Web Material

Measurement error affecting web- and paper-based dietary assessment instruments: Insights from the Multi-Cohort Eating and Activity Study for Understanding Reporting Error

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Web Appendix 1: Overview of Number of Replicate Measures and Excluded Observations

Web Tables 1-4 illustrate, by nutrient-instrument combination, how many non-excluded participants, participants with multiple administrations of data, and non-excluded observations were included in the analysis. The tables additionally show how many participants and observations were excluded for each combination. There is one table for each study, with IDATA stratified by gender.

Observations were excluded on a nutrient-by-nutrient basis for each instrument and study. Excluded observations were identified on the basis of single observations that were more than 2.5 times the interquartile range away from the 25^{th} or 75^{th} percentile, or on the basis of individuals whose contrasts were more than 2.5 times the interquartile range away from the 25^{th} or 75^{th} percentile of contrasts. The percentiles were drawn from the first administration since there was no consistent pattern of drift across administration. A threshold of 2.5 times the IQR was used as opposed to 2 in earlier validation studies to be conservative in terms of excluding data points and individuals.

If an individual had two measurements available, say X1 and X2, there is only one contrast: $(X2-X1)/\sqrt{2}$. This contrast estimates the difference in random measurement errors and, under typical model assumptions, has variance equal to the measurement error variance because of the standardizing factor $\sqrt{2}$ (the square root of the sum of squared contrast coefficients). For ASA24, up to six measures were available and there are up to five orthogonal polynomial contrasts. These contrasts, when standardized, are uncorrelated and thus independent under the assumption of normal error with the same common variance. The second stage of outlier classification based on contrasts stabilized the estimation of the random error variance that is crucial to estimating the measurement error structure.

Individuals identified as extreme based on contrasts were classified as influential and their measurements for a given nutrient/instrument combination excluded.

Web Appendix 2: Measurement Error Modelling[1]

In the covariate-included models, the log of the *j*-th biomarker measurement for individual *i* is expressed as a linear function of age (A_i), logged BMI (B_i), and two additional random terms representing i) person-specific deviations of $\log(T_i)$ from the linear function of A and B, and ii) random measurement error:

$$\log(M_{ij}) = \beta_{oT} + \beta_{AT}A_i + \beta_{BT}\log(B_i) + u_{Ti} + \varepsilon_{Tij},$$

where the last two terms are normally distributed random variables with mean zero and variances σ^2_{uT} and $\sigma^2_{\varepsilon T}$. This model follows from the assumption that the biomarker is a true reference measure, because (writing the definition of u_{Ti} explicitly)

$$\begin{aligned}\log(M_{ij}) &= \beta_{oT} + \beta_{AT}A_i + \beta_{BT}\log(B_i) + [\log(T_i) - (\beta_{oT} + \beta_{AT}A_i + \beta_{BT}\log(B_i))] + \varepsilon_{Tij} \\ &= \log(T_i) + \varepsilon_{Tij}\end{aligned}$$

In a risk model where T is the primary exposure and A and B are confounders, the contribution of T independent of A and B is of interest, information which is carried by u_{Ti}. The measurement error models for the self-report instruments therefore focus on how well the instrument captures u_{Ti}. Specifically, the log of the *j*-th reported intake for individual *i* is expressed as a linear function of u_{Ti}, age, and logged BMI, with two additional random terms representing i) person-specific bias and ii) random error:

$$\log(Q_{ij}) = \beta_{oQ} + \beta_{TQ}u_{Ti} + \beta_{AQ}A_i + \beta_{BQ}\log(B_i) + u_{Qi} + \varepsilon_{Qij},$$

where the last two terms are normally distributed random variables with mean zero and variances σ^2_{uQ} and $\sigma^2_{\varepsilon Q}$. Here, the subscript Q indicates that the equation holds for FFQ-reported intake. Similar expressions are assumed for intakes derived from ASA24 recalls (subscripted by R) and food records (D). This formulation retains terms analogous to those of the standard Kipnis et al.[1] measurement error model. It also adds two systematic bias terms corresponding to age and logged BMI.

In typical regression analysis of diet-health relationships using error-prone measurements instead of true intakes, bias in the regression coefficient for dietary intake is introduced because the exposure axis is distorted while the response axis is unchanged. Under our model, the total variation in, for example, transformed reported FFQ intake (conditional on age and BMI) is comprised of a flattened slope term $\beta^2_{TQ}\mathrm{Var}(\log(T)|A,B)$, a person specific bias term σ^2_{uQ}, and a random error term $\sigma^2_{\varepsilon Q}$. If the error-prone exposures have smaller variance than true exposure (for example, if the dominant factor is the flattened slope, with a coefficient less than 1), then the estimated regression line is steeper than it should be, i.e., exaggerated. The reverse (attenuation) occurs when the error-prone exposures have larger variance than true exposure, which can occur if the flattened slope has a coefficient greater than 1 or if the effects of person-specific bias and/or random error are present. If the sum of the three terms exactly reproduces $\mathrm{Var}(\log(T)|A,B)$, then the regression using self-reported intake will be unbiased for the true relationship. In practice, the net effect of the three terms produces substantial attenuation.

