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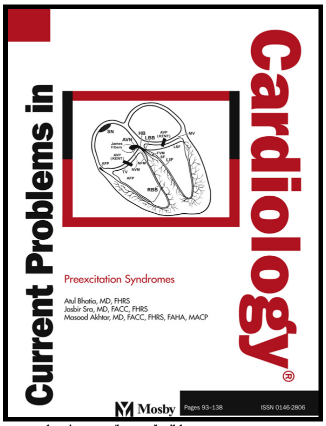

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The Validity of US Nutritional Surveillance: USDA Loss-Adjusted Food Availability Data Series 1971-2010.

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Abstract

Objective: Examine the validity of the 1971-2010 USDA's loss-adjusted food availability (LAFA) per capita caloric consumption estimates.

Design: Estimated total daily energy expenditure (TEE) was calculated for nationally representative samples of US adults, 20 to 74 years using the Institute of Medicine's equations with 'low-active' (TEE L-ACT) and 'sedentary' (TEE SED) physical activity values. TEE estimates were subtracted from LAFA estimates to create disparity values (kilocalories per day; kcal/d). A validated mathematical model was applied to calculate expected weight change in reference individuals resulting from the disparity.

Results: From 1971-2010, the disparity between LAFA and TEE L-ACT varied 394 kcal/d ($p < 0.001$), from -205 kcal/d (95% CI: -214, -196) to +189 kcal/d (95% CI: 168, 209). The disparity between LAFA and TEE SED varied 412 kcal/d ($p < 0.001$), from -84 kcal/d (95% CI: -93, -76) to +328 kcal/d (95% CI: 309, 348). Our model suggests if LAFA estimates were actually consumed, reference individuals would have lost ~1-4kg/year from 1971-1980 (an accumulated loss of ~12 to ~36kg), and gained ~3-7kg/year from 1988-2010 (an accumulated gain of ~42 to ~98kg). These estimates differed from actual measured increments of 10kg and 9kg in reference men and women, respectively over the 39-year period.

Conclusion: The USDA LAFA data provided inconsistent, divergent estimates of per capita caloric consumption over its 39-year history. The large, variable misestimation suggests the USDA LAFA per capita caloric intake estimates lack validity and should not be used to inform public policy.

List of abbreviations:

DLW: Doubly-labeled Water
ERS: Economic Research Service
IOM: Institute of Medicine
Kcal/d: Kilocalories per day
Kg: Kilogram
L-ACT: Low-Active Activity level
LAFA: Loss Adjusted Food Availability Data Series
NHANES: National Health and Nutrition Examination Survey
PA: Physical Activity
SED: Sedentary Activity Level
TEE: Total Daily Energy Expenditure
USDA: United States Department of Agriculture

Introduction

The prevalence of obesity has increased markedly during the latter decades of the 20th century in virtually every population where comprehensive data are available,(1-3) yet despite the economic and public health significance, there is little agreement on presumptive etiologic factors.(3-7) While numerous issues may underlie the lack of consensus,(8, 9) conceptual and methodological limitations to the measurement of caloric consumption appear to play a central role.(10-13) Without accurate assessments of population-level trends in energy intake, there are no valid data to support inferences regarding the role of food and beverage consumption in the etiology of the obesity epidemic and trends in energy-contingent, chronic non-communicable diseases (e.g., cardiovascular diseases and type 2 diabetes mellitus, T2DM).

Nutritional Surveillance

Nutritional surveillance is the systematic collection and analysis of dietary and/or economic data with the objective of describing current population behaviors (e.g., estimating caloric intakes), detecting trends in consumption, and highlighting priorities and potential corrective measures.(14) National nutritional surveillance in the U.S. consists of two main components: the National Health and Nutrition Examination Survey (NHANES) caloric intake data, and the United States Department of Agriculture (USDA) loss-adjusted food availability (LAFA) data series. Recently, we reported that the majority of the NHANES caloric intake data were physiologically implausible and not compatible with life.(10-12) We concluded that these data are pseudoscientific and therefore inadmissible in scientific research and the formation of public policy.(11, 12) That conclusion was supported by an extensive body of literature demonstrating that epidemiologic nutrition surveys suffer from severe, insurmountable systematic biases,(10-12, 15-23) inclusive of false memories,(11, 12, 24) and that estimates of energy intake are often incompatible with life (i.e., survival). (25)

The second main component of U.S. nutritional surveillance is the USDA LAFA data series. The USDA states these data "…*contribute to the Federal dietary guidance system*…[and] *are of interest to agricultural policymakers, economists, nutrition researchers, and nutrition and public health educators*" to "*examine historical trends and to evaluate changes in the American diet"*(26, 27) and "*provide an indication of whether Americans, on average, are consuming more or less of various foods over time.*"(28)

In addition to monitoring general trends in food and beverage consumption, the USDA provides per capita energy intake values from the LAFA data series (28, 29) that are explicitly used by researchers to examine relationships between "*energy intake*," "*food energy supply*," and weight gain and obesity, (30-34) as well as specific commodities and nutrients (e.g., sugar, oils, fat).(34-37) The USDA's "Obesity" webpages address the use of these data for examinations of obesity and "*the intended and unintended consequences of obesity policies.*"(38) In 2010, the US Secretary of Agriculture, Thomas Vilsack stated, "*At a time when the alarm has been clearly sounded on the epidemic of obesity in America, particularly among our children, the ability to track dietary trends is a crucial element of efforts to combat obesity and prevent its adverse health outcomes…*[and] [t]*he only source of long-term food consumption in the country is our Food Availability Data System.*"(39)

Given the extensive use of these data as a proxy for actual consumption in both nutrition research(31) and public health policy,(26, 38-41), examinations of the validity of per capita caloric consumption estimates of the LAFA data series are therefore essential if food and nutrition guidelines are to be empirically supported. Research dating from the 1960s suggests that food supply data lack validity (42) and consistently "*overestimate consumption.*"(34) The substantial misestimation of food waste and loss (43-46) has led to a general consensus that these data are not congruent with actual consumption.(43) Additionally, multiple lines of research suggest substantial changes in PA, PA-related cardiorespiratory fitness, and physical activity energy expenditure (PAEE) over the past five decades,(4, 47-54). These trends suggest large corresponding changes in total daily energy expenditure (TEE) and nutrient-energy partitioning(4) that necessitate an examination of the assumption of the overestimation of caloric consumption as well as quantification of misestimation over time. Therefore, the objective of this study was to critically examine both the assumption that the USDA LAFA data series consistently overestimates actual consumption and the validity of this surveillance tool to estimate trends in caloric consumption from 1971-2010.

