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ORIGINAL RESEARCH

Literacy's Role in Health Disparities

A Mediator of Race and Income With Anemia in African American and White Adults

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Literacy impacts diet quality and may play a role in preventing anemia. This study investigated whether literacy mediates the relationships between race or poverty status and diet quality and anemia. Diet quality was evaluated using mean adequacy ratios for 1895 white and African American adults from Healthy Aging in Neighborhoods of Diversity across the Life Span study. Anemia was diagnosed by World Health Organization standards. Path analysis explored the influence of race and poverty on anemia. Anemia was diagnosed in 223 participants. The synergistic effects of poverty, race, and diet quality influence anemia. Literacy mediated the effects of race and poverty on mean adequacy ratios and anemia, highlighting the role of literacy in physical well-being.
Key words: *African American*, *anemia*, *diet quality*, *health disparities*, *inflammation*, *iron deficiency*, *literacy*

ACCORDING to the National Health and Nutrition Examination Survey data, the prevalence of anemia in the United States rose from 4% to 7.1% from 2003 to 2012, with an average of 5.6% of adults meeting the criteria for anemia.[1] While 5.6% would indicate that anemia is only of mild public health concern (World Health Organization citation), anemia can be a serious health concern for specific groups such as African Americans (AAs), adults older than 60 years, nonpregnant women of reproductive age, and pregnant women. National Health and Nutrition Examination Survey data indicate that anemia is more prevalent in AAs than in whites (Ws) (14.9% and 4%, respectively) and in females than in males (7.6% and 3.5%, respectively), with prevalence peaking at ages 40 to 49 years of age and again at 80 to 85 years of age.

Among US adults, the prevalence of anemia appears evenly distributed among nutritional anemia (NA), anemia of inflammation (AI) and unexplained anemia (UA).[2] Nutritional anemia is typically the result of deficiencies

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of iron, folic acid, and/or vitamin B_{12}.[2] Anemia of inflammation is most commonly associated with underlying conditions such as atherosclerosis, diabetes mellitus, malignancy, and rheumatologic disorders.[3-5] While research on the demographic statistics of individuals classified as either NA or AI is limited, some research suggests that AAs tend to have AI while Ws tend to have NA.[2,6,7] Given the possible etiologies associated with UA,[8,9] UA was not included in this analysis.

To reduce the prevalence of anemia, several factors may contribute to its development and should be explored. Race, poverty status, and literacy are among the factors that contribute to health disparities.[10,11] The higher prevalence of anemia in AAs than in Ws could be due to several factors. A 2014 report by the US Census Bureau found more AAs than Ws are uninsured (22% and 13.7%, respectively), more AAs live in poverty than Ws (26.2% and 10.1%, respectively), and AAs have a lower median income than Ws.[11] African Americans have higher rates of many of the leading causes of death including, hypertension, diabetes, heart disease, stroke, and cancer.[10]

Those in the lowest income groups, compared with those with higher incomes, are at a greater risk for developing anemia.[12,13] Iron deficiency anemia is the most common anemia among low-income groups.[14] Individuals in the lowest income group (<100% of the federal poverty level) are almost 5 times as likely to have poor health as those in the highest income group (≥400% federal poverty level) and are almost twice as likely to have diabetes and heart disease,[15] both of which may be associated with developing anemia.[5,16]

Literacy and the discordance in estimates of literacy levels of individuals by physicians and other health professionals have been suggested as important contributors to health disparities.[17,18] Low literacy is significantly associated with poor overall health status, more hospitalization, and greater rates of mortality.[19-21] African Americans and other minority races are more likely to have marginal or low literacy skills.[22] Individuals with low incomes also tend to indicate lower health literacy compared with those with higher incomes.[22] Understanding the role of literacy among racially and economically diverse populations may be critical to reducing the disparities of health conditions such as anemia.

Literacy appears to contribute to the dietary differences observed between AAs and Ws, with AAs having lower diet quality, resulting in a greater need to improve diet quality to optimize health.[23,24] In addition, low-income adults generally have poorer diet quality than higher-income adults.[25,26] Dietary intake may contribute to the development of anemia, either via energy insufficiency and inadequate micronutrient intake (NA)[27] or energy imbalance of macronutrients leading to inflammatory conditions that contribute to the development of AI.[28,29]

The exploration of literacy and diet quality on the presence of anemia in a racially and socioeconomically diverse population might be beneficial for the prevention and intervention efforts. The Health Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study was designed to investigate the effects of race and socioeconomic status (SES) on health disparities.[30] Although the primary health outcomes were cardiovascular disease and cognitive function, comprehensive medical, dietary, and demographic data were collected. Using data from this study, the aims of this project were to investigate (1) the effects of race and poverty status on the presence of NA and AI and (2) the roles that literacy and diet quality play in the complex relationship between race and poverty status and the presence of NA or AI.