The extent of the attenuation is quantified by the *attenuation factor*, defined as the slope in the regression of true intake on reported intake, which can be estimated from the model parameters, e.g.

$$\lambda_Q = \frac{\mathrm{Cov}(T, Q|A, B)}{\mathrm{Var}(Q|A, B)} = \frac{\beta_{TQ}\sigma^2_{uT}}{\beta^2_{TQ}\sigma^2_{uT} + \sigma^2_{uQ} + \sigma^2_{\varepsilon Q}}.$$

The attenuation factor represents the multiplicative bias in the estimated regression coefficient when a health outcome is regressed on self-reported rather than true intake. Similarly, the correlation between log reported FFQ intake and log true intake is expressed as

$$\rho_{QT} = \frac{\mathrm{Cov}(T, Q|A, B)}{\sqrt{\mathrm{Var}(T|A, B)\mathrm{Var}(Q|A, B)}} = \frac{\beta_{TQ}\sigma_{uT}}{\sqrt{\beta_{TQ}^2\sigma_{uT}^2 + \sigma_{uQ}^2 + \sigma_{\varepsilon Q}^2}}.$$

The correlation between reported and true intake is important because it relates to the loss of power to detect a relationship between intake and health induced by measurement error. The formulas above hold for a single administration of the self-report instrument. If one uses the average of k measurements, rather than just one, the attenuation and correlation factors above hold, with $\sigma_{\varepsilon Q}^2$ replaced with $k^{-1}\sigma_{\varepsilon Q}^2$.

Note that the formulae for the attenuation factors and correlation coefficients do not involve the constant bias terms for age and BMI that are in the measurement error models above, nor do they involve the coefficients for age and BMI in the model for true intake. This reflects the fact that when the goal is to consider true intake conditional on age and BMI (as is often the case in a diet-disease model), then the systematic differences in the measurement error structure due to these covariates are constant and therefore can be ignored in the calculation of attenuation factors and correlation coefficients. Furthermore, it can be shown that constant systematic biases, such as those considered in the model, can induce correlations between the personal characteristics and within-person differences between biomarker and self-report instruments. In other words, this model does not reflect the most complex model possible to account for differences in measurement error structure due to personal characteristics, but it does have features that could conceivably explain relationships between reporting errors and personal characteristics.

If a reference biomarker is available on at least some individuals in the study, techniques such as regression calibration can be used to fully adjust for the biasing effects of random and systematic measurement error. In the full-adjustment case, the expected attenuation factor is 1, but the power loss is equivalent to that expected when the within-person average of the self-report data is used as the exposure in the health risk model. Without a reference biomarker, full adjustment for the effects of measurement error is not possible. However, a partial adjustment, for only the within-person random error, can be performed using the same adjustment techniques assuming that the self-report is itself a reference measure, and enough repeat administrations are available. In the partial-adjustment case, the expected attenuation factor is given by the corresponding formula with $\sigma_{\varepsilon Q}^2$ omitted entirely.

Web Tables 1-11

Web Table 1: IDATA Men excluded observations

Nutrient	Measurement	Total eligible individuals	Eligible individuals w/ 2+ admins	Total eligible observations	Excluded individuals	Excluded individuals w/ 2+ admins	Excluded observations
Energy	**Biospecimen**	347	14	361	0	0	0
	FFQ	490	345	835	10	6	16
	ASA24	491	478	2615	23	12	75
	FR	428	346	774	2	1	3
Protein	**Biospecimen**	462	375	837	5	0	5
	FFQ	493	349	842	5	4	9
	ASA24	501	488	2673	15	1	16
	FR	429	347	776	1	0	1
Sodium	**Biospecimen**	464	372	836	4	2	6
	FFQ	493	349	842	5	4	9
	ASA24	497	484	2657	14	4	34
	FR	427	347	774	3	0	3
Potassium	**Biospecimen**	464	373	837	5	0	5
	FFQ	489	345	834	10	7	17
	ASA24	497	484	2651	17	6	39
	FR	428	345	773	3	1	4
Protein Density	**Biospecimen**	338	288	626	4	1	5
	FFQ	436	325	761	21	2	23
	ASA24	460	447	2428	55	13	78
	FR	414	342	756	4	0	4
Sodium Density	**Biospecimen**	337	288	625	1	1	2
	FFQ	438	324	762	22	2	24
	ASA24	459	449	2451	39	9	55
	FR	412	342	754	4	0	4
Potassium Density	**Biospecimen**	339	292	631	0	0	0
	FFQ	434	333	767	14	3	17
	ASA24	460	450	2471	22	7	35
	FR	414	341	755	5	0	5
Sodium:Potassium Ratio	**Biospecimen**	461	369	830	1	1	2
	FFQ	485	340	825	5	3	8
	ASA24	494	481	2626	1	0	1
	FR	426	345	771	0	0	0

Web Table 2: IDATA Women excluded observations

Nutrient	Measurement	Total eligible individuals	Eligible individuals w/ 2+ admins	Total eligible observations	Excluded individuals	Excluded individuals w/ 2+ admins	Excluded observations
Energy	**Biospecimen**	354	19	373	0	0	0
	FFQ	517	351	868	4	0	4
	ASA24	496	477	2531	16	6	38
	FR	425	333	758	3	3	6
Protein	**Biospecimen**	461	384	845	4	3	7
	FFQ	513	352	865	6	1	7
	ASA24	500	482	2545	21	3	24
	FR	424	333	757	4	3	7
Sodium	**Biospecimen**	463	386	849	2	1	3
	FFQ	515	351	866	4	2	6
	ASA24	497	480	2542	12	3	27
	FR	425	331	756	6	2	8
Potassium	**Biospecimen**	462	386	848	2	2	4
	FFQ	512	351	863	6	3	9
	ASA24	494	476	2518	19	8	51
	FR	427	333	760	3	1	4
Protein Density	**Biospecimen**	342	289	631	4	3	7
	FFQ	469	321	790	30	1	31
	ASA24	465	449	2380	37	3	43
	FR	411	325	736	6	0	6
Sodium Density	**Biospecimen**	347	295	642	0	0	0
	FFQ	467	327	794	23	2	25
	ASA24	463	448	2381	34	6	43
	FR	411	326	737	3	0	3
Potassium Density	**Biospecimen**	345	293	638	0	0	0
	FFQ	470	349	819	2	0	2
	ASA24	465	448	2397	19	2	26
	FR	411	326	737	5	0	5
Sodium:Potassium Ratio	**Biospecimen**	461	381	842	3	0	3
	FFQ	510	347	857	1	1	2
	ASA24	493	475	2512	0	0	0
	FR	424	328	752	1	0	1