Method

Population Anthropometric and Demographic Data

Data for the estimation of total daily energy expenditure (TEE) were obtained from the National Health and Nutrition Examination Surveys (NHANES) for the years 1971-2010 (nine survey waves) (55). The NHANES is a complex, multi-stage sampling of the civilian, non-institutionalized U.S. population conducted by the Centers for Disease Control and Prevention. The National Center for Health Statistics ethics review board approved protocols and written informed consent was obtained from all NHANES participants. The study sample was initially limited to adults aged ≥20 and < 74 years at the time of the NHANES in which they participated, with a body mass index (BMI) ≥18.5 kg/m^2, and complete data on age, sex, and objectively measured height, and weight.(55) The initial inclusion criteria for age and weight was representative of >65% of the U.S. population, and excluded groups with lower TEE and absolute caloric consumption (e.g., elderly, children). This sample consisted of 63,369 adults (28,996 men and 34,373 women). Additional analyses were conducted with the full NHANES sample of participants with complete data on age, sex, and weight. This sample consisted of 144,171 individuals (68,976 males and 75,195 females) from infancy to 90 years of age.

USDA LAFA Data

The USDA LAFA data were obtained from the Economic Research Service (ERS) food availability data series (27), which consist of estimates of approximately 200 raw and semi-processed agricultural commodities adjusted for loss and waste. The LAFA data series represent the residual of the total food supply available for domestic consumption after the subtraction of exports, farm and industrial uses, and divided by the resident population of consumers.(56, 57) These economic data are not inclusive of the final food products that may or may not be consumed.(27) These ERS data are adjusted for food spoilage, and other losses to approximate actual intake,(27) but the USDA publishes these data and estimates with the caveat that the documentation of food waste and losses are extremely limited.(45) In our study, the per capita caloric consumption estimates were averaged across the years that corresponded to each of the nine NHANES survey waves spanning 1971-2010.

Institute of Medicine Total Daily Energy Expenditure (TEE) Equations

In 2002, the Institute of Medicine (IOM) created factorial equations using age, sex, height, weight and physical activity (PA) to estimate TEE.(58, 59) These equations were the result of the US Department of Health and Human Services appointing a multidisciplinary expert panel to review *"the scientific literature regarding macronutrients and energy and develop estimates of daily intake that are compatible with good nutrition throughout the life span and that may decrease the risk of chronic disease…the panel sought to quantify rates and components of daily energy expenditure in healthy adults*... [t]*he recommendation for adults became the daily energy intake necessary to cover total daily energy expenditure (TEE).*"(59) While these equations provide the most accurate estimates of TEE available, the limitations associated with their use are discussed in Brooks et al., (2004).(59)

These equations (see below) allow the estimation of TEE across multiple PA levels (PAL = TEE/BMR [basal metabolic rate]) via the inclusion of values indicative of sedentary (SED; PAL $\geq 1.0 < 1.4$), low-active (L-ACT; PAL $\geq 1.4 < 1.6$), active (PAL $\geq 1.6 < 1.9$), and very active (PAL $\geq 1.9 < 2.5$) lifestyles. Because the average PA of the vast majority of the US population varies from SED to L-ACT,(60) only these two categories were used in our analyses.

Institute of Medicine Equations for Estimating Total Daily Energy Expenditure (TEE) Normal Weight* Adults only:

Equation (1) Men: $TEE = 864 – (9.72 x age [y]) + PA** x (14.2 x weight [kg] + 503 x height[m])$.

Equation (2) Women: $TEE = 387 – (7.31 x age [y] + PA** x (10.8 x weight [kg] + 660.7 x height[m])$.

* Body Mass Index ≥ 18.5 kg/m2 and <25 kg/m^2; ** Multiple PA values were used: "low active" values (L-ACT) of 1.12 and 1.14, and a "sedentary" value (SED) of 1.0, for normal weight men and women, respectively. The use of these values assumes a PAL (i.e., TEE/BMR) of ≥ 1.4 and < 1.6 for L-ACT, and ≥1.0 and <1.4 for SED

Institute of Medicine Equations for Estimating Total Daily Energy Expenditure (TEE) in Overweight/Obese* Adults Only:

Equation (3) Men: $TEE = 1086 – (10.1 \times age [y]) + PA** \times (13.7 \times weight [kg] + 416 \times height [m])$.

Equation (4) Women: $TEE = 448 – (7.95 \times age [y]) + PA** \times (11.4 \times weight [kg] + 619 \times height [m])$.

* Body Mass Index ≥ 25 kg/m^2; ** Multiple PA values were used: "low active" values (L-ACT) of 1.12 and 1.14, and a "sedentary" value (SED) of 1.0, for overweight and obese men and women, respectively. The use of these values assumes a PAL (i.e., TEE/BMR) of ≥ 1.4 and < 1.6 for L-ACT, and >1.0 and <1.4 for SED. Note: age (y = years); weight (kg); height (m = meters);

BMI = body mass index, (kg/m2), BMR = basal metabolic rate; IOM = Institute of Medicine; TEE = total energy expenditure.

Disparity Values: LAFA kcal/d ─ TEE kcal/d

Disparity values were created by subtracting TEE for each participant (as estimated by the IOM TEE equations) from the per capita daily caloric intake as estimated by the LAFA data series. The LAFA data, as provided by the USDA ERS, are not stratified by sex or age. As such, the TEE kilocalories per day (kcal/d) were subtracted from the LAFA per capita daily caloric intake estimates, regardless of sex or age. Negative values indicated underestimation and positive values suggested overestimation of per capita caloric consumption. As detailed below, we conducted additional analyses with the entire NHANES sample (i.e., all ages and sub-categories) for each survey wave to examine disparity values. Children and adolescents have estimated energy requirements (EER) above TEE due to growth and development. As such, disparity values for individuals <18 years were derived from the equation LAFA kcal/d ─ EER kcal/d, with estimates of EER derived using validated age-specific predictive equations.(58)

There is evidence that population-level PA has decreased over the study period.(47-49) There is also very strong evidence that cardiorespiratory fitness (i.e., an objective measure of the confluence of inherited capabilities and recent patterns of PA) in children has declined precipitously across the globe over the past three decades.(51-54) As such, a sensitivity analysis was conducted where disparity values were calculated using the TEE L-ACT for the period of 1971-1980 and the TEE SED value for subsequent years. These analyses are supported by evidence that the largest declines in PA in the US population may have occurred prior to the

1980s.(47, 48) As such, these values may provide lower and upper bounds on the disparity between TEE and the LAFA.

