Practice of Epidemiology

Relation of Children’s Dietary Reporting Accuracy to Cognitive Ability

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A validation study of children’s dietary reporting provided an opportunity to investigate whether cognitive ability is a source of systematic error in dietary recalls. From the fall of 2004 through the spring of 2007, fourth-grade children (n = 374) in Columbia, South Carolina, were observed eating school meals and interviewed to obtain 24-hour dietary recalls; subsequently, measures of dietary reporting error were calculated. The common factor extracted from 4 subject-area achievement tests (scores on which were provided by the school district for 362 children) was used as a measure of cognitive ability. For the 325 children who reported school meals that met the criteria to be reports about school meals, as cognitive ability increased, dietary reporting error decreased; the relation between cognitive ability and dietary reporting performance was stronger among girls than among boys. The mean cognitive ability for 37 children who reported no meals that satisfied the criteria for being reports about school meals was significantly lower than that for the 325 children who reported meals that satisfied these criteria. These findings indicate that cognitive ability is a source of systematic error in children’s dietary recalls. More generally, the quality of epidemiologic survey data may depend systematically on the cognitive ability of respondents.

bias (epidemiology); child; diet surveys; intelligence; mental recall

Abbreviation: PACT, Palmetto Achievement Challenge Tests.

Much of epidemiologic data consists of individuals’ self-reports about past behaviors. In national health surveys, research questionnaires, and clinical assessment instruments, individuals are asked to report about such behaviors as dietary intake, physical activity, medical visits, and use of mobile telephones.

Error in self-reports about these behaviors may be random or systematic. Larger random errors reduce the power of studies to detect relations between reported behaviors and outcomes (e.g., between reported intake of some food and health status); systematic errors may exaggerate or mask relations (1, 2). Systematic error may be associated with, and therefore predictable from, stable characteristics of respondents. For example, the accuracy of dietary and physical activity self-reports is related to such personality characteristics as social desirability and social approval motivation (3–5).

To answer questions about past behaviors accurately, an individual must retrieve appropriate information from memory and utilize that information to formulate responses. Memory is a component of cognitive ability (6), so reporting accuracy may be related to cognitive ability, and cognitive ability may be a source of systematic error in epidemiologic data.

There is little published research on the relation between cognitive ability and dietary reporting accuracy in either children or adults, and the results of extant research are mixed. Some studies of adults have examined the relation of dietary reporting accuracy to educational attainment, a rough proxy for cognitive ability (7, 8). Other studies of adults and some studies of children have assessed the relation of dietary reporting accuracy to such measures as scores on brief short-term memory tests (9, 10); such measures may not be psychometrically reliable.

A validation study of children’s dietary reporting (11) provided an opportunity to further investigate the relation between dietary reporting accuracy and cognitive ability. The primary aim of that validation study was to investigate the effect of retention interval (time between food intake and recall interview) on dietary reporting accuracy.
Fourth-grade children were observed while eating school meals and interviewed to obtain 24-hour dietary recalls (11). Children’s scores on standardized achievement tests were used to construct an index of cognitive ability.

**MATERIALS AND METHODS**

The methods, described previously in detail (11), are summarized here. These were approved by the Institutional Review Board of the University of South Carolina.

Data were collected from fourth-grade children during 3 consecutive school years (from the fall of 2004 through the spring of 2007) in a total of 18 elementary schools in 1 school district in Columbia, South Carolina. At these schools, on average over the data collection period, approximately 85% of children were eligible for free or reduced-price school meals. Participants for the validation study were sampled from a pool of children who had indicated their willingness to participate by providing written parental consent and child assent: Of 2,391 children invited to participate, 74% indicated that they were willing to do so. Each school year, from the center 95% of the age distribution of children who were willing to participate, children were randomly selected such that half were girls and all were usual school-meal eaters. The final sample for the validation study included 374 children (96% black; mean age = 10.0 (standard deviation, 0.9) years when interviewed; at least 91% eligible for free or reduced-price school meals). (Aggregate information about the eligibility of these children for free or reduced-price school meals was obtained from the South Carolina Budget and Control Board Office of Research and Statistics, which linked data from this study to eligibility data provided by the South Carolina Department of Education. For some children, information concerning eligibility for free or reduced-price school meals was missing, so lower-bound percentages of eligible children are reported.)