Web Table 3: MLVS excluded observations

Nutrient	Measurement	Total eligible individuals	Eligible individuals w/ 2+ admins	Total eligible observations	Excluded individuals	Excluded individuals w/ 2+ admins	Excluded observations
Energy	**Biospecimen**	662	100	762	3	1	4
	FFQ	712	641	1353	11	4	15
	ASA24	638	602	2057	9	2	13
	FR	678	654	1332	6	2	8
Protein	**Biospecimen**	687	667	2563	17	5	31
	FFQ	714	644	1358	7	2	9
	ASA24	637	601	2054	9	3	16
	FR	679	657	1336	2	2	4
Sodium	**Biospecimen**	691	672	2587	6	1	7
	FFQ	710	644	1354	8	6	14
	ASA24	638	601	2060	7	1	10
	FR	680	655	1335	4	1	5
Potassium	**Biospecimen**	689	671	2577	13	2	17
	FFQ	712	641	1353	11	4	15
	ASA24	637	601	2058	6	2	12
	FR	681	658	1339	1	0	1
Protein Density	**Biospecimen**	655	646	2487	2	0	2
	FFQ	704	628	1332	14	0	14
	ASA24	617	578	1976	25	3	28
	FR	675	653	1328	2	1	3
Sodium Density	**Biospecimen**	659	651	2511	2	0	2
	FFQ	701	630	1331	13	0	13
	ASA24	617	580	1986	17	3	22
	FR	675	651	1326	2	0	2
Potassium Density	**Biospecimen**	655	646	2489	0	0	0
	FFQ	704	631	1335	10	1	11
	ASA24	617	582	1988	13	2	16
	FR	676	655	1331	0	0	0
Sodium:Potassium Ratio	**Biospecimen**	687	669	2562	5	3	12
	FFQ	705	634	1339	6	4	10
	ASA24	634	597	2042	5	3	13
	FR	680	650	1330	4	0	4

Web Table 4: WLVS excluded observations

Nutrient	Measurement	Total eligible individuals	Eligible individuals w/ 2+ admins	Total eligible observations	Excluded individuals	Excluded individuals w/ 2+ admins	Excluded observations
Energy	**Biospecimen**	735	84	819	3	2	5
	FFQ	778	731	1509	8	3	11
	ASA24	684	536	1789	18	4	28
	FR	756	730	1486	9	3	12
Protein	**Biospecimen**	756	748	2871	19	6	35
	FFQ	781	730	1511	9	0	9
	ASA24	686	536	1792	17	3	23
	FR	758	735	1493	4	1	5
Sodium	**Biospecimen**	760	753	2892	13	1	16
	FFQ	778	732	1510	7	3	10
	ASA24	686	537	1796	21	2	25
	FR	758	736	1494	4	0	4
Potassium	**Biospecimen**	761	754	2898	10	0	10
	FFQ	774	727	1501	12	7	19
	ASA24	686	537	1795	16	2	22
	FR	755	729	1484	10	4	14
Protein Density	**Biospecimen**	730	727	2796	1	0	1
	FFQ	772	711	1483	17	0	17
	ASA24	565	470	1567	11	2	14
	FR	751	730	1481	1	0	1
Sodium Density	**Biospecimen**	734	732	2814	3	0	3
	FFQ	770	720	1490	10	0	10
	ASA24	566	470	1566	15	2	18
	FR	750	727	1477	3	0	3
Potassium Density	**Biospecimen**	730	727	2795	2	0	2
	FFQ	771	720	1491	9	0	9
	ASA24	565	473	1573	8	0	8
	FR	751	730	1481	1	0	1
Sodium:Potassium Ratio	**Biospecimen**	759	752	2880	2	1	5
	FFQ	768	719	1487	6	2	8
	ASA24	685	535	1790	0	0	0
	FR	753	726	1479	1	1	2

Web Table 5. Geometric means of nutrient intakes in the MEASURE[1] (IDATA, WLVS, and MLVS, USA, January 2011 to October 2013) studies based on the first administration of each measure, after exclusion of influential individuals and observations