The *a priori* assumption of our ‘disparity method’ is that if the LAFA data series are a valid proxy for per capita caloric consumption and that the kcal/d estimates will reliably approximate TEE. This assumption is valid because over the course of a year most individuals (inclusive of those gaining weight) are approximately in energy balance on a daily basis (i.e., energy expenditure = energy intake).(61, 62) Therefore, misestimation between LAFA and TEE indicates limitations to the validity and reliability of the LAFA data series to estimate per capita daily caloric consumption.

Modeling of Alterations in Weight via IOM TEE and USDA LAFA

A validated, dynamical mathematical model of human energy expenditure and weight change was used to quantify yearly alterations in body weight of hypothetical reference men and women for each of the nine NHANES survey waves based on the disparity between the TEE (SED and L-ACT) and the LAFA estimates. (63, 64) The hypothetical reference individuals were 35 year old men and women, with mean heights and weights from nationally representative data for each of the survey waves.(65, 66) This reference age was used because the 30-40 year age group represented the largest segment of the US adult population over the study period.(67) The dynamical model estimates the changes in weight resulting from alterations in energy intake and energy expenditures, and accounts for weight dependent changes in energy expenditure through specific formulations of weight dependent terms for physical activity and resting metabolic rate.

The yearly weight changes, weight changes across all years in each survey wave, and the sum of the absolute values of yearly changes in weight across the study period are presented.

Statistical Analyses

Data processing and statistical analyses were performed using SPSS® V.19 in 2013 and 2014. Survey-to-survey contrasts and trend analyses via linear regression were conducted for the disparities between TEE (L-ACT and SED and EER for <19 years) and LAFA estimates. Analyses accounted for the complex survey design of NHANES via the incorporation of stratification, clustering and post-stratification weighting to maintain a nationally representative sample for each survey period. All analyses included adjusted means, and an $\alpha < 0.05$ (2-tailed) was used to identify statistical significance. Additional analyses were conducted with the entire NHANES sample (i.e., all ages and sub-categories) for each survey wave to more fully examine disparity values.

Results

Individuals Ages 20 – 74 Years

Figure 1 depicts the trends in TEE L-ACT and TEE SED compared with trends in the LAFA data series over the study period. LAFA increased from 2,060 kcal/d in the early 1970s to a maximum of 2,603 kcal/d in 2003-2004 and decreased to 2,524 kcal/d in 2009-2010. The overall increasing trends for TEE (both L-ACT and SED) from NHANES I through NHANES

2009-2010 were significant (*p <0.001*), suggesting an increase in energy expenditure over time. Because the PA level was held constant, the increments in TEE were driven by increases in body weight (data not presented). From the 1970s to 2010, TEE L-ACT increased 157 kcal/d, from 2,265 kcal/d (95% CI: 2,256, 2,274) to 2,422 kcal/d (95% CI: 2,406, 2,438). TEE SED increased 137 kcal/d (trend *p < 0.001*), ranging from a low of 2,144 kcal/d (95% CI: 2,136, 2,153) to a high of 2,281 kcal/d (95% CI 2,266, 2,295). Survey-to-survey increments in TEE L-ACT and TEE SED were observed from NHANES II to NHANES III and NHANES III to NHANES 1999-2000 (both *p < 0.001*).

<Insert Figure 1>

Figure 2 depicts the kcal/d disparity between LAFA and TEE (L-ACT and SED). Non-zero kcal/d values indicate misestimation of per capita caloric consumption. The disparity between TEE L-ACT and LAFA ranged 394 kcal/d, from -205 kcal/d to +189 kcal/d. The disparity between TEE SED and LAFA ranged 412 kcal/d, from -84 kcal/d to +328 kcal/d. With the exception of TEE L-ACT in 1988-94 (i.e., NHANES III), (*p = .179*, 95% CI: -4.2, +22.5), 17 of the 18 estimates (2 PA levels and 9 survey waves) were significantly different from zero (*p <0.001*), indicating continuous misestimation across the 39-year study period. Differences in disparity values were observed in five of the eight survey-to-survey transitions in both TEE L-ACT and TEE SED.

<Insert Figure 2>

Figure 3 depicts the kcal/d disparity between LAFA and TEE, with the assumption that population level PA decreased across the study period.(48, 49) As such, the TEE L-ACT were used for the two early surveys (i.e., NHANES I & II), and the TEE SED values were used from

NHANES III to 2009-2010. Non-zero kcal/d values indicate misestimation of caloric consumption.

The disparity between TEE (assuming a population shift from L-ACT to SED) varied from -205 kcal/d in the 1970s to a maximum of +328 kcal/d in 2003-2004, and decreased to +243 kcal/d in 2009-2010; a range of 533 kcal/d. The overall trend was significant (*p <0.001*), as were the survey-to-survey differences from NHANES I through NHANES 1999-2000 (*p <0.001*) and NHANES 2001-2002 (*p<0.05*), and 2007-2008 to 2009-2010 (*p <0.001*). All disparity values were significantly different from zero indicating continuous misestimation across the 39-year study period (*p <0.001*).

