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Development and validity of a 3-day smartphone-assisted 24-hour recall to assess beverage consumption in a Chinese population: a randomized cross-over study

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Abstract

This paper addresses the need for diet assessment methods that capture the rapidly changing beverage consumption patterns in China. The objective of this study was to develop a 3-day smartphone-assisted 24-hour recall to improve the quantification of beverage intake amongst young Chinese adults (n=110) and validate, in a small subset (n=34), the extent to which the written record and smartphone-assisted recalls adequately estimated total fluid intake, using 24-hour urine samples. The smartphone-assisted method showed improved validity compared to the written-assisted method, when comparing reported total fluid intake to total urine volume. However, participants reported consuming fewer beverages on the smartphone-assisted method compared to the written-assisted method, primarily due to decreased consumption of traditional zero-energy beverages (i.e. water, tea) in the smartphone-assisted method. It is unclear why participants reported fewer beverages in the smartphone-assisted method than the written-assisted method. One possibility is that participants found the smartphone method too cumbersome, and responded by decreasing beverage intake. These results suggest that smartphone-assisted 24-hour recalls perform comparably but do not appear to substantially improve beverage quantification compared to the current written record based approach. In addition, we piloted a beverage screener to identify consumers of episodically consumed SSBs. As expected, a substantially higher proportion of consumers reported consuming SSBs on the beverage screener compared to either

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LPS was involved in study design, data collection, analysis and interpretation of results, and writing the manuscript. JH, JZ, and SZ were involved in the study design, data collection, and editing the manuscript. ES, SD, and BMP were involved in the study design, interpretation of results, and editing the manuscript. JH and ES were responsible for designing and testing the smartphone application. MAM was involved in the study design, interpretation of results, and editing the manuscript.

CONFLICTS OF INTEREST AND FUNDING DISCLOSURE

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recall type, suggesting that a beverage screener may be useful in characterizing consumption of episodically consumed beverages in China's dynamic food and beverage landscape.

Keywords

Diet assessment; nutrition epidemiology; mobile technology; sugar sweetened beverages; China

INTRODUCTION

During recent decades, the nutrition transition in China has been characterized by a shift towards energy dense diets, reduced physical activity, and increasing rates of obesity.[1-3] This transition is often marked by increased consumption of caloric sweeteners and specifically sugar-sweetened beverages (SSBs) like soda and soft drinks.[4-8] SSB consumption has been linked to increased risk of obesity, type II diabetes, and cardiovascular disease.[9-11] However, evidence regarding SSB consumption in China is mixed: sales data show that sales of soft drinks and other beverages including fruit juice, sweetened tea, and bottled water are rapidly growing,[12,13] yet dietary data show that SSB consumption in China remains quite low.[14]

The discrepancy between beverage sales and consumption data suggests that current methods of beverage intake assessment may not adequately capture all beverage consumption. Since 1989, the China Health and Nutrition Survey (CHNS) has used 3 consecutive 24-hour recalls, with written notes to aid recall, to capture short-term food and beverage intake. While the 24-hour recall is a widely used and relatively accurate method for obtaining diet intake data,[15] it is prone to omissions and inaccurate portion size estimation,[16,17] and the extent of underreporting varies by numerous factors, including sex, age, and overweight/obesity.[18-22]

The recent development of smartphone technology for diet assessment has offered a promising new way to record beverage consumption, as participants can easily capture images of beverages prior drinking.[23,24] In particular, video records provide an enhanced ability to see all food items in a shot, and also can encompass voice annotation, allowing the participants to describe the foods or beverages consumed.[25] These videos and vocal records can then be used during 24-hour recalls to prompt memory and aid portion size estimation, improving the accuracy of the 24-hour recall.[26] In addition, Ecologic Momentary Assessment (EMA) periodically prompts participants to record beverages they have recently consumed, [27,28] further reducing the likelihood of omission. Because the smartphone video record provides a multi-pronged approach for memory enhancement, including visual and audio components and periodic prompts, it has the potential to improve 24-hour recalls beyond the written record that is currently used to enhance recalls in the China Health and Nutrition Survey. However, little worked has explored whether these features can be used to enhance recall and reduce omissions of beverages during 24-hour recalls in a Chinese population.