		Women						Men					
		IDATA Women			WLVS			IDATA Men			MLVS		
Component	Instrument	Geometric Mean	LCL	UCL	Geometric Mean	LCL	UCL	Geometric Mean	LCL	UCL	Geometric Mean	LCL	UCL
Energy	**FFQ**	1491.32	1438.43	1546.15	1904.23	1864.03	1945.30	1918.06	1846.74	1992.13	2091.26	2048.20	2135.23
	ASA24	1748.66	1690.83	1808.46	1705.92	1658.55	1754.64	2243.89	2167.30	2323.19	2236.99	2175.61	2300.11
	FR	1727.03	1681.91	1773.35	1743.59	1718.15	1769.41	2247.68	2189.76	2307.13	2310.25	2275.25	2345.79
	Biospecimen	2129.04	2091.57	2167.19	2161.83	2136.88	2187.06	2749.00	2699.54	2799.37	2745.43	2714.29	2776.93
Protein	**FFQ**	57.28	55.02	59.63	82.61	80.75	84.51	72.75	69.73	75.90	84.84	82.93	86.79
	ASA24	70.20	67.56	72.94	70.26	67.94	72.65	90.34	86.92	93.90	90.74	87.94	93.64
	FR	66.83	65.13	68.58	71.47	70.28	72.68	86.99	84.63	89.41	94.36	92.66	96.09
	Biospecimen	75.67	73.15	78.27	59.14	57.78	60.53	104.55	101.19	108.02	77.71	75.84	79.62
Potassium	**FFQ**	2827.56	2729.00	2929.68	3329.86	3257.29	3404.05	3327.63	3209.86	3449.72	3592.94	3514.72	3672.89
	ASA24	2588.75	2496.75	2684.14	2574.07	2491.88	2658.96	3060.32	2951.20	3173.46	3239.68	3139.30	3343.26
	FR	2479.49	2408.35	2552.73	2639.54	2591.99	2687.97	3006.37	2919.79	3095.53	3471.41	3405.52	3538.57
	Biospecimen	2727.87	2621.81	2838.22	2906.13	2833.39	2980.75	3693.93	3566.01	3826.43	3516.10	3421.73	3613.07
Sodium	**FFQ**	2196.60	2110.81	2285.87	2082.50	2033.50	2132.69	2888.42	2770.40	3011.47	2174.64	2120.25	2230.42
	ASA24	2908.82	2792.69	3029.78	2827.48	2738.26	2919.61	3820.02	3673.47	3972.43	3577.21	3459.71	3698.71
	FR	2901.27	2820.21	2984.65	2613.04	2563.86	2663.16	3792.47	3690.02	3897.77	3195.38	3125.94	3266.36
	Biospecimen	3236.87	3091.56	3389.00	3286.06	3197.89	3376.66	4656.32	4448.56	4873.78	3306.93	3197.64	3419.95

[1]Abbreviations: ASA24, Automated Self-Administered 24-hour Dietary Assessment Tool 24HR; FFQ, food frequency questionnaire; FR, food record; IDATA, Interactive Diet and Activity Tracking in AARP; MLVS, Men's Lifestyle Validation Study; WLVS, Women's Lifestyle Validation Study

Web Table 6. Geometric means of nutrient densities in the MEASURE[1] (IDATA, WLVS, and MLVS, USA, January 2011 to October 2013) studies based on the first administration of each measure, after exclusion of influential individuals and observations

		Women						Men					
		IDATA Women			WLVS			IDATA Men			MLVS		
Component	Instrument	Geometric Mean	LCL	UCL	Geometric Mean	LCL	UCL	Geometric Mean	LCL	UCL	Geometric Mean	LCL	UCL
Protein density	FFQ	155.06	152.48	157.69	173.34	171.29	175.42	152.81	150.07	155.61	161.69	159.60	163.81
	ASA24	160.27	156.03	164.63	164.80	160.86	168.85	160.96	156.85	165.17	162.09	158.46	165.81
	FR	154.28	151.58	157.02	164.60	162.48	166.74	154.80	152.14	157.51	163.21	160.93	165.51
	Biospecimen	144.57	139.46	149.87	109.27	106.83	111.78	154.98	149.86	160.28	113.33	110.74	115.97
Potassium density	FFQ	1907.21	1866.21	1949.10	1744.12	1724.15	1764.32	1741.40	1706.71	1776.81	1719.66	1697.02	1742.59
	ASA24	1477.55	1436.73	1519.53	1513.54	1477.57	1550.39	1358.37	1319.77	1398.10	1453.66	1419.92	1488.20
	FR	1435.70	1404.73	1467.35	1514.92	1491.66	1538.54	1335.15	1308.71	1362.14	1505.21	1481.81	1528.97
	Biospecimen	1291.78	1233.54	1352.76	1338.58	1303.02	1375.12	1336.66	1284.97	1390.43	1281.57	1246.91	1317.20
Sodium density	FFQ	1493.25	1469.46	1517.43	1097.10	1081.45	1112.98	1515.75	1488.65	1543.35	1039.42	1023.61	1055.46
	ASA24	1670.21	1623.88	1717.86	1668.57	1628.98	1709.13	1694.56	1650.51	1739.78	1600.86	1564.24	1638.33
	FR	1674.40	1641.79	1707.67	1501.79	1479.42	1524.50	1682.98	1653.17	1713.33	1383.47	1359.40	1407.97
	Biospecimen	1546.60	1467.20	1630.30	1516.81	1476.74	1557.97	1682.09	1600.48	1767.85	1199.04	1158.42	1241.10
Sodium: potassium	FFQ	0.78	0.76	0.80	0.63	0.62	0.64	0.87	0.85	0.89	0.60	0.59	0.62
	ASA24	1.12	1.08	1.16	1.10	1.07	1.14	1.26	1.21	1.30	1.11	1.07	1.14
	FR	1.17	1.14	1.20	0.99	0.97	1.01	1.26	1.23	1.29	0.92	0.90	0.94
	Biospecimen	1.19	1.14	1.24	1.13	1.10	1.17	1.26	1.21	1.32	0.95	0.92	0.98

[1]Abbreviations: ASA24, Automated Self-Administered 24-hour Dietary Assessment Tool 24-hour recall; FFQ, food frequency questionnaire; FR, food record; IDATA, Interactive Diet and Activity Tracking in AARP; MLVS, Men's Lifestyle Validation Study; WLVS, Women's Lifestyle Validation Study

Web Table 7. Attenuation and correlation factors[1] for reported intakes of energy in the MEASURE[2] (IDATA, WLVS, and MLVS, USA, January 2011 to October 2013) studies