<Insert Figure 3>

Full NHANES Sample

Using the entire sample (i.e., all ages and sub-categories), the disparity between TEE L-ACT (and EER L-ACT for individuals <19 years) varied from -13 kcal/d in the 1970s to a maximum of +389 kcal/d in NHANES 2003-2004, decreasing to +302 kcal/d in 2009-2010. This is a range in disparity of 402 kcal/d. The overall trend was significant *(p <0.001)*, as were the survey-to-survey differences from NHANES I to NHANES II (*p <0.007)* and NHANES II through NHANES 1999-2000 *(p <0.001)* and NHANES 2007-2008 to 2009-2010 *(p <0.001).*

The disparity for TEE SED (and EER SED for individuals <19 years) varied from 96 kcal/d in the 1970s, reaching a maximum of +516 kcal/d in 2003-2004, decreasing to +430 in 2009-2010. This is a range in disparity of 420 kcal/d. The overall trend was significant *(p <0.001,* as were the survey-to-survey differences from NHANES I to NHANES II (*p <0.002),* NHANES II to NHANES III *(p <0.001,* and NHANES III to NHANES 1999-2000 *(p <0.022)* and NHANES 2007-2008 to 2009-2010 *(p <0.001).*

Mathematical Modeling of Alterations in Weight via Disparity Values

Tables 1 and 2 depict the changes in bodyweight for hypothetical reference men and women for each of the nine NHANES survey waves induced by the disparity between the LAFA values and the TEE L-ACT and TEE SED, respectively. The alterations in weight between TEE L-ACT and LAFA varied from a yearly loss of ~4kg and ~5kg in men and women respectively, to a yearly gain of ~4kg, in both men and women (i.e., a range of ~8-9kg). The alterations in weight associated with the disparity between TEE SED and LAFA in men varied from a yearly loss of ~2kg in both men and women to a yearly gain of ~7kg and ~8kg in men and women, respectively (i.e., a range of 9-10kg).

Tables 1 and 2 also depict the measured changes in weight and the sum of the absolute values of the estimated mean changes in weight across the entire study period compared to that of the actual population-level gain in our reference individuals (65, 66, 68). Our models suggest that if the LAFA kcal/d estimates were actually consumed reference men and women would have lost ~1-4kg/year from 1971-1980 (a total accumulated loss of ~12kg to ~36kg), and gained ~3-7 kg/year from 1988-2010 (a total accumulated gain of ~42kg to ~98kg). The estimates differed from the actual measured changes in weight over the 39-year study period in reference individuals (i.e., gains of 10kg and 9kg in men and women, respectively). (65, 66, 68) From 1971-2010, the sum of the absolute values of the estimated mean alterations in weight from the disparity of LAFA and the TEE L-ACT were ~76kg and ~78kg for reference men and women, respectively. The sum of the absolute values of the estimated mean alterations in weight from the disparity of LAFA and the TEE SED were ~110kg for both reference men and women. This suggests substantial misestimation of per capita caloric consumption by the LAFA data series.

<Insert Table 1 & 2>

Discussion

The purpose of this study was to examine the validity of the USDA's loss-adjusted food availability data (LAFA) as a tool to estimate per capita caloric consumption. The USDA LAFA data series provided inaccurate and inconsistent estimates of per capita caloric consumption over its history, independent of population changes in PA (Fig. 1-3 and tables 1 and 2). The LAFA estimates varied considerably from TEE, with significant increments and decrements between the majority of surveys. Our results suggest that while the LAFA data are promoted by the USDA as a proxy estimates for trends in per capita caloric consumption, (29) the validity of the LAFA data series as a research tool or an empirical foundation for public health policy development is extremely limited.

With the assumption that PA remained static across the study period, the misestimation of per capita caloric consumption varied substantially (~400 kcal/d). With the incorporation of decreasing levels of population PA (as suggested by multiple lines of research (47-54, 69)), the range of the disparity between the LAFA data series and TEE increased to >500 kcal/d. Our inclusion of the empirically supported decreasing trends in PA is a significant strength that overcomes the limitations of previous research examining the LAFA data series.(43) If PA and other forms of energy expenditure were unchanged over the study period, the 'energy balance' conceptualization of obesity(70) suggests that increasing caloric consumption would be the only explanation for the obesity epidemic. Nevertheless, if PA and PAEE have declined as precipitously as current evidence suggests,(4, 47-49, 69) the actual increments in population-level weight over the study period(65, 66, 68) lead to the counter-stereotypical conclusion that caloric consumption may have actually declined as the prevalence of obesity increased. This has been referred to as the "'move less–eat somewhat less but still too much' scenario."(13) Unfortunately, there are no valid data to support any speculations regarding population-level trends in actual caloric consumption.(10-12)

Trends in LAFA – TEE disparity

From the early 1970s through 2008, both the LAFA estimates of per capita consumption and TEE increased, albeit not at similar rates. From NHANES 2007-2008 to NHANES 2009-2010, the LAFA estimates decreased while the population-level TEE increased. The reason for this lack of concordance may be due to the incorporation of updated food loss data, potentially leading to a decrement in misestimation.(44, 45) Nevertheless, these opposing trends strongly suggest the LAFA data series fails to serve the purpose for which it is promoted (i.e., examination of trends in per capita consumption; e.g., see (29)).

The strongest evidence for the lack of validity of the LAFA data series are the predicted changes in weight associated with the disparity between the TEE and the LAFA estimates via mathematical modeling. From 1971-1980, if the LAFA kcal/d estimates were actually consumed, reference men and women would have lost ~1-4kg/year from 1971-1980 (a total of ~12kg to ~36kg), and yet from 1988-2010 they would have gained ~3-7 kg/year (a total of ~42kg to

~98kg), respectively. These estimates differ substantially from the actual measured changes in weight in reference individuals over the 39-year study period (i.e., no changes in weight from 1971-1980, and gains of 10kg and 9kg from 1999-2010 in men and women, respectively (65, 66)). The extent of this disparity is substantial given that the gain in weight associated with the disparity for any four year period from 1999-2010 was greater than the change in weight over the entire 39-year study period. These data clearly support our conclusion that the LAFA data series is of limited value in the assessment of trends in per capita caloric consumption and related public health policy.

In addition, all nutrients must be ingested within the food and beverages consumed needed to meet minimum energy requirements.(71) As such, it is a simple analytic truth that both macronutrient and micronutrient consumption (i.e., dietary patterns; e.g., protein, sodium) are misestimated when total energy intake is misestimated.(23) Therefore, the assumption that the LAFA data can be used to examine trends in patterns of the consumption of specific commodities and/or specific nutrients is not empirically supported.