Each validation study participant was observed while eating 2 school meals and was later interviewed to obtain a dietary recall about a 24-hour period during which those meals had been observed. Children were assigned randomly to 1 of the 6 interview conditions yielded by crossing two 24-hour target periods (prior 24 hours (i.e., the 24 hours preceding the interview) or the previous day (midnight to midnight of the previous day)) with 3 interview times (morning, afternoon, evening), subject to the constraint that half of the children assigned to each interview condition were girls. There were 62 or 64 children (half girls) in each interview condition. Over the 6 interview conditions, the time from the midpoint between the 2 observed school meals to the interview ranged from approximately 4 hours (afternoon interview about the prior 24 hours) to approximately 35 hours (evening interview about the previous day).

Validation study participants who were to have morning interviews about the prior 24 hours were observed while eating lunch on one day and breakfast on the next day; all others were observed while eating breakfast and lunch on the same day. An observer watched as many as 3 children simultaneously during school meals and recorded the food items eaten by each child. During each school year, as many as 6 researchers conducted observations. Each school year, interobserver reliability was assessed for every pair of observers by ascertaining whether the observers agreed to within one-fourth serving on the amounts eaten. Each observer was involved in at least one such assessment during each week of data collection. The mean levels of interobserver agreement for each of breakfast and lunch in each data collection year exceeded 94%.

During each school year, as many as 3 researchers conducted morning and afternoon interviews after breakfast and lunch, respectively, in person at the children’s schools and evening interviews by telephone. Interviewers followed protocols modeled on the Nutrition Data System for Research protocol (NDS-R 4.03; Nutrition Coordinating Center, University of Minnesota, Minneapolis, Minnesota). An interviewed child was to report everything consumed during the specified target period. Interview quality control procedures were applied throughout data collection: The audio-recording and typed transcript of each interview were reviewed by an interviewer other than the one who had conducted the interview. An interview passed quality control only if it had been conducted according to protocol and was not corrupted by uncontrollable circumstances (e.g., interruption, technology problems).

The Palmetto Achievement Challenge Tests (PACT) (12), which measured achievement in 4 subject areas (language arts, mathematics, science, and social studies), were administered by school staff during May of each data collection year. In 2003, the reliabilities (quantified by Cronbach’s alpha) of the fourth-grade tests ranged from 0.81 (science) to 0.92 (language arts) (13). The school district provided PACT scores for children who participated in the validation study.

Only reports about school meals in 24-hour dietary recalls were analyzed, because only school meals were observed. A reported meal was treated as referring to a school meal only if a child identified “school” as the location, named the meal correctly, and reported the mealtime correctly. Any food item observed eaten and reported eaten was classified as a match, any item observed eaten but not reported eaten was classified as an omission, and any item reported eaten but not observed eaten was classified as an intrusion. Items were weighted by meal component (combination entrée = 2; condiment = 0.33; others = 1). Then, for each child, 2 dietary reporting-error measures were calculated: 1) The omission rate is omissions divided by the sum of matches and omissions; and 2) the intrusion rate is intrusions divided by the sum of matches and intrusions (14). These measures describe different aspects of memory performance. The omission rate is the unreported proportion of what was to be reported, and the intrusion rate is the incorrect proportion of what was reported (14, 15). These have been termed input-bound and output-bound measures of memory performance, respectively (15).