Instrument	Women								Men							
	IDATA Women				WLVS				IDATA Men				MLVS			
	Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
FFQ - Single	0.06[3]	0.02	0.19[3]	0.06	0.06	0.02	0.13	0.04	0.10[3]	0.02	0.38[3]	0.12	0.11	0.02	0.24	0.04
FFQ - Two	0.07[3]	0.02	0.20[3]	0.07	0.07	0.02	0.14	0.04	0.11[3]	0.03	0.40[3]	0.12	0.13	0.02	0.26	0.04
FFQ - Adjusted[4]	0.09[3]	0.03			0.08	0.02			0.13[3]	0.03			0.16	0.03		
ASA24 - Single	0.08[3]	0.02	0.22[3]	0.05	0.07[3]	0.01	0.16[3]	0.03	0.08[3]	0.02	0.30[3]	0.09	0.08[3]	0.01	0.22[3]	0.03
ASA24 - Four	0.15[3]	0.03	0.30[3]	0.06	0.13[3]	0.03	0.22[3]	0.04	0.16[3]	0.03	0.40[3]	0.12	0.16[3]	0.02	0.30[3]	0.04
ASA24 - Six	0.17[3]	0.03	0.32[3]	0.07	0.15[3]	0.03	0.23[3]	0.05	0.17[3]	0.03	0.42[3]	0.12	0.18[3]	0.03	0.31[3]	0.05
ASA24 - Twelve	0.19[3]	0.04	0.34[3]	0.07	0.17[3]	0.04	0.25[3]	0.05	0.19[3]	0.04	0.45[3]	0.13	0.20[3]	0.03	0.33[3]	0.05
ASA24 - Adjusted[4]	0.21[3]	0.04			0.20[3]	0.04			0.22[3]	0.04			0.23[3]	0.04		
FR - Single[5]	0.14	0.03	0.28	0.06	0.29	0.02	0.42	0.03	0.14	0.03	0.37	0.11	0.33	0.02	0.52	0.03
FR - Two[5]	0.19	0.04	0.32	0.07	0.35	0.03	0.46	0.03	0.19	0.04	0.42	0.13	0.39	0.03	0.56	0.03
FR – Adjusted[4,5]	0.29	0.06			0.43	0.04			0.26	0.06			0.46	0.03		

[1]Attenuation and correlation factors were estimated using a measurement error model.
[2]Abbreviations: ASA24, Automated Self-Administered 24-hour Dietary Assessment Tool 24-hour recall; FFQ, food frequency questionnaire; FR, food record; IDATA, Interactive Diet and Activity Tracking in AARP; MLVS, Men's Lifestyle Validation Study; WLVS, Women's Lifestyle Validation Study
[3]Self-reported intakes were collected using online (versus paper-based) instruments.
[4]Refers to attenuation factors that would pertain if repeat self-report administrations were adjusted for random error using regression calibration.
[5]The FR was weighed in WLVS and MLVS and unweighed in IDATA.

Web Table 8. Attenuation and correlation factors[1] for reported intakes of protein and protein density in the MEASURE[2] (IDATA, WLVS, and MLVS, USA, January 2011 to October 2013) studies

Component	Instrument	Women								Men							
		IDATA Women				WLVS				IDATA Men				MLVS			
		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation	
		Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
Protein	FFQ - Single	0.17[3]	0.03	0.30[3]	0.05	0.26	0.03	0.33	0.04	0.21[3]	0.03	0.35[3]	0.05	0.27	0.03	0.33	0.04
	FFQ - Two	0.21[3]	0.04	0.33[3]	0.05	0.31	0.03	0.36	0.04	0.24[3]	0.03	0.38[3]	0.05	0.33	0.04	0.36	0.04
	FFQ - Adjusted[4]	0.26[3]	0.04			0.38	0.04			0.28[3]	0.04			0.41	0.05		
	ASA24 - Single	0.19[3]	0.02	0.31[3]	0.03	0.22[3]	0.02	0.34[3]	0.03	0.22[3]	0.02	0.35[3]	0.03	0.20[3]	0.02	0.31[3]	0.03
	ASA24 - Four	0.39[3]	0.04	0.45[3]	0.05	0.48[3]	0.04	0.51[3]	0.04	0.47[3]	0.04	0.51[3]	0.04	0.43[3]	0.04	0.45[3]	0.04
	ASA24 - Six	0.45[3]	0.05	0.48[3]	0.05	0.56[3]	0.05	0.54[3]	0.04	0.54[3]	0.05	0.55[3]	0.04	0.49[3]	0.05	0.49[3]	0.04
	ASA24 - Twelve	0.53[3]	0.06	0.52[3]	0.05	0.66[3]	0.06	0.59[3]	0.05	0.63[3]	0.06	0.59[3]	0.04	0.58[3]	0.06	0.53[3]	0.05
	ASA24 - Adjusted[4]	0.63[3]	0.07			0.80[3]	0.09			0.76[3]	0.07			0.70[3]	0.08		
	FR - Single[5]	0.42	0.05	0.43	0.05	0.68	0.04	0.64	0.03	0.44	0.04	0.46	0.04	0.72	0.04	0.67	0.03
	FR - Two[5]	0.55	0.06	0.49	0.05	0.82	0.04	0.70	0.03	0.56	0.06	0.52	0.04	0.83	0.04	0.72	0.03
	FR – Adjusted[4,5]	0.77	0.09			1.01	0.05			0.75	0.08			0.98	0.05		
Protein Density	FFQ - Single	0.34[3]	0.06	0.32[3]	0.05	0.29	0.04	0.26	0.03	0.23[3]	0.06	0.24[3]	0.06	0.35	0.04	0.32	0.04
	FFQ - Two	0.57[3]	0.09	0.41[3]	0.06	0.43	0.06	0.31	0.04	0.33[3]	0.08	0.28[3]	0.07	0.49	0.06	0.39	0.04
	FFQ - Adjusted[4]	1.76[3]	0.49			0.80	0.12			0.62[3]	0.16			0.84	0.11		
	ASA24 - Single	0.08[3]	0.03	0.14[3]	0.04	0.13[3]	0.02	0.22[3]	0.04	0.11[3]	0.03	0.19[3]	0.04	0.10[3]	0.02	0.17[3]	0.03
	ASA24 - Four	0.17[3]	0.05	0.19[3]	0.06	0.27[3]	0.05	0.31[3]	0.05	0.22[3]	0.05	0.26[3]	0.06	0.20[3]	0.04	0.24[3]	0.05
	ASA24 - Six	0.19[3]	0.06	0.21[3]	0.06	0.30[3]	0.05	0.33[3]	0.06	0.24[3]	0.06	0.28[3]	0.06	0.23[3]	0.05	0.26[3]	0.05
	ASA24 - Twelve	0.22[3]	0.07	0.22[3]	0.07	0.35[3]	0.06	0.35[3]	0.06	0.27[3]	0.06	0.30[3]	0.07	0.26[3]	0.05	0.28[3]	0.05
	ASA24 - Adjusted[4]	0.25[3]	0.08			0.41[3]	0.07			0.31[3]	0.07			0.30[3]	0.06		
	FR - Single[5]	0.39	0.07	0.35	0.06	0.57	0.04	0.50	0.03	0.32	0.06	0.31	0.05	0.56	0.04	0.49	0.03
	FR - Two[5]	0.54	0.09	0.41	0.06	0.72	0.05	0.56	0.03	0.45	0.08	0.36	0.06	0.69	0.05	0.54	0.04
	FR – Adjusted[4,5]	0.85	0.15			0.99	0.08			0.76	0.15			0.90	0.07		