Limitations to LAFA Data Series

The LAFA series and other economic food supply data are quite distal from actual food and beverage consumption, and are subject to a large range of well-established, non-trivial errors. As such, their use as a proxy for per capita caloric consumption has been criticized by both academics and independent evaluators.(72-75) While the criticisms of the LAFA data are extensive, many revolve around the fact that these data reflect only the reported amounts of “raw and semi-processed commodities” available for domestic consumption in the United States(56,

76) and do not represent the final food products that may be consumed or discarded. As such, the USDA food supply data merely "represent the amount of nutrients that disappear into the marketing system and are neither a direct measure of actual nutrient consumption nor are they based on the quantity of the food actually ingested."(56) These indirect data collection protocols are predisposed to accumulative errors as inaccurate estimates regarding use, waste, and loss are propagated across the numerous stages of food distribution channels. As Muth et al. (2011) stated, the current loss-adjusted food availability data are incomplete and overstate actual consumption because the level of "documentation of food losses… ranged from little to none for estimates at the retail and customer levels."(45) Additionally, it appears that the LAFA data series may have become less reliable for the examination of trends over its history because of the non-proportionality (i.e., non-linearity) of food supply and waste as food availability increases.(43, 45, 77-80) These results support that "[f]ood balance sheets are notoriously weak on detail, waste estimations and amounts in general"(74) and buttress the Food and Agricultural Organization of the United Nations statement that "…where the basic data are incomplete and unreliable, an estimate of food available for human consumption is unlikely to be accurate."(81)

Study Limitations

There are limitations to our study. While the IOM TEE equations were specifically created to provide the most accurate estimates of TEE(58, 59), and are based on the current gold standard measure of energy expenditure (i.e., doubly-labeled water(82)), there are limitations to their use.(59) Nevertheless, prior to embarking on the present analysis of the LAFA data series, we validated our own protocol for estimating TEE and food-energy requirements in the US population.(60) Our method included objective estimates of PA from accelerometry-based PA monitors, and our sample was representative of the US population (i.e., the NHANES). Our novel method demonstrated a 0.98 correlation (p <0.001) with the IOM estimates and the kcal/d estimates differed by less than 2% across the entire nationally representative sample of US citizens.(60) The fact that these two disparate methods produce nearly identical estimates of TEE demonstrates the accuracy and reliability of the IOM equations to estimate the TEE of the US population and supports our assumptions regarding its use.

Additionally, neither the LAFA data series nor our estimates account for consumption by individuals not included in the Current Population Surveys such as homeless individuals (estimated at ~650,000 people in 2009),(83) undocumented aliens (estimated at ~4% of the U.S. population or 12.4 million people in 2007),(84) or tourists (~62 million visitors in 2011).(85) Furthermore, neither the LAFA data series nor our analyses can account for the increasing amount of food available for human consumption that is fed to pets and other animals. This limitation may be substantial given that over the study period, the pet population increased from 65 million to more than 135 million in 2007 (excluding strays and animals in humane shelters).(86) As such, the inability of the LAFA data series to account for these significant confounding factors lends credence to our conclusion that it lacks validity as a proxy for trends in per capita caloric consumption and its intended purpose as stated by multiple USDA ERS publications to “provide an indication of whether Americans, on average, are consuming more or less of various foods over time.”(87, 88)

Summary

The USDA LAFA data series are ostensibly the empirical foundation for US food-based public health policy development and yet provided varying and divergent estimates of per capita caloric consumption inconsistent with known changes in both population-level and reference individuals' weight over its history. The varying misestimation, inclusive of both under and over estimations, over the past four decades, suggests that despite the USDA's claims, the LAFA data series lack validity, and therefore cannot be used as a tool to estimate trends in per capita caloric consumption. Importantly, as evidenced by our sensitivity analyses, our estimates of the discrepancies between LAFA per capita consumption and total daily energy expenditure values is independent of any purported changes in population-level PA.

The confluence of our previous results (10-12) with the present study suggests that there are no valid population-level data on energy intake. As such, speculations regarding the role of caloric consumption in the etiology of the obesity epidemic do not have empirical support. Importantly, the lack of concordance between food supply data and the prevalence of obesity suggests that reductionist models derived from superficial economic data (e.g., see (31)) are of limited value in nutrition and obesity research. Given this reality, examinations of obesity and related chronic non-communicable diseases must include evidence demonstrating decades-long decrements in physical activity (PA), PA-related cardiorespiratory fitness, and physical activity energy expenditure (PAEE)(47-54, 69) as well as recent work detailing the mechanisms of nutrient-energy partitioning in the non-genetic intergenerational transmission of obesity and T2DM.(4, 7, 89, 90)

Conclusion

The USDA LAFA estimates of per capita caloric consumption were inconsistent with known changes in US population weight and estimated changes in total daily energy expenditure over its 39-year history. The large, variable misestimation suggests the USDA LAFA data lack validity as a proxy for per capita caloric intake and should not be used to inform related dietary guidelines or public policy. The confluence of our previous results with the present study suggests that food and beverage consumption data derived from invalid data collection protocols may have constrained the scientific community's understanding of the etiology of the obesity epidemic.

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Contributions: E. Archer had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: E. Archer and S. Blair participated in the initial concept and design of this project.

Analysis and interpretation of data: All statistical analyses and mathematical calculations were performed by E. Archer and D. Thomas. The interpretation was performed by E. Archer with assistance from all authors.

Drafting of the manuscript: E. Archer drafted the manuscript.

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Commentary

Obesity has been implicated as one of the major risk factors for cardiovascular disease and its prevalence has increased during the last decades (1). However, there is little agreement on the particular reasons why this increased in the prevalence of obesity has happened. Caloric consumption has been implicated as one of the etiologic factors by which obesity can occur, however a previous study by the authors (2) has shown that memory-based dietary assessment methods (M-BM) data has limitations to guide caloric intake and it cannot be used to inform national dietary guidelines. In the issue of the Journal, Archer et al report (3) the validity of the 1971-2010 USDA's loss-adjusted food availability (LAFA) per capita as an estimate of caloric consumption. The authors calculated the estimated total daily energy expenditure (TEE) utilizing the Institute of Medicine's equations with 'low-active' (TEE L-ACT) and 'sedentary' (TEE SED) physical activity values. These TEE estimates were subtracted from LAFA estimates to create disparity values (kilocalories per day; kcal/d) and a validated mathematical model was applied to calculate expected weight change in reference individuals resulting from the disparity. The authors demonstrate that The USDA LAFA data provided inconsistent estimates of per capita caloric consumption and thus, there are no valid population-level data on energy intake. In addition, they state that speculations regarding the role of caloric consumption in the etiology of the obesity epidemic do not have empirical support and because of the lack of concordance between food supply data and the prevalence of obesity are of limited value in obesity research. More importantly, they state that obesity not only should report caloric intake but also should include evidence demonstrating decades-long decrements in physical activity (PA), PA-related cardiorespiratory fitness, and physical activity energy expenditure.