METHODS

HANDLS study

The HANDLS study is a prospective population-based cohort study. The baseline cohort (2004-2009) comprised 3720 AA and W adults 30 to 64 years of age. Participants were drawn from 13 predetermined neighborhoods (defined as groups of contiguous census tracts) in the city of Baltimore, Maryland. Four factors were selected for sampling: age (7, 5-year age bands from 30 to 64 years), self-reported race (AA and W), sex, and SES (operationalized by household incomes below or above 125% of the 2004 federal poverty guidelines). Those participants with household income above 125% of the poverty line were identified as above poverty and those below as below poverty (BP). The HANDLS baseline population had a mean age of 47.7 years, 59% were AA, 45% were male, and 41% of participants were BP.[30] All participants spoke English. Individuals were excluded if they were pregnant or within 6 months of active treatment for cancer. Further detailed information on the study design, eligibility, and recruitment of participants can be found elsewhere.[30]

The HANDLS baseline data were collected in 2 phases conducted 4 to 10 days apart.[31] Phase 1 was a household survey conducted in the participant's home by a recruitment and sampling contractor. Participants completed questionnaires detailing their background, demographic information, education experience, occupational status, household income, physical activity, and health status information. A trained interviewer administered the first 24-hour dietary recall. The second phase took place in mobile research vehicles, where a medical history survey, a physical examination, fasting blood draw, cognitive testing, and body composition measurements, and physical performance measures were administered by a physician or member of medical staff. A trained interviewer administered a second 24-hour dietary recall.

Study population

Of the 3720 eligible participants enrolled at baseline, 2177 participants completed both 24-hour dietary recalls. Of the 2177 with complete dietary data, 89 participants were excluded for having chronic kidney disease or sickle cell disease and 111 were excluded for missing blood markers of anemia (serum ferritin, transferrin saturation percentage [Fe-Sat], serum folate, and serum vitamin B_{12}). Anemia criteria were applied to the remaining 1977 eligible participants. Participants with UA were excluded (n = 82). No other exclusions were made. Institutional review boards at National Institute of Environmental Health Sciences and at the University of Delaware approved the study protocol. All HANDLS participants provided written informed consents and were compensated monetarily. A flow diagram of the household sampling to eligible participants for this study is presented in Figure 1.

Dietary methods

The United States Department of Agriculture (USDA) Automated Multiple Pass Method was used to conduct both 24-hour dietary recalls. Recalls were conducted on all days of the week to account for variations in diet between weekdays and weekends. The Automated Multiple Pass Method involves 5 steps designed to provide cues and prompt thorough recall for all foods and drinks consumed throughout the previous day.[32] These steps include (1) quick list of all foods consumed the previous day; (2) a forgotten foods list that includes probes for commonly forgotten foods; (3) probes to determine the time a food was consumed and at which meal; (4) detailed questions including amounts of foods consumed, additions to foods, and where food was obtained; and (5) a final review to probe any foods not previously remembered. An illustrated food model booklet as well as other visual measurement aids was used to increase the accuracy of estimating food and drink quantities. A trained coder using the USDA Survey Net data-processing system to match the foods with codes in the Food and Nutrient Database for Dietary Studies version 3.0 coded each recall.[33] The nutritional supplement questionnaire was not administered during baseline data collection to minimize subject burden since the participants were on the mobile research vehicles for at least 6 hours.