[1]Attenuation and correlation factors were estimated using a measurement error model.
[2]Abbreviations: ASA24, Automated Self-Administered 24-hour Dietary Assessment Tool 24-hour recall; FFQ, food frequency questionnaire; FR, food record; IDATA, Interactive Diet and Activity Tracking in AARP; MLVS, Men's Lifestyle Validation Study; WLVS, Women's Lifestyle Validation Study
[3]Self-reported intakes were collected using online (versus paper-based) instruments.
[4]Refers to attenuation factors that would pertain if repeat self-report administrations were adjusted for random error using regression calibration.
[5]The FR was weighed in WLVS and MLVS and unweighed in IDATA.

Web Table 9. Attenuation and correlation factors[1] for reported intakes of potassium and potassium density in the MEASURE[2] (IDATA, WLVS, and MLVS, USA, January 2011 to October 2013) studies

Component	Instrument	Women								Men							
		IDATA Women				WLVS				IDATA Men				MLVS			
		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation	
		Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
Potassium	FFQ - Single	0.26[3]	0.04	0.33[3]	0.05	0.32	0.03	0.41	0.04	0.26[3]	0.04	0.36[3]	0.05	0.43	0.04	0.49	0.04
	FFQ - Two	0.30[3]	0.05	0.36[3]	0.05	0.36	0.04	0.43	0.04	0.29[3]	0.04	0.38[3]	0.05	0.48	0.04	0.53	0.04
	FFQ - Adjusted[4]	0.36[3]	0.06			0.42	0.04			0.33[3]	0.05			0.55	0.05		
	ASA24 - Single	0.31[3]	0.03	0.40[3]	0.04	0.28[3]	0.02	0.45[3]	0.03	0.30[3]	0.03	0.44[3]	0.03	0.29[3]	0.02	0.43[3]	0.03
	ASA24 - Four	0.55[3]	0.05	0.54[3]	0.04	0.51[3]	0.04	0.61[3]	0.04	0.55[3]	0.04	0.60[3]	0.04	0.51[3]	0.04	0.57[3]	0.04
	ASA24 - Six	0.60[3]	0.06	0.56[3]	0.05	0.56[3]	0.04	0.64[3]	0.04	0.60[3]	0.05	0.62[3]	0.04	0.56[3]	0.04	0.59[3]	0.04
	ASA24 - Twelve	0.66[3]	0.06	0.59[3]	0.05	0.62[3]	0.05	0.67[3]	0.04	0.67[3]	0.05	0.66[3]	0.04	0.61[3]	0.05	0.62[3]	0.04
	ASA24 - Adjusted[4]	0.74[3]	0.07			0.70[3]	0.06			0.75[3]	0.06			0.68[3]	0.06		
	FR - Single[5]	0.53	0.05	0.51	0.04	0.69	0.03	0.74	0.03	0.50	0.04	0.55	0.04	0.68	0.04	0.67	0.03
	FR - Two[5]	0.66	0.06	0.56	0.05	0.77	0.04	0.79	0.03	0.61	0.05	0.61	0.04	0.76	0.04	0.71	0.03
	FR – Adjusted[4,5]	0.86	0.09			0.88	0.04			0.77	0.07			0.86	0.05		
Potassium Density	FFQ - Single	0.45[3]	0.07	0.40[3]	0.05	0.40	0.05	0.32	0.04	0.36[3]	0.07	0.33[3]	0.06	0.45	0.05	0.39	0.04
	FFQ - Two	0.59[3]	0.08	0.46[3]	0.06	0.55	0.06	0.37	0.04	0.46[3]	0.08	0.37[3]	0.06	0.58	0.06	0.44	0.04
	FFQ - Adjusted[4]	0.84[3]	0.13			0.86	0.11			0.64[3]	0.12			0.79	0.09		
	ASA24 - Single	0.19[3]	0.04	0.24[3]	0.05	0.23[3]	0.03	0.33[3]	0.04	0.15[3]	0.03	0.22[3]	0.05	0.21[3]	0.03	0.31[3]	0.04
	ASA24 - Four	0.31[3]	0.06	0.31[3]	0.06	0.39[3]	0.05	0.43[3]	0.05	0.24[3]	0.05	0.28[3]	0.06	0.34[3]	0.04	0.40[3]	0.04
	ASA24 - Six	0.33[3]	0.07	0.32[3]	0.06	0.43[3]	0.05	0.45[3]	0.05	0.25[3]	0.06	0.29[3]	0.07	0.36[3]	0.04	0.41[3]	0.05
	ASA24 - Twelve	0.36[3]	0.07	0.33[3]	0.07	0.47[3]	0.06	0.47[3]	0.05	0.28[3]	0.06	0.31[3]	0.07	0.39[3]	0.05	0.43[3]	0.05
	ASA24 - Adjusted[4]	0.39[3]	0.08			0.52[3]	0.06			0.30[3]	0.07			0.43[3]	0.05		
	FR - Single[5]	0.62	0.07	0.49	0.05	0.68	0.04	0.62	0.03	0.43	0.06	0.37	0.05	0.64	0.04	0.58	0.03
	FR - Two[5]	0.79	0.09	0.55	0.06	0.79	0.04	0.67	0.03	0.57	0.08	0.43	0.06	0.73	0.05	0.62	0.03
	FR – Adjusted[4,5]	1.10	0.14			0.93	0.05			0.85	0.14			0.86	0.06		