This is a very provocative and interesting manuscript. As the authors alluded to there are some limitations to the calculations, but it portraits that some of the data we utilized in reporting caloric intake have limitations and should not be taken as gold standard. Thus, one should be cautious to make public policy regarding caloric intake and its implications for the epidemic of obesity. The problem is that these databases are the only comprehensive source of information on the food and nutrient intake of the US population and dietary intake data are collected using standardized, validated protocols and there are many studies that have linked dietary intake and physical activity as key determinants of obesity. (4)

In conclusion, the authors suggest the USDA LAFA data lack validity as an estimation for per capita caloric and therefore one should be cautious to the role on the understanding of the etiology of the obesity epidemic.

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Table 1: Estimated Changes in Weight from the Disparity of IOM TEE L-ACT − USDA LAFA*

	NHANES I 1971-1974	NHANES II 1976-1980	NHANES III 1988-1994	NHANES 1999-2000	NHANES 2001-2002	NHANES 2003-2004	NHANES 2005-2006	NHANES 2007-2008	NHANES 2009-2010
*Disparity: LAFA-TEE (kcal/day)	-205	-173	9	139	174	189	175	179	101
Men (35 years old)									
Height (cm)+	175	175	176	176	176	176	176	176	176
Start Weight (kg): from NHANES+	79	79	83	87	87	88	88	89	89
End Weight (kg)	75	75	83	90	91	92	92	93	91
Yearly Change in Weight (kg)	-4	-4	0	3	4	4	4	4	3
Accumulated Change over Survey Wave (kg)	-16	-16	0	6	8	8	8	8	6
++Total Accumulated Change Over Study Period: 1971-2010 (|kg|)	16	32	32	38	46	54	62	70	76
Women (35 years old)									
Height (cm)+	162	162	162	163	163	162	162	162	162
Start Weight (kg): from NHANES+	66	66	70	74	74	75	75	75	75
End Weight (kg)	61	62	70	77	78	79	79	79	77
Yearly Change in	-5	-4	0	3	4	4	4	4	2

Weight (kg)									
Accumulated Change over Survey Wave (kg)	-20	-16	0	6	8	8	8	8	4
++Total Accumulated Change Over Study Period: 1971-2010 (|kg|)	20	36	36	42	50	58	66	74	78

* All estimates rounded to the nearest integer; ++ Absolute value of alterations in weight of reference individuals over the study period; + Sources (65, 66, 68)

Table 2: Estimated Changes in Weight from the Disparity of IOM TEE SED −USDA LAFA*

	NHANES I (1971-1974)	NHANES II (1976-1980)	NHANES III (1988-1994)	NHANES 1999-2000	NHANES 2001-2002	NHANES 2003-2004	NHANES 2005-2006	NHANES 2007-2008	NHANES 2009-2010
*Disparity: LAFA-TEE (kcal/day)	-84	-52	138	276	313	328	315	319	243
Men (35 years old)									
Height (cm)+	175	175	176	176	176	176	176	176	176
Start Weight (kg): from NHANES +	79	79	83	87	87	88	88	89	89
End Weight (kg)	77	78	86	93	94	95	95	96	95
Yearly Change in Weight (kg)	-2	-1	3	6	7	7	7	7	6
Accumulated Change over Survey Wave (kg)	-8	-4	18	12	14	14	14	14	12
++Total	8	12	30	42	56	70	84	98	110

Accumulated Change Over Study Period: 1971-2010 (|kg|)									
Women (35 years old)									
Height (cm)+	162	162	162	163	163	162	162	162	162
Start Weight (kg): from NHANES +	66	66	70	74	74	75	75	75	75
End Weight (kg)	64	65	73	80	81	83	82	82	80
Yearly Change in Weight (kg)	-2	-1	3	6	7	8	7	7	5
Accumulated Change over Survey Period (kg)	-8	-4	18	12	14	16	14	14	10
++Total Accumulated Change Over Study Period: 1971-2010 (|kg|)	8	12	30	42	56	72	86	100	110

* All estimates rounded to the nearest integer; ++ Absolute value of alterations in weight over study period; + Sources (65, 66, 68)

1. **Figure 1: Institute of Medicine (IOM) estimated Total Daily Energy Expenditure (TEE) in kilocalories per day (kcal/d) using 'sedentary' (SED) and 'low-active (L-ACT) PA value and USDA LAFA data by NHANES Survey Year.**
    a. USDA LAFA = United States Department of Agriculture Loss Adjusted Food Availability Data; IOM = Institute of Medicine, TEE = Estimated Total Daily Energy Expenditure, NHANES = National Health and Examination Survey, kcal/d = kilocalories per day, L-ACT = 'Low Active' PA value used in IOM TEE equation; SED = 'Sedentary' PA value used in IOM TEE equation.
2. **Figure 2: Disparity between USDA Loss Adjusted Food Availability (LAFA) and Institute of Medicine (IOM) Estimated Total Daily Energy Expenditure (TEE SED, TEE L-ACT) in kilocalories per day (kcal/d) by NHANES Survey Year. Non-zero values indicate misestimation.**
    a. USDA LAFA = United States Department of Agriculture Loss Adjusted Food Availability Data; IOM = Institute of Medicine, TEE = Estimated Total Daily Energy Expenditure, NHANES = National Health and Examination Survey, kcal/d = kilocalories per day, SED = 'Sedentary' PA value used in IOM TEE equation. L-ACT = 'Low Active' PA value used in IOM TEE equations.
3. **Figure 3: Disparity between USDA Loss Adjusted Food Availability (LAFA) and Institute of Medicine (IOM) Estimated Total Daily Energy Expenditure (TEE) in kilocalories per day (kcal/d) by NHANES Survey Wave; assuming a population level decrease in PA from 1971 to 2010. Non-zero values indicate misestimation. TEE L-ACT was used for NHANES I & II and TEE SED was used from NHANES III to 2009-2010.**
    a. USDA LAFA = United States Department of Agriculture Loss Adjusted Food Availability Data; IOM = Institute of Medicine, TEE = Estimated Total Daily Energy Expenditure, NHANES = National Health and Examination Survey, kcal/d = kilocalories per day, SED = 'Sedentary' PA value used in IOM TEE equation. L-ACT = 'Low Active' PA value used in IOM TEE equations.