Clinical measures

Participants were weighed (kg) without shoes and coats using a calibrated Health O Meter digital scale (Pelstar, LLC, Alsip,

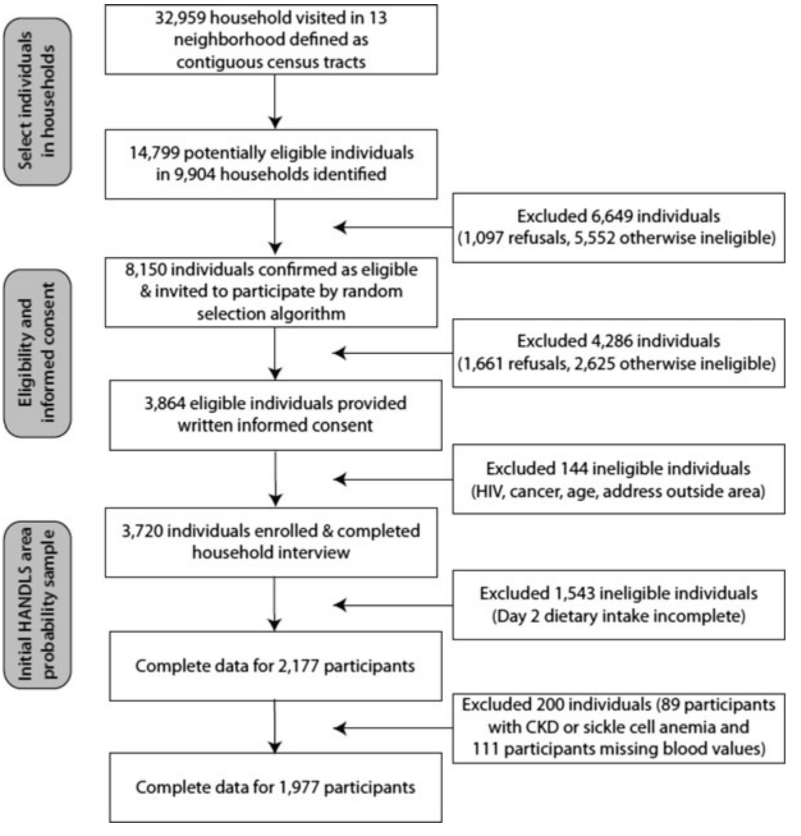

Figure 1. A flow diagram of the household sampling to eligible participants for this Healthy Aging in Neighborhoods of Diversity across the Life Span study. CKD indicates chronic kidney disease; HANDLS, Healthy Aging in Neighborhoods of Diversity across the Life Span; HIV, human immunodeficiency virus.

Illinois). Height (cm) was obtained with the participant's heels and back against a height meter supplied by Novel Products, Inc (Rockton, Illinois), and body mass index (BMI) was calculated from measured height and weight. Body mass index was calculated using the equation: BMI = weight (kg)/[height (m)]^2.[31] For this project, participants were categorized as having a BMI of less than 25 (normal) or a BMI of 25 or more (overweight and obese).

Fasting venous blood specimens were collected from participants in the morning when they arrived at the mobile research vehicles visit and analyzed by Quest Diagnostics, Inc (Chantilly, Virginia). Fasting blood results included 2 indicators for iron (Fe) status: FeSat (transferrin saturation) (serum iron/total iron binding capacity) and serum ferritin (ng/mL), plus measures of serum folate (ng/mL), serum vitamin B_{12} (pg/mL), and C-reactive protein (CRP) (mg/L). Serum Fe and total iron binding capacity were assessed using the standard clinical laboratory spectrophotometric assay. Serum ferritin was measured using a standard chemiluminescence assay. Serum folate and vitamin B_{12} were measured using enzyme immunoassay. High-sensitivity CRP levels were assessed by the nephelometric method utilizing latex particles coated with CRP monoclonal antibodies. All assays were considered reliable but with any method there are limitations that are described on the Quest diagnostics Web site.[34]

Assessment of anemia

Participants with anemia were identified by the World Health Organization standard that defines anemia as a Hb level less than 13 g/dL in men and less than 12 g/dL in women.[35] After identifying individuals with anemia, the type of anemia was determined.[36,37] Anemic individuals were classified with NA if they had low serum ferritin ($\leq$30 ng/mL) or normal serum ferritin (31-99 ng/mL) and as low FeSat ($<$16%) if they had folate less than 4 ng/mL or if they had vitamin B_{12} less than 200 pg/mL.[37] Anemia of inflammation was defined as having elevated serum ferritin ($\geq$100 ng/mL) or normal serum ferritin (31-99 ng/mL) with elevated FeSat ($>$45%).