[1]Attenuation and correlation factors were estimated using a measurement error model.
[2]Abbreviations: ASA24, Automated Self-Administered 24-hour Dietary Assessment Tool 24-hour recall; FFQ, food frequency questionnaire; FR, food record; IDATA, Interactive Diet and Activity Tracking in AARP; MLVS, Men's Lifestyle Validation Study; WLVS, Women's Lifestyle Validation Study
[3]Self-reported intakes were collected using online (versus paper-based) instruments.
[4]Refers to attenuation factors that would pertain if repeat self-report administrations were adjusted for random error using regression calibration.
[5]The FR was weighed in WLVS and MLVS and unweighed in IDATA.

Web Table 10. Attenuation and correlation factors[1] for reported intakes of sodium and sodium density in the MEASURE[2] (IDATA, WLVS, and MLVS, USA, January 2011 to October 2013) studies

Component	Instrument	Women								Men							
		IDATA Women				WLVS				IDATA Men				MLVS			
		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation	
		Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
Sodium	FFQ - Single	0.15[3]	0.04	0.23[3]	0.06	0.15	0.03	0.23	0.05	0.17[3]	0.04	0.24[3]	0.06	0.20	0.04	0.26	0.05
	FFQ - Two	0.17[3]	0.05	0.24[3]	0.07	0.17	0.04	0.24	0.05	0.19[3]	0.05	0.26[3]	0.06	0.23	0.04	0.28	0.05
	FFQ - Adjusted[4]	0.21[3]	0.06			0.20	0.04			0.23[3]	0.06			0.28	0.05		
	ASA24 - Single	0.19[3]	0.03	0.28[3]	0.04	0.17[3]	0.02	0.29[3]	0.04	0.21[3]	0.03	0.29[3]	0.04	0.21[3]	0.03	0.31[3]	0.04
	ASA24 - Four	0.40[3]	0.06	0.41[3]	0.06	0.36[3]	0.05	0.43[3]	0.06	0.43[3]	0.06	0.41[3]	0.05	0.44[3]	0.05	0.46[3]	0.05
	ASA24 - Six	0.45[3]	0.07	0.43[3]	0.06	0.41[3]	0.06	0.46[3]	0.06	0.49[3]	0.07	0.43[3]	0.05	0.51[3]	0.06	0.49[3]	0.05
	ASA24 - Twelve	0.53[3]	0.08	0.47[3]	0.07	0.48[3]	0.07	0.50[3]	0.07	0.56[3]	0.08	0.47[3]	0.06	0.59[3]	0.07	0.53[3]	0.06
	ASA24 - Adjusted[4]	0.63[3]	0.10			0.59[3]	0.09			0.66[3]	0.09			0.71[3]	0.09		
	FR - Single[5]	0.35	0.06	0.35	0.06	0.50	0.04	0.58	0.04	0.46	0.06	0.41	0.05	0.49	0.04	0.55	0.04
	FR - Two[5]	0.47	0.08	0.40	0.07	0.64	0.05	0.66	0.05	0.62	0.08	0.47	0.06	0.58	0.05	0.60	0.04
	FR – Adjusted[4,5]	0.72	0.13			0.88	0.07			0.98	0.14			0.72	0.06		
Sodium Density	FFQ - Single	0.34[3]	0.08	0.29[3]	0.07	0.25	0.04	0.30	0.05	0.27[3]	0.08	0.22[3]	0.06	0.30	0.05	0.28	0.04
	FFQ - Two	0.55[3]	0.13	0.36[3]	0.08	0.33	0.05	0.34	0.06	0.39[3]	0.12	0.26[3]	0.08	0.40	0.07	0.32	0.05
	FFQ - Adjusted[4]	1.35[3]	0.37			0.49	0.08			0.70[3]	0.22			0.60	0.10		
	ASA24 - Single	0.11[3]	0.04	0.17[3]	0.06	0.11[3]	0.03	0.21[3]	0.05	0.09[3]	0.04	0.12[3]	0.05	0.17[3]	0.03	0.25[3]	0.04
	ASA24 - Four	0.23[3]	0.08	0.24[3]	0.08	0.22[3]	0.05	0.30[3]	0.07	0.16[3]	0.07	0.16[3]	0.07	0.34[3]	0.05	0.35[3]	0.05
	ASA24 - Six	0.26[3]	0.09	0.26[3]	0.08	0.25[3]	0.06	0.32[3]	0.07	0.18[3]	0.07	0.17[3]	0.07	0.38[3]	0.06	0.37[3]	0.06
	ASA24 - Twelve	0.31[3]	0.10	0.28[3]	0.09	0.29[3]	0.07	0.34[3]	0.08	0.20[3]	0.08	0.18[3]	0.08	0.44[3]	0.07	0.40[3]	0.06
	ASA24 - Adjusted[4]	0.36[3]	0.12			0.34[3]	0.08			0.23[3]	0.10			0.51[3]	0.08		
	FR - Single[5]	0.34	0.08	0.31	0.07	0.45	0.04	0.51	0.05	0.25	0.08	0.19	0.06	0.58	0.05	0.54	0.04
	FR - Two[5]	0.49	0.11	0.37	0.08	0.61	0.06	0.59	0.05	0.39	0.13	0.24	0.07	0.73	0.06	0.61	0.04
	FR – Adjusted[4,5]	0.85	0.21			0.98	0.10			0.94	0.34			0.99	0.08		