The pairwise correlations between the scale scores of the PACT subject-area tests ranged from 0.58 to 0.65, which suggested that the 4 subject-area tests measured a smaller number of underlying constructs. The PACT scores were factor analyzed by using the principal factors method with squared multiple correlations as prior communality.
estimates; these ranged from 0.50 to 0.54. One factor explained all of the common variability in the 4 subject-area tests. The correlations of the subject-area tests with this factor ranged from 0.75 to 0.79, indicating that between 56% and 62% of the variability in each subject-area test was associated with variation in the latent construct represented by the factor. This factor was extracted, and the score on it was estimated for each child. This factor score was used as the measure of cognitive ability.

Each of omission rate and intrusion rate was regressed on target period, interview time, cognitive-ability factor score, and all of their interactions, as well as potential confounders—sex, the interaction of sex and cognitive-ability factor score, days between interview and PACT administration, data collection year, and interviewer. For neither omission rate nor intrusion rate were the interactions of cognitive-ability factor score with the manipulated variables that determined retention interval (target period, interview time, their interaction) significant (all $P > 0.21$, 2 sided), so these interaction terms were removed; in addition, in neither model were the effects of days between interview and PACT administration, data collection year, and interviewer significant (all $P > 0.18$, 2 sided), so these were also removed. The results described in this article are based on regressions of omission rate and intrusion rate on target period, interview time, their interaction, cognitive-ability factor score, sex, and the interaction of sex and cognitive-ability factor score. Comparable models were tested for the weighted number of items observed eaten and the weighted number of items reported eaten. All statistical tests were 2 sided. (Both the omission rate and the intrusion rate increased significantly as the retention interval was lengthened (11)).

To display the unique relation of each of omission rate and intrusion rate to the cognitive-ability factor score, residuals were calculated, removing from each error rate what was predictable from target period, interview time, the interaction of target period and interview time, sex, and the interaction of sex and cognitive-ability factor score.

RESULTS

For 12 of the 374 children who participated in the validation study, PACT scores were unavailable. Of the 362 children whose PACT scores were available, 37 children (36 black; 16 girls; at least 86% eligible for free or reduced-price school meals) reported no meals that met the criteria for being reports about school meals. Thus, complete data—both PACT scores and dietary-reporting omission and intrusion rates—were available for 325 children (312 black; 164 girls; at least 91% eligible for free or reduced-price school meals). For these children, interviews occurred between 216 days before and 8 days after PACT administration (mean difference = 115 (standard deviation, 59) days).

Relations of omission rate and intrusion rate to cognitive ability

For the 325 children with complete data, Figure 1 shows the means of the omission rate and intrusion rate residuals by cognitive-ability factor-score decile. Each panel shows that, as cognitive ability increased, dietary reporting error decreased. For omission rate residuals, $r = -0.31$ ($P < 0.001$); for intrusion rate residuals, $r = -0.20$ ($P = 0.001$). The proportion of variability in omission rate associated uniquely with cognitive ability was 0.08; by comparison, the proportion of variability uniquely associated with the variables that determined the retention interval was 0.21. For intrusion rate, the comparable values were 0.03 and 0.27, respectively.

Numbers of items observed eaten and reported eaten

The weighted number of items observed eaten was not significantly related to the manipulated variables that determined the retention interval (target period, interview time, and their interaction), to cognitive-ability factor score, or to any of the examined potential confounding variables. The weighted number of items reported eaten, although not related to the manipulated variables that determined the retention interval or to any of the examined potential confounding variables, increased with cognitive-ability factor score ($P = 0.053$). (In the model from which the nonsignificant interaction terms and confounding variables were removed, $P < 0.001$).

Association with sex

Each of omission rate and intrusion rate was associated significantly with the interaction of sex and cognitive-ability factor score (for omission rate, $P = 0.001$; for intrusion rate, $P = 0.01$). The omission rate was inversely related to cognitive-ability factor score for both girls and boys, although the relation was stronger for girls than for boys; for girls, the partial correlation of the omission rate and cognitive-ability factor score (with target period, interview time, and their interaction partialled out) was −0.42; for boys, it was −0.14. The intrusion rate was inversely related to cognitive-ability factor score for girls (partial $r = -0.27$), whereas for boys, these were unrelated (partial $r = -0.01$).