In addition, 24-hour recalls may miss beverages that are only sporadically consumed, potentially resulting in an underestimation of the proportion of SSB consumers in China, where such beverages are currently infrequently consumed. Accurately capturing intake of episodically consumed beverages such as SSBs is important in China, where rapid changes in the food and beverage landscape could mean that a beverage that is infrequently consumed today may be widely and readily consumed in the near future. Typically, food frequency questionnaires have provided a valid, reliable method to assess intake over longer periods of time and thus better capture infrequently consumed foods.[29] However, to our knowledge, no work has tested the use of a short, beverage-specific food frequency questionnaire (i.e. beverage screener) in this population. Thus, a second key question is whether the use of a beverage screener can improve estimation of episodically consumed beverages to pinpoint emerging patterns in SSB consumption in China.

The objectives of this study are to 1) compare beverage consumption data collected using a 3-day smartphone-assisted 24-hour recall (SA-24R) vs. beverage data collected using the current CHNS gold standard of measuring dietary intake, the written record-assisted 24-hour recall (WA-24R) and 2) validate, in a small subset, the extent to which each recall method adequately estimates total beverage intake based on correlation with total urine volume measured in 24-hour urine samples. We hypothesized that the smartphone-assisted approach would improve the current written record-assisted approach to collecting beverage intake by minimizing omissions and improving quantification of beverages. Specifically, we hypothesized that participants would report higher intake of SSBs and total beverages in the SA-24R compared to the WA-24R. The third objective of this study is to pilot and evaluate the use of a beverage screener (BEVQ) to identify consumers of episodically consumed SSBs. We hypothesized that the proportion of participants consuming SSBs would be higher in the BEVQ than from either recall method.

MATERIALS AND METHODS

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the institutional review boards at University of North Carolina, Chapel Hill; University of California, Berkeley; and the Shanghai Center for Disease Control and Prevention. Written consent was obtained from all subjects.

A screenshot of the EMA as well as a supplemental document containing additional results will be available by emailing the corresponding author.

Study population

Healthy adults age 20 to 40y were recruited from communities in urban Shanghai and a nearby rural district between March and May of 2013 by contacting community leaders of registered residents in each neighborhood. Of 120 participants who were contacted and randomized, 117 signed the consent. One participant dropped out prior to dietary data collection, and 3 participants were excluded for having received prior diagnoses of hypertension or diabetes, leaving a sample of 110 participants (52 rural, 58 urban) (**Supplement** Figure 1). Forty-six participants (22 rural, 24 urban) volunteered to participate in two 24-hour urine collections.

Data Collection

Participation involved completion of a demographic questionnaire, anthropometry, BEVQ, SA-24R, and WA-24R. All questionnaires and interviews were conducted in Mandarin. Dietary data was collected Saturday evening to Tuesday evening of each week, for two consecutive weeks, in order to capture 1 weekend day and 2 weekdays for each recall type.[30] Participants were randomized to participate in the SA24-R and WA-24R as follows: Sequence 1: (Week 1) SA-24R + BEVQ, (Week 2) WA-24R; or Sequence 2: (Week 1) WA-24R, (Week 2) SA-24R + BEVQ. Recalls collected on sequential periods that captured the same days of the week were used to minimize potential respondent fatigue, [31-34] as well as learning effects, since factors such as increased familiarity may influence reporting on subsequent recalls.[30,35] As administering recall series within a one week timeframe could also lead to a learning effect, participants were randomized to either the WA-24R or the SA-24R first. Because beverage intakes may have varied across periods encompassed by the different recall types, the mean intake across both periods was used as the estimate of “usual intake”. Similar to other dietary validation studies, our aim was to assess the concordance of estimated usual intakes based on different assessment methods.[36-38] Both methods were also validated against total urine volume in a subset of participants, as described below.

For all participants, Visit 1 included the completion of a demographic questionnaire about age, education, occupation, and disease history. Visit 1 also included anthropometric measurements. Height was measured to the nearest centimeter using a wall-mounted stadiometer and body weight was measured in light clothing without shoes to the nearest 0.1 kilogram using an electronic scale (Seca, Hanover,MD). Body mass index (BMI) was calculated as kg/m^2 and overweight/obesity was defined as having a BMI ≥ 25 kg/m^2.[39] Sequence 1 participants then received training on how to complete the SA-24R and Sequence 2 participants received training on how to complete the WA-24R, including use of a guidebook to assist with portion size estimation. Each participant also received a user manual on smartphone operation. For each recall type, the 24-hour recalls were conducted each evening from Sunday to Tuesday.