Measures

Variables included in the analyses were race, poverty status, literacy, and diet quality. Race was self-reported as AA or W. Poverty status was defined as self-reported household income dichotomized into less or greater than 125% of the 2004 federal poverty guidelines. Literacy was assessed using the reading subtest of the Wide Range Achievement Test (WRAT)—3rd Edition.[38] The WRAT measures the ability to recognize and name letters and words. The total WRAT Reading score equaled the sum of total correctly pronounced letters and total correctly pronounced words and served as the literacy measurement. A WRAT score of 37 to 40 represents a sixth- to eighth-grade reading level, and a score of 41 to 46 represents a high school reading level.

Nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR) scores were used to assess nutrient-based diet quality.[39,40] The NAR score was determined by taking each participant's daily intake of a nutrient divided by the recommended dietary allowance for that nutrient. Nutrient adequacy ratio scores were determined for 17 micronutrients: vitamins A, C, D, E, B_6, B_{12}, folate, iron, thiamin, riboflavin, niacin, copper, zinc, calcium, magnesium, phosphorus, and selenium. The recommended dietary allowance was adjusted for the age and sex of participants and vitamin C was adjusted for smokers.[41] The NAR score was then converted into a percent with values exceeding 100 truncated to 100. Mean adequacy ratio scores were calculated by averaging the NAR scores: MAR = ($\sum$NAR scores)/17.[40] Nutrient adequacy ratio and MAR were calculated separately for each daily intake and then averaged together. Mean adequacy ratio scores, based on food intakes only, were used as the nutrient-based diet quality variable.

Covariates

Demographic characteristics included age (years) and sex (male or female). Cigarette smoking was coded as current smoker or nonsmoker. Handgrip strength, which is used as an indicator of total-body muscle strength and physical performance, was assessed using the Jamar Hydraulic Hand Dynamometer.[42] The hand dynamometer registers the maximum kilograms of force per trial. Two trials were conducted with both the right and left hands. The mean of the 2 trials by the dominant hand was used in the analysis.

Statistical analyses

Demographic and descriptive statistics means and standard errors for continuous variables and frequencies and percentages for categorical variables are reported in the Table. One-way analyses of variance for continuous variables and χ^2 tests for categorical variables were used to test for differences among participants with NA, participants with AI, and participants not diagnosed with anemia. Two statistical programs were used for analysis: SPSS software, release 23 and Mplus software, version 7.31. For the path analysis, standardized estimates are reported. Alpha level was set to .05.

Path analysis is a special case of Structural Equation Modeling in which all variables in the model are directly observed. It is a multivariate statistical technique that allows researchers to test complicated models, while allowing variables to be both outcomes and predictors at the same time. Conceptually, it can be considered a set of simultaneously estimated multiple regression equations.

Approaching this analysis through multiple regressions rather than path analysis would be burdensome as it would require a separate

Table. Characteristics of Healthy Aging in Neighborhoods of Diversity Across the Life Span Study Participants Categorized by Anemia Diagnosis by World Health Organization Criteria[a]

	Nutritional Anemia (N = 160)	Anemia of Inflammation (N = 63)	No Anemia (N = 1672)	*P*
Sex; % female	85.6[a]	42.9[b]	53.8[b]	**<.001**
Race; % AA	80.6[a]	90.5[a]	52.0[b]	**<.001**
Income, %; <125% poverty	51.9[a]	47.6[a,b]	40.8[b]	**.016**
Current smoker, %	38.5[a]	55.6[b]	49.1[b]	**.029**
BMI $\geq$25 kg/m^2, %	75.6	67.7	70.8	.368
Age, $\bar{X} \pm$ SE, y	43.8 ± 0.7[a]	52.8 ± 1.1[b]	47.8 ± 0.2[c]	**<.001**
WRAT score, $\bar{X} \pm$ SE	41.3 ± 0.6[a,b]	39.4 ± 1.1[a]	42.5 ± 0.2[b]	**.004**
MAR, $\bar{X} \pm$ SE	67.3 ± 1.2[a]	72.3 ± 1.5[a,b]	71.8 ± 0.4[b]	**.001**
Handgrip strength, $\bar{X} \pm$ SE, kg	30.9 ± 0.7[a]	35.5 ± 1.5[a,b]	35.6 ± 0.5[b]	**.017**
CRP mg/L, $\bar{X} \pm$ SE	8.4 ± 1.0[a]	15.0 ± 4.3[b]	4.3 ± 0.2[c]	**<.001**
Energy, $\bar{X} \pm$ SE, kcal	1847 ± 80	2061 ± 134	2032 ± 24	.073
Hb, $\bar{X} \pm$ SE, g/dL	11.0 ± 0.1[a]	11.6 ± 0.1[b]	14.1 ± 0.03[c]	**<.001**
Serum iron, $\bar{X} \pm$ SE, μg/dL	45.8 ± 3.0[a]	73.5 ± 5.5[b]	88.9 ± 0.9[c]	**<.001**
Serum ferritin, $\bar{X} \pm$ SE, ng/mL	21.0 ± 1.8[a]	226.4 ± 19.1[b]	129.6 ± 4.0[c]	**<.001**
FeSat, $\bar{X} \pm$ SE, %	11.8 ± 0.6[a]	23.1 ± 1.7[b]	26.0 ± 0.3[b]	**<.001**
Folate, $\bar{X} \pm$ SE, ng/mL	12.8 ± 0.4[a]	13.7 ± 0.9[a,b]	14.5 ± 0.2[b]	**.003**
Vitamin B_{12}, $\bar{X} \pm$ SE, pg/mL	480.3 ± 17.1[a]	585.5 ± 38.9[b]	512.7 ± 5.7[a]	**.010**

