.

The weighted estimates for the proportion of 'Yes' to this question in the smartphone web mode was 1.4 percent with a margin of error of 0.6 percentage points at a 95 percent confidence level, whereas the weighted estimate in the CAPI mode was 0.6 percent with a margin of error of 0.07 percentage points at the same confidence level.

Statistical Geographic Information Service (2022) of Statistics Korea provided daily-based administrative data on the cumulative number of confirmed COVID-19 cases by 17 administrative divisions (8 cities and 9 provinces). As of the last day (November 28) of the smartphone web survey, the cumulative number of confirmed cases nationwide was 33,311, and as of that (October 31) of the CAPI survey, it was 26,511 (these numbers include nonadults of about 10 percent, but cannot be separated). Dividing these numbers by the adult population size (43,526,824) yields confirmed adult percentages of 0.8 percent and 0.6 percent which are very small, respectively.

Since in addition to confirmed cases, those who were in contact with patients with confirmed infection or suspected infection were also quarantined, the actual percentage ever being quarantined or hospitalized would be moderately higher than 0.8 percent or 0.6 percent (e.g., 1.2 percent). It is noteworthy that the weighted confidence interval 1.4%±0.6%P or (0.8%, 2.0%) in the smartphone web survey, mentioned above, is very likely to contain such an actual percentage, whereas that 0.6%±0.07%P or (0.53%, 0.67%) in the CAPI is unlikely to contain it. This sufficiently shows the possibility that, despite the relatively small number of respondents, a smartphone web survey can be pretty accurate without being inferior to a large-scale CAPI survey, even when estimating the percentage for a rare population.

Discussion

Face-to-face surveys long have been regarded as the 'gold standard mode' for obtaining high-quality data have suffered greatly due to rising costs of in-person visits and decreasing response rates. This threat to data quality has been exacerbated by the COVID-19 pandemic. These problems are expected to only grow over time and eventually become nearly insurmountable for researchers. It is time to actively seek alternative sources of high-quality survey data.

Because of several attractive advantages besides the obvious lack of need for interviewers such as low costs, the quick launch of surveys, respondent convenience, and low social desirability bias in sensitive topics, not surprisingly, many survey organizations or researchers have used web surveys. They have recently become more popular due to safety issues, especially since the COVID-19 pandemic. Regardless of their popularity, web surveys on the general population still face the main methodological issues concerning data quality: undercoverage, lack of sample representativeness, and low response rates.

Following the study (smartphone web versus cell phone CATI) of Kim and Couper (2021), which was implemented before the COVID-19 pandemic, we conducted a national RDD smartphone web survey using SMS text message invitations, which combines telephone sampling and mobile technology, for comparison with a large-scale national CAPI survey during the COVID-19 pandemic. The smartphone web survey based on a truly random sample of cell phone numbers and multiple follow-up reminders spanning sufficient timeframes was successfully completed without the typical methodological problems found in ordinary web surveys on the general population. Despite the relatively small number of respondents, the survey quality was high enough to provide accurate data whilst maintaining the original strengths of web surveys. This proved advantageous to the CAPI mode in many respects. In addition, if a smartphone web survey were to be conducted with the same sample size, the variance of a weighted estimate (or margin of error) would be very likely to be smaller than that in a CAPI survey. Such an adjustment could significantly increase the accuracy of survey estimates.

We hope these findings will inspire researchers, especially in academic and non-profit survey research organizations, to further develop web survey methodology that can obtain survey data more conveniently, efficiently, and accurately in a less costly manner. The smartphone web survey methodology and findings we presented cannot be applied in some countries due to legal issues. In that case, they could be guidance or a checklist of sorts to see what might be missed when using or exploring alternative web survey methods. Also, they may help understand what researchers should keep in mind when considering mixed-mode data collection involving a web survey or an online panel survey.

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Data Availability

The anonymized data for the smartphone web survey are available from an author at a given email address. The reports and microdata for the CAPI survey can be downloaded by request from the KCHS website (https://chs.kdca.go.kr/chs/main.do).

Software Information

The survey sampling and analyses were conducted using SAS 9.4.

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