During the SA-24R, participants were provided with a smartphone (Samsung Galaxy Y), and asked to wear it on their waist in a small belt during all waking hours and utilize the CalFit system of applications installed on each device.[40-42] For all beverages and foods consumed, participants were instructed to place a provided fiduciary marker next to the items and take a brief video of the items. Using a provided script template, participants stated their location, the time, the items to be consumed, and the portion sizes of the items. In addition, on 4 occasions throughout the day, the participants were prompted to complete a brief EMA asking if they had consumed any beverages in the preceding hours, the beverage type, and if they added anything to the beverage (ice, sugar, cream, etc) (**Supplement Figure 2**). During the 24-hour recall, trained interviewers reviewed the videos with the participants to prompt their recall of foods and beverages consumed.

During the WA-24R, participants were asked to write notes on a paper log about all food and beverages consumed. The written notes included the general type of food but not portion size, condiments, or recipes (i.e. “bowl of noodles”). During the 24-hour recall, interviewers reviewed the written notes with the participants. All diet recall data were coded and entered by trained staff at the Shanghai CDC and checked for completeness.

Energy and water per 100 g for each beverage were based on a Chinese food composition table (FCT) in which all foods were measured using the Perkin-Elmer Analyst 800.[43] For beverages which have not yet been updated in the Chinese FCT due to their new emergence in the food supply, composite nutrient values for similar foods from the USDA food database were used.[44] Total fluid intake included all fluid in beverages, soups, and foods. Beverages were categorized into beverage groups and classified as an SSB or non-SSB based on their level of processing (fresh or packaged/bottled) and added sugar content (Supplement **Table 1**). SSBs include soda, sports drinks, sweetened fruit drinks, sweetened milk drinks, sweetened coffee and tea, and smoothies. Beverages with zero energy were categorized into traditional zero-energy beverages, which included water, loose-leaf tea, and soup (often consumed as a beverage in China), and bottled zero-energy beverages, which included diet soda and unsweetened bottled teas. A recall day was considered eligible for inclusion in the study if the participant completed the dietary interview, total kJ were >2092 kJ and <20920 kJ and total fluid intake were >500g and <4000 g, as values outside this range are considered extreme and may not reflect usual intake.[45] Of 110 participants, 84% recorded 6 eligible recall days, 11% recorded 5 days, 3% recorded 4 days, and 2% recorded 2 or 3 recalls days.

To validate total fluid intake collected by the 24-hour recalls, volunteers participating in the urine sample sub-study provided two 24-hour samples, one each for the SA-24R and the WA-24R.[46-49] Participants collected all urine beginning with the first urine of the second day of the recall until the first urine on the third day of the recall in provided leak-proof plastic containers, and recorded start and stop times.[46] Urine samples were analyzed for total volume (mL). Urine samples were considered complete if the participant reported a duration between 22 and 26 hours and total volume was >500 mL.[50] Using a power calculation for paired t-tests, to achieve 80% power at an alpha of 0.05 to detect a 50 mL difference between fluid intake and urine output, 32 volunteers were needed to participate in each urine sample.

BEVQ Development and Testing

The BEVQ was developed to capture episodic intake and estimate mean daily intake of beverage categories including water, sugar sweetened beverages, and alcohol and two open-ended questions for "other" beverages **(Supplement Table 2)**. The beverage categories were adapted from a validated beverage questionnaire screener in consultation with a panel of experts about beverages that are commonly consumed in China.[51] The BEVQ was piloted amongst staff at the Shanghai CDC to evaluate whether the questionnaire was understandable and comprehensive.[52] For each beverage, participants selected whether they consume the specific category of beverage (yes/no), the frequency of intake (daily, weekly, monthly, yearly), how often they drink the beverage during the selected unit (1-7 occasions, with an open category for >7), and how much they drink when they drink the beverage (mL). For comparison with the SA-24R and WA-24R, traditional and bottled zero calorie beverages were combined into one category, since the BEVQ did not have a separate item for bottled water. In addition, soup intakes from the recalls were excluded in this comparison since soup was not an item on the BEVQ. Other categories included 100% juice, unsweetened milk, alcohol, and SSBs (including soda, fruit drinks, sweetened tea, smoothies, and sweetened coffee beverages).