Abbreviations: AA, African American; BMI, body mass index; CRP, C-reactive protein; FeSat, transferrin saturation; Hb, hemoglobin; MAR, mean adequacy ratio; WRAT, Wide Range Achievement Test.
Continuous variables are presented as mean ± SE; categorical variables are presented as N (%). Within rows, columns with different subscripts are significantly different.
The boldface values are significant *P* values at $P < .05$.

regression model for each endogenous outcome variable (ie, no anemia, NA, and AI). An endogenous outcome variable is any variable that is predicted by another variable in the model. In addition, path analysis can model indirect and direct effects as well as assess specific hypotheses of the parameters in the model. A direct effect is a regression-like relationship between 2 variables hypothesizing a direct link between them, for example, A→B, here A has a direct effect on B. An indirect effect can be defined as a relationship between 2 variables that operate through other variables, for example, A→B→C, here A's effect on C goes through B. In this study, A can be represented by race or poverty status, B is literacy or MAR, and C is anemia outcome.

The influence of race and poverty status on literacy and MAR and their role on the presence of anemia were examined using path analyses. Four separate analyses were run independently to determine the effects of race and poverty status on anemia outcomes and whether they were mediated by literacy and MAR or both. The first compared anemia types (NA and AI) with the exogenous predictor of race; the second used poverty status as the exogenous predictor in the model. The third and fourth models compared NA with those without anemia, using race and poverty status as exogenous variables. The conceptual model that was tested is shown in Figure 2A.

Model fit was evaluated using the χ^2 test, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Weighted Root Mean Residual (WRMR), and the Root Mean Square Error of Approximation (RMSEA). Model modifications were made, and the final models are presented in Figures 2B and 2C; the modifications for this analysis involved removal of nonsignificant pathways to create more parsimonious models. For a more detailed

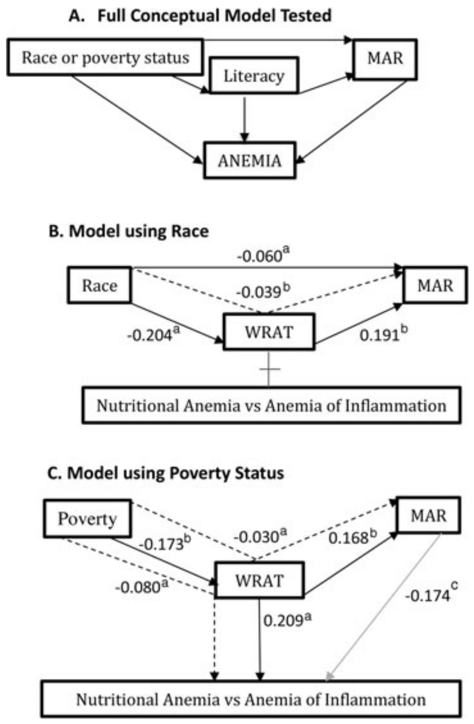

Figure 2. Using path analysis, the direct and indirect effects of race or poverty status and literacy (WRAT) on nutrient-based diet quality (MAR) and World Health Organization anemia type were tested as well as the effect of MAR on anemia. **A.** Shows the conceptual model tested. **B.** Shows the effects of race and WRAT on MAR and anemia type. **C.** Shows the effects of poverty status and WRAT on MAR and anemia type. WRAT: adjusted for sex, smoking, and energy. MAR: adjusted for sex, age, smoking, and energy. Anemia: adjusted for sex. Solid black line: significant direct effect; solid tan line: marginally significant direct effect; dashed black line: significant indirect effect; red crossed line: no direct or indirect effects, [a]<0.05. [b]<0.001. [c]Marginally significant. MAR indicates mean adequacy ratio; WRAT, Wide Range Achievement Test.