Children who reported no meals that met the criteria for being reports about school meals

Of the 362 children for whom PACT data were available, cognitive-ability factor scores ranged from −2.34 to 2.88, with the mean = 0 (standard deviation, 0.91). For the 37 children who reported no meals that met the criteria for being reports about school meals, the mean cognitive-ability factor score of −0.57 was significantly less than the mean score of 0.07 for the 325 children who reported meals that met the criteria ($t$ test; $P < 0.0001$).

DISCUSSION

For 10-year-old children, reporting accuracy about dietary intake was related to cognitive ability. Each of 2 dietary-reporting error rates decreased as cognitive ability increased. The effects, although modest in size, are striking.
Survey data quality may depend systematically on the cognitive ability of respondents.

Among the children who reported meals that satisfied the criteria to be reports about school meals, the relation between cognitive ability and dietary-reporting performance was manifested more strongly in omission rates (the unreported fraction of what was to be reported) than in intrusion rates (the fraction of reported items that was incorrect). Although the weighted numbers of items that children were observed eating were unrelated to any of the studied explanatory variables, as cognitive ability increased, the weighted numbers of items reported increased. Children with higher cognitive ability reported more items, and what they reported better matched what they were supposed to report, than children with lower cognitive ability.

The stronger relation of cognitive ability to omission rate than to intrusion rate was due, in part, to different relations between cognitive ability and these measures for boys and girls. Each of omission rate and intrusion rate was more strongly related to cognitive ability for girls than for boys; in fact, for boys, the intrusion rate was not related to cognitive ability. However, even for girls, the relation between cognitive ability and the omission rate was stronger than that between cognitive ability and the intrusion rate.

The stronger relation of cognitive ability to the omission rate than to the intrusion rate may also be due, in part, to the nature of these measures. The weighted number of items observed eaten was unrelated to cognitive ability, whereas the weighted number of items reported eaten increased with cognitive ability. Given these relations, in the best case, all

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Figure 1. Mean omission rate residuals (A) and intrusion rate residuals (B) by decile of cognitive-ability factor score, Columbia, South Carolina, 2004–2007. Residuals were computed from regression of the omission rate and the intrusion rate, respectively, on the variables that determined retention interval (target period, interview time, and their interaction), sex, and the interaction of sex and cognitive-ability factor score. Error bars represent standard deviations. Data are from 325 fourth-grade children who participated in a dietary reporting validation study.
reported items would be matches, so the omission rate would be inversely related to cognitive ability (because with increasing cognitive ability, children would report an increasing fraction of what they had been observed eating), and the intrusion rate would be 0% regardless of cognitive ability. In the worst case, all reported items would be intrusions, so both the omission rate and the intrusion rate would be 100% regardless of cognitive ability. In the average of these best and worst cases, the omission rate would be inversely related to cognitive ability, whereas the intrusion rate would be constant at 50%; any actual case is likely to be between the best and worse cases. The relations between cognitive ability and the dietary-reporting performance measures are, of course, not determined entirely by the number of items reported, because the correctness of the reported items matters, but the intrusion rate may be intrinsically less responsive to variation in other variables than is the omission rate.

The mean cognitive ability of children who reported no meals that satisfied the school-meal-report criteria was significantly lower than that of children whose reports satisfied these criteria. This finding augments results concerning the relation between cognitive ability and dietary-reporting error measures in the children for whom these measures could be calculated.