To derive average daily intake, the unit of frequency was multiplied by the number of occasions the beverage is consumed during that unit and multiplied by the amount consumed during each occasion, then divided by the number of days in that unit of frequency. (For example, 1 week × 6 occasions/week × 100 mL/occasion × 1 week/7 days). Average daily grams and energy for each beverage was determined by multiplying the number of ml per day by the energy and grams per ml for each category.

For all participants, the BEVQ was administered on the last day of the SA-24R. However, because the BEVQ asks about each participant's usual intake of beverages rather than recent or short-term intake, answers to the BEVQ refer to each participant's long-term pattern of beverage intake rather than intake of beverages while they were participating in the study.

Statistical analyses

All statistical analyses were performed using STATA, version 12 (Stata Corporation, College Station, Texas). Mean daily intake was calculated as total intake (in grams and kJ) of each beverage group divided by number of eligible recall days for each participant. Mean intake in grams and kJ of total beverages and each beverage category for the SA-24R and WA-24R were compared using paired *t*-tests and Spearman rank correlation coefficients. Bland Altman plots were used to assess bias between SA-24R and WA-24R. Pearson correlation coefficients were calculated to assess total fluid intake reported in the SA-24R and WA-24R against total urine volume from the respective 24-hour urine samples. Quartiles of mean daily intake were used to derive weighted *k* statistics to assess the level of agreement between the SA-24R, WA-24R, and BEVQ for key beverage categories. Repeated measures mixed models were used to assess the effects of overweight/obese, urbanicity, and sequence on mean beverage intake in the SA-24R compared to the WA-24R.

RESULTS

The sample was 54% male and mean age was 29.6 y (± 0.29). Twenty-four percent of participants were overweight/obese (n=26).

Mean beverage intakes (g) from the SA-24R and the WA-24R are presented in **Table 1**. During the SA-24R, participants reported 222 fewer g/day total beverages than in the WA-24R (p <0.01). Differences in beverage intake reporting by recall method were largely attributable to traditional zero-energy beverages, as participants reported 229 fewer g/day of traditional zero-energy beverages during the SA-24R compared to the WA-24R (p <0.01). Mean intake of zero-energy bottled beverages was 12 g higher during the SA-24R compared to the WA-24R, but this difference was not statistically significant. Mean intakes of soda and soft drinks, sweetened tea and coffee, sweetened fruit drinks, sweetened milk, and total SSBs were not different between the SA-24R compared to the WA-24R. Examining caloric beverages only, participants reported mean ± SE 522±66 kJ/day total beverage intake during the WA-24R compared to 441±55 kJ/day during the SA-24R (*p*=0.226) (**Supplement Table 3**). Mean intake of SSBs was 350 ± 56 kJ/day during the WA-24R compared to 296 ± 9 kJ/day during the SA-24R (*p*=0.492).

Spearman correlation coefficients (**Table 1**) ranged between 0.21 (fruit juice) and 0.60 (total beverages) for mean beverage intake (g) between the SA-24R and WA24R, with the exception of a correlation of −0.06 for sweetened fruit drinks. This latter beverage type was the smallest contributor (<3%) to beverage intake. SSBs had a correlation coefficient of 0.50 for mean grams of intake (p<0.001). Results were similar for kilojoules (data not shown).

Of 44 volunteers who agreed to provide 24 h urine samples during the SA-24R, 34 provided a complete urine sample and of 46 volunteers during the WA-24R, 36 provided a complete sample, providing >80% power to detect a 50mL difference between urine volume and total fluid output at an alpha of 0.05 for each recall type. Among subjects with complete samples, total urine volumes ranged from 528 to 2562 mL, with no meaningful difference in fluid intakes reported on urine sample collection days vs. other days among sub-study participants (data not shown). Total fluid intake during the SA-24R was 1208 ±140 mL compared to total urine volume of 1342±88 mL, with a Spearman correlation of 0.42 (p=0.014). Total fluid intake during the WA-24R was 1400±130 mL compared to total urine volume of 1336±93 mL, with a correlation of 0.31 (p=.0624). Scatter plots of urine volume vs. reported fluid intake suggested of presence of 4 individuals in each recall with extremely poor agreement (>1200ml or <−1200ml difference between total urine volume and total fluid intake). Excluding these individuals improved Spearman correlations to 0.58 for the SA-24R(p<0.01) and 0.46 for the WA-24R(p=0.01).