overview of path analysis, see the study by Kim and Bentler.[43]

RESULTS

Characteristics of study participants

Of the 1895 HANDLS participants included in this study, 56% were AA, 56% were females, 42% were BP, 44% were current smokers, and 12% were classified as having anemia. The mean (±SE) age was 47.62 ± 0.21 years, mean (±SE) literacy score by WRAT was 42.32 ± 0.19, mean (±SE) handgrip strength was 35.21 ± 0.44, and mean (±SE) BMI was 29.87 ± 0.18.

The Table shows demographic characteristics of participants (n = 1895) based on diagnosis of NA (n = 160) and AI (n = 63) compared with those without anemia (n = 1672). Participants with NA tended to be female, AA, BP, and nonsmokers. They were significantly younger than those with AI or no anemia; they had the lowest MAR scores and lowest handgrip strength. Those with AI tended to be male, AA, above poverty, and smokers. They were significantly older than those with NA and no anemia. They had the lowest WRAT scores, the highest MAR scores, and higher handgrip strength than those with NA. Those with no anemia tended to be female, AA, above poverty, and nonsmokers. They had the highest WRAT scores and lowest CRP scores.

As expected, those with NA had the lowest values for all markers related to anemia (Table). Those with AI had higher Hb, serum iron, FeSat, and vitamin B_{12} measures than those with NA, as well as the highest level of serum ferritin. Those without anemia had the highest levels of Hb, serum iron, FeSat, and folate.

Path analysis with outcome measure predicting NA to AI

Using path analysis, the direct and indirect effects of race or poverty status on anemia type were tested along with the effects of MAR and literacy on anemia classification. In addition, the covariates of smoking, total energy intake, sex, and age were included in the analyses. The Barron and Kenny (1986) framework was used to assess mediation; all steps were satisfied. The final model for race fits well, $\chi^2_{12} = 21.32$, $P = .046$, CFI = 0.95, TLI = 0.90, WRMR = 0.79, and RMSEA = 0.03, and is depicted in Figure 2B. The final model for SES fits the data well, $\chi^2_{12} = 15.14$,

P = .234, CFI = 0.98, TLI = 0.95, WRMR = 0.64, and RMSEA = 0.01, and is shown in Figure 2C.

Race model

In the race model with anemia type (NA vs AI) as the outcome (Figure 2B), there was partial mediation of the relationship between race and MAR ($R^2 = 0.16$, $P < .001$) through literacy. The direct effect ($\beta = -.060$, $P = .018$) and indirect effect ($\beta = -.039$, $P < .001$) were both significant. Race was significantly related to literacy ($\beta = -.204$, $P = .001$). Literacy was significantly related to MAR ($\beta = .191$, $P < .001$). There was no significant effect of race on anemia type, either directly or through mediators.

Poverty model

In the poverty status model of anemia type (NA vs AI) (Figure 2C), there was full mediation of the relationship between poverty status and MAR ($R^2 = 0.16$, $P < .001$) through literacy; the direct effect was not significant ($\beta = .028$, $P = .290$) but the indirect effect was ($\beta = -.030$, $P = .022$). Literacy also fully mediated the relationship between poverty status and anemia type ($R^2 = 0.45$, $P < .001$); the direct effect was not significant ($\beta = .234$, $P = .300$) but the indirect effect was ($\beta = -.080$, $P = .041$). Mean adequacy ratios had a marginally significant effect on anemia type ($\beta = -.174$, $P = .088$). Poverty status was significantly related to literacy ($\beta = -.173$, $P < .001$). Literacy was significantly related to MAR ($\beta = .168$, $P < .001$) and also significantly related to anemia type ($\beta = .209$, $P = .028$).