[1]Attenuation and correlation factors were estimated using a measurement error model.
[2]Abbreviations: ASA24, Automated Self-Administered 24-hour Dietary Assessment Tool 24-hour recall; FFQ, food frequency questionnaire; FR, food record; IDATA, Interactive Diet and Activity Tracking in AARP; MLVS, Men's Lifestyle Validation Study; WLVS, Women's Lifestyle Validation Study
[3]Self-reported intakes were collected using online (versus paper-based) instruments.
[4]Refers to attenuation factors that would pertain if repeat self-report administrations were adjusted for random error using regression calibration.
[5]The FR was weighed in WLVS and MLVS and unweighed in IDATA.

Web Table 11. Attenuation and correlation factors[1] for reported intakes of sodium:potassium in the MEASURE[2] (IDATA, WLVS, and MLVS, USA, January 2011 to October 2013) studies

Instrument	Women								Men							
	IDATA Women				WLVS				IDATA Men				MLVS			
	Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation		Attenuation		Correlation	
	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE	Est	SE
FFQ - Single	0.55[3]	0.06	0.50[3]	0.05	0.71	0.05	0.55	0.03	0.56[3]	0.06	0.51[3]	0.05	0.65	0.05	0.52	0.03
FFQ - Two	0.64[3]	0.07	0.54[3]	0.05	0.83	0.06	0.59	0.03	0.64[3]	0.07	0.54[3]	0.05	0.76	0.06	0.56	0.04
FFQ - Adjusted[4]	0.74[3]	0.08			0.98	0.07			0.73[3]	0.08			0.90	0.07		
ASA24 - Single	0.33[3]	0.03	0.42[3]	0.03	0.33[3]	0.03	0.41[3]	0.03	0.33[3]	0.03	0.40[3]	0.03	0.43[3]	0.03	0.50[3]	0.03
ASA24 - Four	0.72[3]	0.06	0.62[3]	0.05	0.73[3]	0.06	0.60[3]	0.04	0.72[3]	0.06	0.59[3]	0.04	0.82[3]	0.05	0.69[3]	0.03
ASA24 - Six	0.83[3]	0.07	0.66[3]	0.05	0.83[3]	0.07	0.65[3]	0.04	0.84[3]	0.07	0.64[3]	0.04	0.92[3]	0.06	0.73[3]	0.03
ASA24 - Twelve	0.97[3]	0.08	0.72[3]	0.05	0.98[3]	0.08	0.70[3]	0.05	1.00[3]	0.08	0.69[3]	0.05	1.03[3]	0.07	0.77[3]	0.04
ASA24 - Adjusted[4]	1.18[3]	0.11			1.19[3]	0.12			1.23[3]	0.11			1.18[3]	0.08		
FR - Single[5]	0.65	0.06	0.58	0.04	0.74	0.04	0.69	0.03	0.75	0.05	0.64	0.04	0.70	0.03	0.70	0.03
FR - Two[5]	0.85	0.07	0.67	0.05	0.90	0.04	0.76	0.03	0.95	0.07	0.72	0.04	0.82	0.04	0.76	0.03
FR – Adjusted[4,5]	1.21	0.12			1.14	0.06			1.32	0.11			0.99	0.05		

[1]Attenuation and correlation factors were estimated using a measurement error model.
[2]Abbreviations: ASA24, Automated Self-Administered 24-hour Dietary Assessment Tool 24-hour recall; FFQ, food frequency questionnaire; FR, food record; IDATA, Interactive Diet and Activity Tracking in AARP; MLVS, Men's Lifestyle Validation Study; WLVS, Women's Lifestyle Validation Study
[3]Self-reported intakes were collected using online (versus paper-based) instruments.
[4]Refers to attenuation factors that would pertain if repeat self-report administrations were adjusted for random error using regression calibration.
[5]The FR was weighed in WLVS and MLVS and unweighed in IDATA.

REFERENCE

1. Kipnis V, Subar AF, Midthune D, et al. Structure of dietary measurement error: Results of the OPEN biomarker study. Am J Epidemiol. 2003;158(1):14-21.