Figure 1a, b, and c showed the Bland Altman Plot comparing mean daily intake (g) from beverages in the SA-24R to the WA-24R. For total beverages, the mean bias was −222g (95% CI −313g to 131g). The mean bias for traditional zero-energy beverages was −228g (95%CI −321g to 137g) and for SSBs, the mean bias was −25g kJ (95% CI −64g to 15g), showing lower intakes for each beverage type in the SA-24R.

The mixed models for repeated measures indicated that there was no difference in reporting of total beverages between the two recall types by urbanicity. Being overweight/obese was associated with decreased reporting of total beverage intake on the SA-24R (**Supplement Figure 3).** Overweight/obese participants reported 430 g/day fewer beverages on the SA-24R than on the WA-24R, while non-overweight participants underreported beverages on the SA-24 relative to the WA-24R by 158 g/day (p<0.01). Overweight/obese participants also reported 65 g/day fewer SSBs on the SA-24R relative to the WA-24R, while non-overweight participants reported 12 g/day fewer SSBs on the SA-24R relative to the WA-24R. However, these differences were not statistically significant (p=0.266). Sequence also mattered: overall, those who completed the SA-24R in the first week first reported 89 fewer g/day total beverages on the SA-24R compared to the WA-24R. However, those who completed the WA-24R in the first week reported 360 fewer g/day total beverages on the SA-24R than on the WA-24R (*p*<0.01) (not shown). There were no differences in reporting of SSBs on the SA-24R compared to the WA-24R by urbanicity, sequence, or overweight.

Since episodically consumed beverage types may not be captured with a limited number of recalls, we also compared intakes reported on BEVQ vs. the mean of three 24R collected using both methods. Percent consumers and weighted *k* statistics for the SA-24R, WA-24R, and BEVQ are reported in **Table 2**. With the exception of zero-energy beverages, more participants reported consuming other beverage types in the BEVQ than in either recall type. Notably, 88% of participants reported consuming SSB in the BEVQ compared to only 55% and 56% in the SA-24R and the WA-24R, respectively ($p<0.05$). Participants reported higher mean daily intakes of beverages in the BEVQ, including total beverages (1326 ± 90 g), water (1031 ± 79), 100% juice (18 ± 5 g), milk (56 ± 10 g), and SSBS (185 ± 26 g).The SA-24R and the WA-24R demonstrated similar fair levels of agreement with the BEVQ for quartiles of intake of total beverages, SSBs, and alcohol, with *k* statistics ranging from 0.27 to 0.36. Non-sweetened beverages including zero calorie beverages, 100% fruit juice, and unsweetened milk showed only slight agreement between recall types with the BEVQ. Total beverages and SSBs showed moderate correlation between the recall methods and the BEVQ, with Spearman correlations of 0.31 and 0.43 for total beverages for the SA-24R and WA-24R, respectively ($p<0.01$), and correlations of 0.48 and 0.43 for SSBs for the SA-24R and WA-24R, respectively ($p<0.01$).

DISCUSSION

In this study, the SA-24R and WA-24R showed moderate correlation between reported fluid intake and total urine output. Correlations between the two methods showed moderate agreement across beverage categories, with an average Spearman rank correlation of 0.42. Despite these moderate correlations, mean beverage intake was significantly lower by 222 g/day in the SA-24R compared to the WA-24R. This study also showed significantly lower reporting of beverage intake on the SA-24R by overweight participants compared to normal weight participants.

Overall, the correlations between the SA-24R and WA-24R were similar to those found when comparing nutrients in short-term diet assessment methods across different time periods.[36,37] For example, comparing two 24-hour recalls and a 4-day food record, Frankenfeld found Pearson correlations between 0.4 and 0.6 for most nutrients, with moderate to low *k* values for quartiles ($k=0.11$ to 0.52).[36] The underreporting of mean intake on the SA-24R is similar to other studies of digital diet assessment when compared to paper-based methods. For example, participants underreported energy by 640 kJ on a record of voice-annotated photograph of food items compared to a concurrent written food diary .[25] Lazarte, who also used a digital food record to enhance (rather than replace) 24-hour recalls, reported that despite high correlations for most nutrients, participants underreported nutrients when using the modified-24h recall method compared to a weighed food record.[26]

One explanation for the decreased reporting in the SA-24R is that when a participant forgets or chooses not to take a video of a beverage, and the video log is used to prompt memory during the 24-hour recall, the participant may be more likely to omit the beverage than they would if the participant were using a written log to jog the memory.[27] Since the written record contains fewer details than the video record, participants may have been less reliant on the written record during a recall, and so less prone to omission of an absent beverage.