Path analysis with outcome measure predicting NA to No anemia

A model for NA compared with no anemia was analyzed for race and poverty status. The final model for race yielded adequate fit, $\chi^2_{12} = 22.92$, $P = .028$, CFI = 0.95, TLI = 0.90, WRMR = 0.86, and RMSEA = 0.03 (Figure 3A). The final model for poverty status fits well, $\chi^2_{10} = 12.03$, $P = .283$, CFI = 0.99, TLI = 0.96, WRMR = 0.60, and RMSEA = 0.01 (Figure 3B).

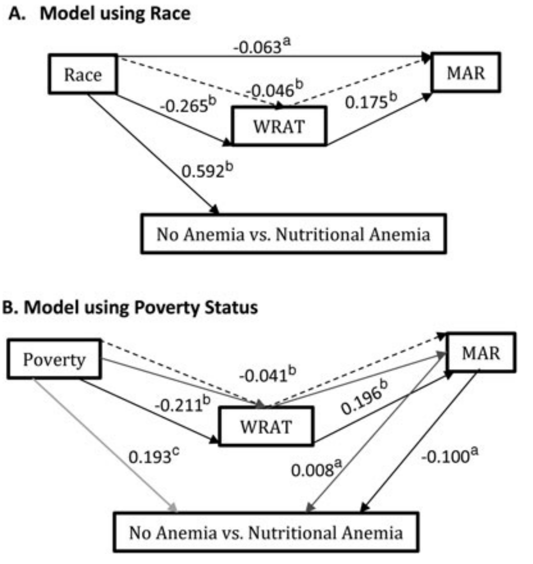

Figure 3. Using path analysis, the direct and indirect effects of race or poverty status and literacy (WRAT) on nutrient-based diet quality (MAR) and World Health Organization nutritional anemia to no anemia diagnosis were tested along with the effect of nutrient-based diet quality on anemia. **A.** Shows the conceptual model tested. **B.** Shows the effects of race and WRAT on MAR and anemia type. **C.** Shows the effects of poverty status and WRAT on MAR and anemia type. WRAT: adjusted for sex, smoking, and energy. MAR: adjusted for sex, age, smoking, and energy. Anemia: adjusted for sex. Solid black line: significant direct effect; solid tan line: marginally significant direct effect; dashed black line: significant indirect effect; solid blue line: significant indirect effect through multiple variables. [a]<0.05. [b]<0.001. [c]Marginally significant. MAR indicates mean adequacy ratio; WRAT, Wide Range Achievement Test.

Race model

As shown in Figure 3A, there was partial mediation found in the relationship between race and MAR ($R^2 = 0.16$, $P < .001$) through literacy. The direct effect ($\beta = -.063$, $P = .015$) and indirect effect ($\beta = -.046$, $P < .001$) were both significant. There was no mediation of the relationship between race and anemia ($R^2 = 0.25$, $P < .001$) by literacy; the direct effect ($\beta = .592$, $P = <.001$) was significant while the indirect effect ($\beta = -.023$, $P = .366$) was not significant. Race was significantly related to literacy ($\beta = -.265$, $P < .001$). Literacy was significantly related to MAR ($\beta = .175$, $P < .001$).

Poverty model

There was full mediation of the relationship between poverty status and MAR ($R^2 = 0.16$, $P < .001$) through literacy (Figure 3B). The direct effect ($\beta = .026$, $P = .290$) was not significant but the indirect effect was ($\beta = -.041$, $P < .001$). The relationship of poverty with anemia was partially mediated but not by literacy alone ($R^2 = 0.188$, $P < .001$). The direct effect was marginally significant ($\beta = .193$, $P = .064$), while the indirect effect was not significant ($\beta = .005$, $P = .807$). This partial mediation occurred via the indirect effect on anemia through both literacy and MAR ($\beta = .008$, $P = .046$). Mean adequacy ratio was significantly related to anemia ($\beta = -.100$, $P = .035$). Poverty status was significantly related to literacy ($\beta = -.211$, $P < .001$). Literacy was significantly related to MAR ($\beta = .196$, $P < .001$).

DISCUSSION

Using path analysis allowed for the investigators to measure the effects of race and poverty status on anemia separately. The race model revealed that being AA was related to lower WRAT scores, lower MAR, and a higher likelihood of NA (compared with no anemia). The poverty status model indicated that BP status was associated with lower WRAT, lower MAR, and more NA (compared with AI and no anemia). In all of the models, WRAT was positively associated with MAR. However, the findings of this study did not find consistent evidence to support nutrient-based diet quality measured by MAR as a predictor of anemia. Only poverty models found MAR to be associated with outcome. In the model comparing NA with AI, this association was only marginally significant and, therefore, may not truly be an effect.