Figure 1.

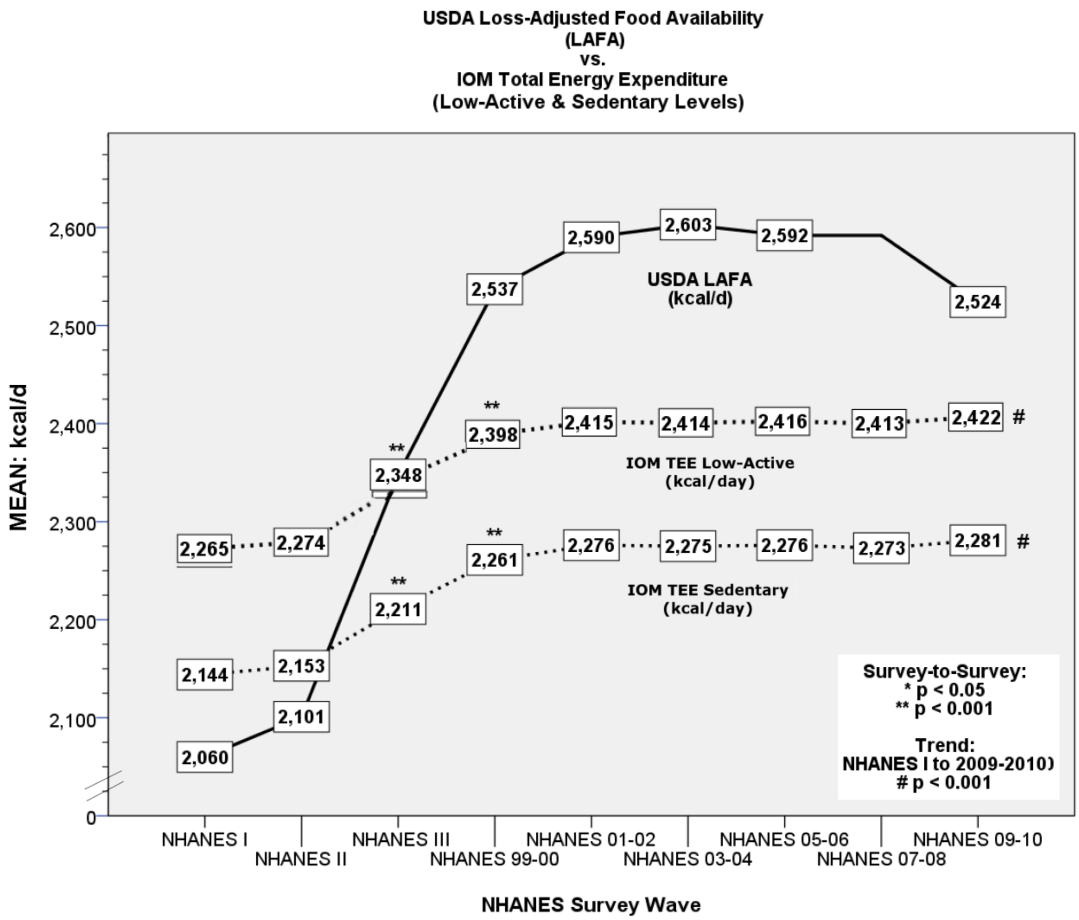

USDA Loss-Adjusted Food Availability
(LAFA)
vs.
IOM Total Energy Expenditure
(Low-Active & Sedentary Levels)
MEAN: kcal/d
2,600
2,500
2,400
2,300
2,200
2,100
0
2,060
2,101
2,153
2,348
2,537
2,590
2,603
2,592
2,524
USDA LAFA
(kcal/d)
2,265
2,274
**
2,398
2,415
2,414
2,416
2,413
2,422
#
IOM TEE Low-Active
(kcal/day)
2,144
2,211
2,261
2,276
2,275
2,276
2,273
2,281
IOM TEE Sedentary
(kcal/day)
Survey-to-Survey:
* p < 0.05
** p < 0.001
Trend:
NHANES I to 2009-2010)
# p < 0.001
NHANES I
NHANES II
NHANES III
NHANES 99-00
NHANES 01-02
NHANES 03-04
NHANES 05-06
NHANES 07-08
NHANES 09-10
NHANES Survey Wave

Figure 2.