Previous research on the relation of dietary reporting accuracy to cognitive ability has provided mixed results. In some studies of adults’ dietary reporting, the relation between reporting accuracy and educational attainment, a proxy for cognitive ability, has been explored (7, 8): in these small studies, compared with respondents with less education, energy underreporting was less prevalent among respondents with more education, and the validity of food frequency questionnaire responses relative to 24-dietary recalls was somewhat higher. There is little published research on the relation between cognitive ability, measured directly, and dietary reporting accuracy in either children or adults. In one study of low-income women, the reported energy intake (from four 24-hour dietary recalls) better approximated energy expenditure (from doubly labeled water) as the scores on a standard measure of academic skills increased (16). One study of older adults found that a global measure of cognition was inversely related to suspected errors in energy intake reported on a food frequency questionnaire (17), and another study of older adults found a relation between a measure of short-term memory and the relative validity of food-frequency-questionnaire responses compared with 4-day weighed diet records (9). However, other studies of older adults have found no relation between measured dietary variables and estimates of cognitive function (18, 19). In one relative validation study of dietary reporting in 9- to 11-year-old children, in which responses to a self-completion questionnaire were compared with those to 24-hour dietary recalls, the error rate was inversely related to performance on a test of short-term memory (10).

Among the strengths of this investigation of the relation between dietary reporting accuracy and cognitive ability are that the studied sample of children was large and that the study was a true validation study (i.e., the reference information was collected by direct observation of meals). In addition, the measure of cognitive ability that was used (the common factor extracted from 4 psychometrically reliable subject-area achievement tests) is likely highly psychometrically reliable.

Despite the likely reliability of the measure of cognitive ability, among the limitations of this investigation is that the measure of cognitive ability was derived from tests of academic achievement rather than from more academically neutral assessments. “Cognitive ability,” rather than “intelligence” or “general intelligence,” was the term chosen to characterize the variable represented by the factor extracted from the subject-area achievement tests to avoid an explicit commitment to the notion that this factor is a measure of intelligence. The PACT were designed to measure academic achievement, so the factor extracted may represent academic achievement. However, academic achievement and scores on tests of general intelligence are highly correlated (20–24), and it is plausible that the single factor extracted from the variability common to 4 moderately correlated subject-area achievement tests is related to the factor representing general intelligence that would be extracted from the subtests of a standard test of intelligence.

Other limitations of this study are that the sample was racially and socioeconomically homogeneous. However, the homogeneity of these characteristics of the sample reduces the viability of race and socioeconomic status as alternative accounts of the relation that was found between cognitive ability and dietary reporting performance.

It is notable that systematic reporting error associated with cognitive ability occurs in 24-hour dietary recall data. Data from 24-hour recalls are often used as the reference information in relative validation studies to evaluate the performance of such other dietary assessment methods as food frequency questionnaires. The 24-hour recall has been chosen for these purposes because respondents need not be literate (as the procedure is usually interviewer administered), the respondent burden is assumed to be lower than that of other dietary self-report methods, and the relative immediacy of the procedure is assumed to maximize accuracy (25). However, at least in children, 24-hour dietary recall performance deteriorates as the retention interval increases (11), and the results presented in this article show that, regardless of retention interval, dietary recall performance depends systematically on cognitive ability.

Procedural modifications of 24-hour recalls may attenuate some sources of systematic error. For example, awareness of the effect of the retention interval on 24-hour dietary recall accuracy leads to the suggestion that the retention interval be minimized in order to maximize accuracy. Similarly, the effect of social desirability on 24-hour dietary recalls could be attenuated by arranging interview conditions to minimize the respondent’s sense that he or she was being judged by an interviewer. There may not be a modification of the 24-hour dietary recall procedure that would offset the systematic error associated with cognitive ability. New technologies could be applied to obtain dietary recalls more frequently for shorter periods (e.g., using ecological momentary assessment (26, 27)). This might reduce error associated with cognitive ability, although the expense and respondent burden associated with such data collection...
are likely to be high, and validation is likely to be difficult; further, independent of cognitive ability, even the accuracy with which fourth-grade children report a single meal within 90 minutes of eating is not perfect (28).

Previous research with adults has identified respondent characteristics associated with systematic bias in food frequency responses relative to 24-hour dietary recalls (3–5). The results presented in this article show that, at least in fourth-grade children, cognitive ability is a potential source of systematic bias in the standard itself. Additional research is necessary to ascertain the extent to which this bias pervades dietary self-reports by older children and adults.

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