Conversely, they may have had more familiarity with the written record and found it easier to briefly note the beverage than to take a voice-annotated video, increasing the memory-enhancement capability of the written record compared to the video record.

Another explanation is that the smartphone-based approach may have influenced consumption patterns, as participant reactivity to the method is unknown.[27] One possibility is that the decreased reporting of traditional zero-energy beverages in the SA-24R was not misreporting, but a reflection of participants consuming fewer traditional zero-energy beverages when using the smartphone. Perhaps using a smartphone increased participant's awareness of how much they were drinking, or was simply too cumbersome to use, resulting in decreased consumption of these beverages. For example, some participants reported that they felt embarrassed while taking videos of food in public places or at work. Higher respondent burden on the SA-24R may also explain why participants who completed the WA-24R first reported fewer beverages on the SA-24R than those who completed the SA-24R first. Since the SA-24R was more difficult to complete, participants who had already completed the WA-24R felt even more burdened by the SA-24R relative to the WA-24R and responded by reporting fewer beverages on the SA-24R.

It is possible that simply photographing beverages prior to consumption would yield the same benefit for enhancing memory during the 24-hour recall, but would be less cumbersome. Similarly, the use of EMA alone, without photos, to prompt participants to think about beverage intake throughout the day may achieve the same memory-enhancement benefit and be even less burdensome. Future work is required to understand which method provides the greatest benefit in terms of reducing omission and improving portion size estimation during the 24-hour recall, while minimizing respondent burden and remaining culturally acceptable.

Notably, however, the majority of underreporting in the SA-24R relative to the WA-24R was accounted for by differences in the reporting of traditional zero-energy beverages (water, tea) and there were no substantial differences in intake or energy for any other beverage. This suggests that both methods provide similar estimates of intakes of energy-containing beverages. The findings from SA-24R correlated with those of the WA-24R with regard to SSBs. One possibility is that respondents are more likely to record and also to remember beverages that are sold in discrete packaged containers, such as a can of Cola or a pouch of sweetened milk, than they are beverages that are consumed continuously, like tea and water. In addition, traditional zero-energy beverages are very frequently consumed in China, making them less memorable than rarely-consumed SSBs, and potentially contributing to increased omissions.

Despite the apparent decreased reporting in the SA-24R compared to the WA-24R, the SA-24R showed stronger correlation with total urine output than did the WA-24R, suggesting higher validity. One alternate explanation for the higher reported intake of traditional zero-energy beverages like water and tea in the WA-24R relative to the SA-24R is that when using the written method, participants overestimate their intake of these beverages. Such an effect could occur because the written record provides less detail than the smartphone video record, making it more difficult to accurately estimate portion size during the 24-hour recall. Although we were adequately powered to detect a 50 mL difference between total fluid intake and total urine volume, further research using additional validation methods such as hydration biomarkers is required to understand the nature of beverage intake misreporting using both of these instruments.

The Bland-Altman plots showed that for total beverages and for SSBs, the bias between the SA-24R and WA-24R was not consistent across levels of intake, with the bias increasing with higher intakes of beverages. Previous studies have shown that although portion size estimation from digital photography is valid,[53,54] people are more likely to correctly estimate smaller portions and more likely to underestimate larger portions.[54,55] In addition, most studies testing the validity of portion size estimation from digital photographs have compared estimation from photographs against direct estimation in real time. More research is needed to understand how estimation from digital images and direct estimation compare when recall occurs at a later time, such as during a typical 24-hour recall.

Decreased reporting on the SA-24R relative to the WA-24R by overweight/obese participants is not surprising, considering other digital diet assessment studies have shown that obese men showed more underreporting using personal digital assistant to record food intake than did normal weight men.[56] Interestingly, however, we found that overweight/obese participants did not show decreased reporting of SSBs on the SA-24R relative to the WA-24R, compared to normal weight participants. This result is in contrast to previous work, which shows that overweight and obese individuals are more prone to social desirability bias, and tend to report lower energy from perceived “unhealthy foods” like snacks, high fat, and high carbohydrate foods.[22,57,58] We would expect that taking videos of unhealthy beverages like SSBS would further exacerbate this bias if overweight or obese participants were more embarrassed to show videos of the foods they have consumed, resulting in decreased reporting of SSBs on the SA-24R relative to the WA-24R. One explanation for the lack of this effect in the current study is that the tendency to underreport SSBs increases with BMI, with obese participants showing greater underreporting than overweight or normal weight participants. However, due the limited sample size of obese participants in this study (n=5), we were unable to test whether obese participants respond differently to the SA-24R than the overweight participants.