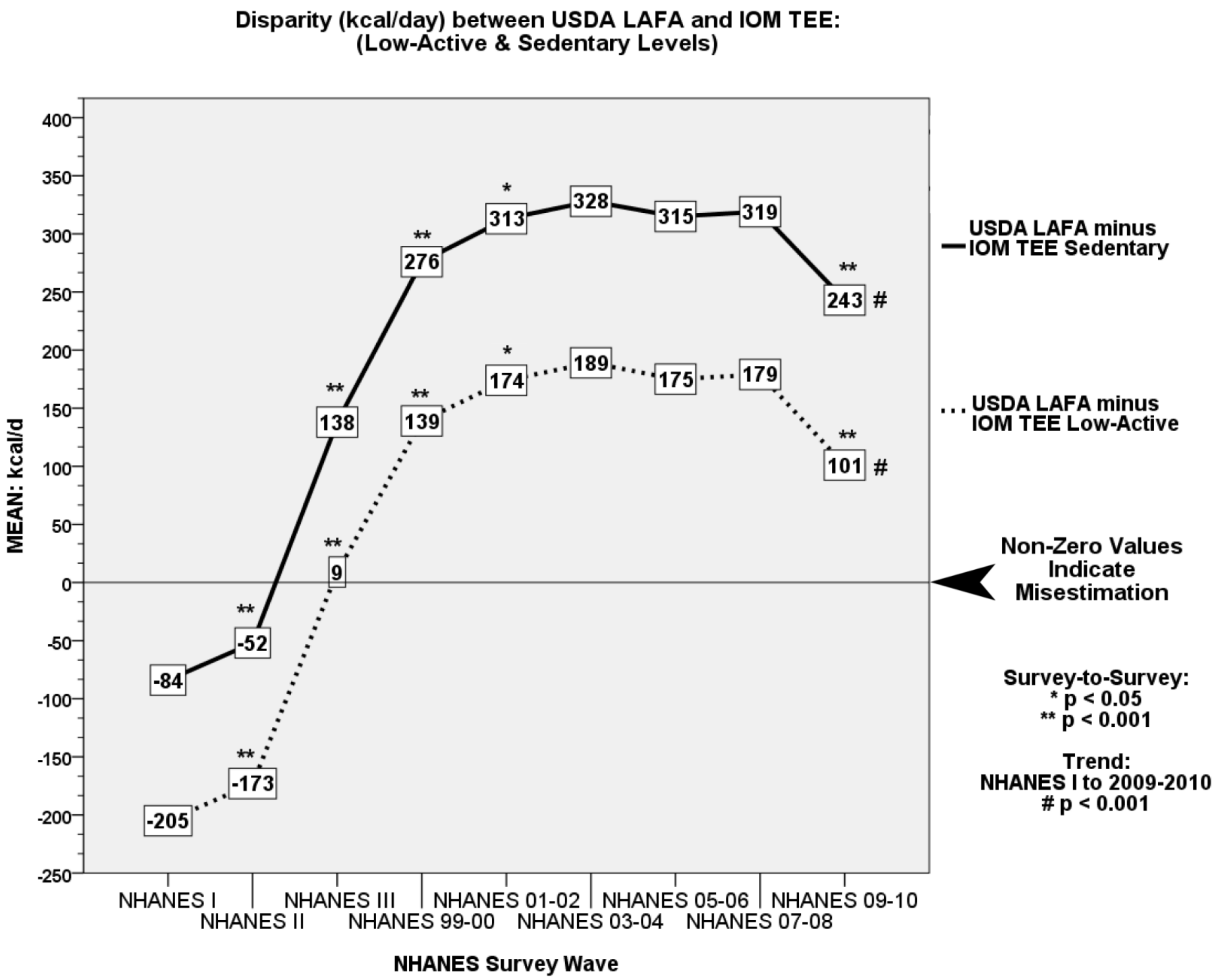
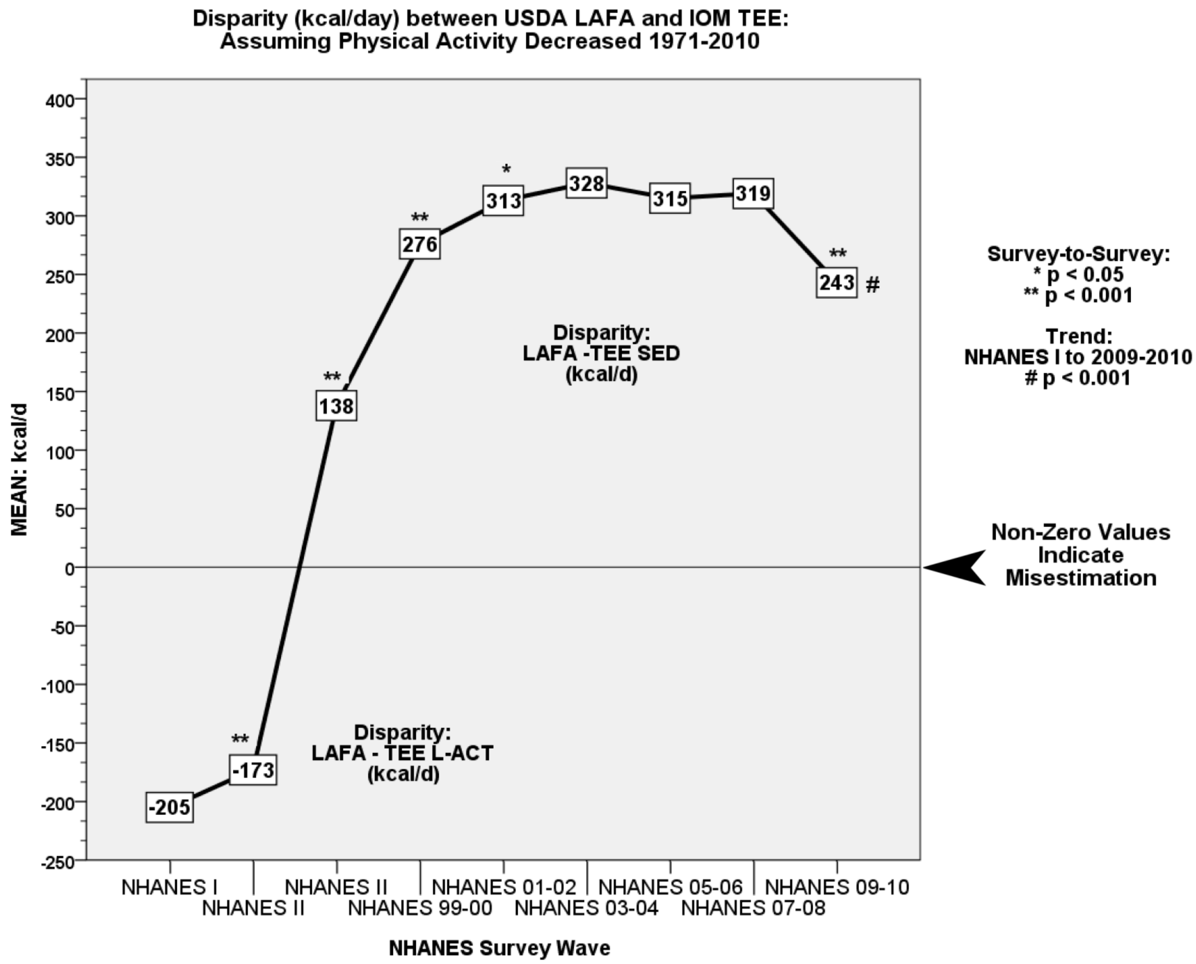


Figure 3.


Disparity (kcal/day) between USDA LAFA and IOM TEE:
Assuming Physical Activity Decreased 1971-2010
MEAN: kcal/d
400
350
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-205
-173
138
276
313
328
315
319
243
**
*
#
Disparity:
LAFA -TEE SED
(kcal/d)
Disparity:
LAFA - TEE L-ACT
(kcal/d)
NHANES I
NHANES II
NHANES II
NHANES 99-00
NHANES 01-02
NHANES 03-04
NHANES 05-06
NHANES 07-08
NHANES 09-10
NHANES Survey Wave
Survey-to-Survey:
* p < 0.05
** p < 0.001
Trend:
NHANES I to 2009-2010
# p < 0.001
Non-Zero Values
Indicate
Misestimation