Literacy, measured by WRAT scores, appears to play a critical role in the effects of race and poverty status on MAR and anemia. In the race models, WRAT partially mediated the effects of race on MAR and, in the poverty status models, WRAT fully mediated this relationship. Wide Range Achievement Test also mediated the effects of poverty status on anemia outcomes when comparing NA with AI.

While the United States may have much lower rates of anemia than poorer countries and regions, the United States also showed the least amount of progress and was the only region that did not reduce anemia rates from 1990 to 2010.[44] After the age of 50 years, the prevalence of anemia rises rapidly with the highest prevalence of anemia being found in those 80 to 85 years of age.[1,2] Regardless of the cause, anemia is associated with fatigue, poor physical performance, lower muscle strength, and increased risk of hospitalization and mortality.[45-47] Thus, identifying factors contributing to anemia is critical to the development of prevention strategies and treatment plans.

The importance of literacy on health outcomes is emphasized throughout the related literature[19-21,48,49] and may be just as important as race or poverty status. Sentell and Halpin[17] found that while race and education were predictors of health status outcomes, once literacy was added to the regression model, race and education lost statistical significance while literacy remained associated. The complex relationship between literacy, race and poverty, and health disparities such as anemia may be exacerbated by physician and health care staff, who may overestimate literacy levels. Kelly and Haidet[18] found that, in 40% of patients, the physician overestimated patient literacy, and overestimation occurred more frequently with racial minorities. This error may contribute to higher medical costs and inefficient use of health care services observed among those with low literacy.[50,51]

This study found that poverty status was directly associated with literacy and indirectly associated with MAR (mediated by literacy). These results are supported by other research. Prins and Mooney[22] found that those with low income were more likely to have literacy levels below those in higher-income brackets.

The impact of income on diet quality is widely recognized. In a subgroup of adults examined in National Health and Nutrition Examination Survey 1999-2002, it was found that low-income adults consumed less energy and were less likely to eat at or above the adequate intake or estimated average requirement levels for many micronutrients of the Dietary Reference Intakes.[25] The association between poverty status and the development of anemia could in part be due to food choices by this population. Previous studies have found that all eating patterns of the HANDLS study population represent a Western diet.[40,52]

Strengths and limitations

This study has several notable strengths. First, the study represents a large cohort of AA and W urban adults. Second, using path analysis allowed for the investigation of the separate effects of race and poverty status on anemia as well as literacy MAR. Third, MAR scores were based on two 24-hour recalls to better represent typical intake. Finally, assessing overall nutrient-based diet quality provides a comprehensive understanding of the relationship between diet and anemia. Many studies investigating anemia have focused specifically on the deficiency of one particular nutrient, neglecting the examination of the multiple micronutrients needed to minimize risk for anemia.[27,53,54]

As with any study, there are some limitations. First, the baseline data were cross-sectional; therefore, a direct causal relationship between variables cannot be made. Second, although the overall sample size was large, only 223 HANDLS study participants had anemia. There was also a large difference between sample size of those with anemia, and those without anemia. Next, data on dietary supplements were not collected at baseline, so MAR is based only on diet and does not take into account nutrients from dietary supplements. In addition, bias of underreporting with dietary recalls can occur.[55] Finally, this study used the World Health Organization standard for diagnosing anemia. Although this is widely used across research, it may present a racial bias. The lower limit of normal Hb concentrations, as well as other important biomarkers for diagnosing anemia, is considerably lower in AA than in W.[45,56,57] Beutler and Waalen[57] proposed a set of Hb values that would consider race and age as variables in constructing standard parameters for anemia diagnosis that reduces the lower limit of normal Hb.

CONCLUSION

This study highlights the fundamental role of literacy in health outcomes. Race and poverty status continue to be critical factors in health disparities and poor health outcomes. This work, however, demonstrates that literacy is a central transduction factor between the social determinates of health and health status. The relationship between poverty status and diet quality is fully mediated by literacy. There is full mediation of the relationship between poverty and anemia through literacy. Several studies have found that limited literacy is associated with increased hospitalization[21] and mortality among adults.[49] Addressing low literacy in populations at particular risk for anemia and other chronic diseases and their detrimental health effects are necessary steps in improving health outcomes.

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