The majority of respondents reported consuming SSBs. Although a number of studies have reported that the multiple-day 24-hour recall method can be a good estimator of usual nutrient intake at the population level,[59,60] a much higher proportion of respondents reported consuming SSBs in the BEVQ than in either recall method. The recall methods showed moderate correlation with the BEVQ for total beverages and SSBs, consistent with results from Hedrick, who found correlations between 0.46- 0.49 for total beverage and SSB intake between a beverage screener and 4-day food record.[51] The higher proportion of consumers in the BEVQ reflects the changing diet patterns in China: while the number of consumers of SSBs is increasing rapidly, many of these consumers still drink SSBs only episodically (less than once a week, usually on special occasions), and hence this consumption may not be reflected in 3-day consecutive recalls. Methods that incorporate both the probability of consumption based on frequency questionnaires, along with recalls, to estimate and the amount of intake, such as the NCI method or Multiple Source Method can provide a better estimation of emergent beverage consumption patterns in China's dynamic food environment.[61,62]

This study had several important limitations. Due to rapid changes in China's food supply, the FCT does not contain all the newly available beverages, making it difficult for interviewers to correctly identify emergent beverages like SSBs. In this study, all beverages were examined and coded to the appropriate beverage group, including new beverage groups created explicitly for this study, by trained researchers. However, it is possible that the discrepancy between the FCT and the current Chinese food supply accounts for more of the low reporting of SSBs in Chinese nutrition surveys than do issues with the current recall method. In addition, the recalls were conducted on consecutive days, and SA-24R and WA-24R were conducted on consecutive weeks, which reduces intra-individual variation in beverage intake. It is also unclear why underreporting on the SA-24R was greater when the WA-24R was completed first. One possibility is that, if the WA-24R was more difficult to complete, respondents who completed the WA-24R first felt more burdened by the study and thus reported fewer beverages during the SA-24R during the second week. While the EMA was helpful in prompting participants to recall their beverage intake, there is also a strong possibility that the receipt of reminders throughout the day altered beverage consumption of the respondents. Future research should address the extent to which the EMA and process of taking videos affects the type and amount of beverages and foods participants consume.

Conclusion

The use of a SA-24R does not appear to improve the quantification of beverage intake compared to a WA-24R recall in a Chinese population. The SA-24R may be a useful aid for capturing images of SSBs and other packaged beverages, but substantial underreporting or under-consumption of water and other non-caloric beverages, particularly by overweight individuals, poses a considerable barrier to future use of this instrument for overall beverage intake. The incorporation of a beverage screener may be useful in identifying episodic consumers of SSBs in addition to recall methods. More work is required to understand the optimal method for collecting information on beverage intake in the dynamic Chinese food environment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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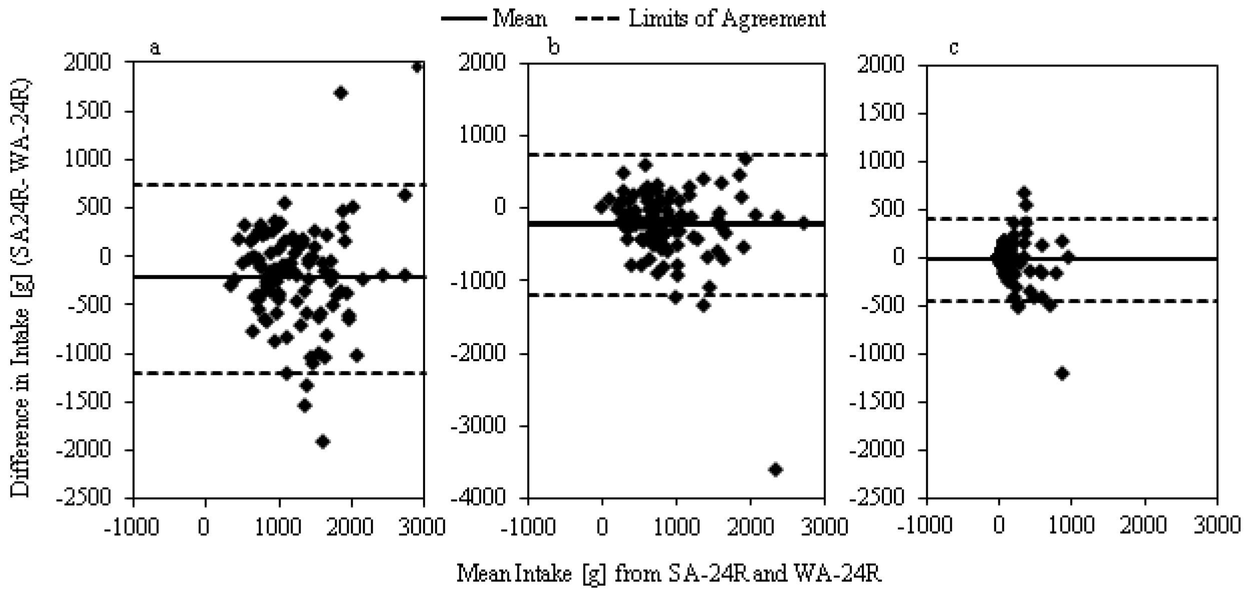

Figure 1a,b,c.

Bland-Altman Plot of a) Total Beverage Intake b) Traditional Zero Energy Beverage Intake and c) Sugar-Sweetened Beverage Intake between SA-24R and WA-24R[g/d]

Table 1

Mean daily beverage intake (g) from SA-24R compared to the WA-24R†

	SA-24R		WA-24R			
	Mean	SE	Mean	SE	Spearman rank	Mean difference (%)‡
All Beverages, Total	1088*	51	1310	53	0.60**	−222 (−17)
Traditional Zero -Energy Beverages	761*	48	990	59	0.64**	−229 (−23)
Zero-Energy Bottled Beverages	102	20	90	25	0.42**	12 (13)
100% Fruit Juice	22	6	27	6	0.210	−4 (−19)
Milk, Unsweetened	56	10	59	10	0.47**	−3 (−5)
Soda and Soft Drinks	27	8	47	12	0.35**	−20 (−43)
Tea and Coffee, Bottled/Sweetened	31	9	36	9	0.44**	−5 (−14)
Fruit Drinks, Sweetened	7	3	6	2	−0.060	1 (−17)
Milk, Sweetened	54	12	51	13	0.45**	3 (6)
Alcohol	29	11	35	13	0.60**	−6 (−17)
SSB, Total	137	20	162	25	0.50**	−25 (−15)

‡Mean individual difference between SA-24R and WA-24R in grams and percentage in parentheses. For each individual, the percentage difference was calculated as (mean beverage intake from SA-24R - mean beverage from WA-24R/mean beverage from WA-24R)*100

*From paired t-test, the mean from the SA-24R was significantly different from the mean from WA-24R for any beverage type (p<0.01)

**Spearman rank correlation coefficient for beverage type between SA-24R and WA-24R was significant (p<0.01)

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Table 2

Percent consumers and weighted κ statistics for the SA-24R, WA-24R, and BEVQ[†]

	% Consumer			SA-24R vs. WA-24R		SA24-R vs. BEVQ		WA24-R vs. BEVQ	
	SA-24R	WA-24R	BEVQ	κ	% Agreement	κ	% Agreement	κ	% Agreement
Zero-Energy Beverages[‡]	100	100	99	0.51	80	0.21	67	0.33	72
100% Fruit Juice	19[ab]	23	44	0.19	73	0.21	69	0.13	64
Milk, Unsweetened	35[b]	38[a]	51	0.36	74	0.14	61	0.28	67
Sugar Sweetened Beverages	55[ab]	56[a]	88	0.38	72	0.29	68	0.30	69
Alcohol	8[ab]	9[a]	45	0.59	94	0.29	73	0.27	72
All Beverages, Total	--	--	--	0.49	79	0.31	71	0.36	73

[†]SA-24R is the 3-day consecutive smartphone-assisted 24-hour recall, WA-24R is the 3-day consecutive written-assisted 24-hour recall, and BEVQ is the China Beverage Validation Study beverage screener.

[‡]Zero calorie beverages includes traditional zero calorie beverages like water and tea, as well as bottled zero calorie beverages.

[a]Significantly different from BEVQ, $p < 0.05$ from χ^2 test

[b]Significantly different from WA-24R, $p < 0.05$ from χ^2 test