Insulin MMAS (I-MMAS-8)

Preface

You indicated that you are taking medication for your diabetes. Individuals have identified several issues regarding their medication taking behavior and we are interested in your experiences. There is no right or wrong answer. Please answer each question based on your personal experience. Please answer each question below by checking the box that best describes your response.

---

1. Do you sometimes forget to take your insulin?

☐ Yes ☐ No

2. People sometimes miss taking their insulin or take less than prescribed for reasons other than forgetting. Thinking over the past 2 weeks, were there any times when you did not take your prescribed insulin?

☐ Yes ☐ No

3. Have you ever cut back or took less of your insulin without telling your doctor, because you felt worse when you took it or wanted to avoid other negative consequences of taking insulin?

☐ Yes ☐ No

4. When you travel or leave home, do you sometimes forget to bring along your insulin?

☐ Yes ☐ No

5. Did you take all your as prescribed the last time you were supposed to?

☐ Yes ☐ No

6. When you feel like your diabetes is under control, do you sometimes take less of your insulin than prescribed?

☐ Yes ☐ No

7. Taking insulin every day is a real inconvenience for some people. Do you ever feel hassled about sticking to your insulin regimen?

☐ Yes ☐ No

8. How often do you have difficulty remembering to take all your insulin?

☐ Never ☐ Rarely ☐ Sometimes ☐ Often ☐ Always

HHS Public Access

Author manuscript

J Behav Med. Author manuscript; available in PMC 2017 August 01.

Published in final edited form as:

J Behav Med. 2016 August ; 39(4): 633–641. doi:10.1007/s10865-016-9741-y.

Measuring Insulin Adherence among Adults with Type 2 Diabetes

Chandra Y. Osborn and **Jeffery S. Gonzalez**

Vanderbilt University Medical Center, Yeshiva University, Albert Einstein College of Medicine

Abstract

Non-adherence to insulin is common and associated with suboptimal health. We adapted the Morisky Medication Adherence Scale to specify insulin adherence (MIAS) and compared it to the Adherence to Refills and Medication Scale for Diabetes (ARMS-D) and the Summary of Diabetes Self-Care Activities medications subscale (SDSCA-MS) and an insulin-specific (SDSCA-IS) version. A sample of 144 insulin-treated adults (58% African American/Black, 34% Caucasian/White, 8% Other/Mixed race; 6.9% Hispanic) completed these measures along with a HbA_{1C} test. The internal consistency and factor structure of the MIAS were adequate; 59% of participants forgot to take insulin and 46% reported non-adherence. The MIAS was associated with the ARMS-D, SDSCA-MS, and SDSCA-IS (p<.001), and higher MIAS scores were marginally associated with better self-rated health (p=.057), but significantly associated with fewer emergency room visits (p=.001), and better HbA_{1C} (p=.001). The MIAS is a valid and reliable insulin adherence assessment tool for practice and research applications.

Keywords

medication adherence; insulin therapy; type 2 diabetes; measurement

Adults with type 2 diabetes (T2DM) are often prescribed oral glucose-lowering agents and/or insulin to achieve glycemic control, thereby preventing macrovascular and microvascular complications. Medication adherence facilitates these and other benefits, whereas medication non-adherence is associated with a cascade of unfavorable health outcomes, including suboptimal glycemic control (Feldman et al., 2014; Piette et al., 2004), emergency room visits (Balkrishnan et al., 2003), hospitalizations (Ho et al., 2006), higher

Correspondence concerning this article should be addressed to Chandra Y. Osborn, PhD, MPH, Vanderbilt Center for Health Behavior and Health Education, 2525 West End Ave. Suite 370, Nashville, TN 37203. Contact: chandra.osborn@vanderbilt.edu.
Chandra Y. Osborn, PhD, MPH, Department of Medicine, Department of Biomedical Informatics, Center for Health and Health Education, Vanderbilt University Medical Center.
Jeffery S. Gonzalez, PhD, Ferkauf Graduate School of Psychology, Yeshiva University; Diabetes Research Center, Albert Einstein College of Medicine.

Conflict of interest: Authors Chandra Y. Osborn and Jeffery S. Gonzalez declare that they have no conflict of interest.

The contents of this manuscript are solely the responsibility of the authors and do not necessarily represent official views of the National Institutes of Health.

Human and animal rights and informed consent: Human and Animal Rights and Informed Consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

The authors have no conflict of interests or financial disclosures to report.

healthcare costs (Balkrishnan et al., 2003), and pre-mature mortality (Ho et al., 2006). The scope of the non-adherence problem depends on the population being studied (Peyrot et al., 2012a, 2012b), reasons for non-adherence, and how adherence is measured (i.e., self-report, pharmacy claims) (Gonzalez et al., 2011).

Currently, studies report adherence rates as low as 67% for oral glucose-lowering agents (Cramer, 2004) and 43% for insulin (Davies et al., 2013). Certain populations have higher rates of non-adherence to diabetes treatment, including racial/ethnic minorities (Osborn, Cavanaugh, et al., 2011), populations with low socioeconomic status (SES; defined as having a limited income, education, or lack of health insurance), and/or persons with more social stressors (Osborn et al., 2014), limited health literacy (Osborn, Cavanaugh, et al., 2011), and depression (Gonzalez et al., 2007; Osborn, Patel, et al., 2011). Factors associated with non-adherence to insulin, specifically, include older age (Egede et al., 2011), being female (Egede et al., 2011; Peyrot et al., 2010), being a racial/ethnic minority (Cramer et al., 2005), having low SES and a T2DM diagnosis (versus type 1 diabetes) (Peyrot et al., 2010), among other factors (Davies et al., 2013).

The reasons for non-adherence to insulin also differ from adherence to oral glucose-lowering agents. Persons with T2DM who are non-adherent report omitting insulin doses because of fear and embarrassment with administration in public and the inflexibility and demands of the regimen (e.g., persons on adjustable insulin must adjust their insulin dose based on carbohydrate intake, physical activity and blood glucose levels) (Peyrot et al., 2012b), the pain associated with injections (Rubin et al., 2009), and fear of hypoglycemia and weight gain (Ross et al., 2011). Insulin-treated patients also report more emotional distress than patients on oral medications (Baek et al., 2014), and such distress is associated with both non-adherence and suboptimal glycemic control (Gonzalez et al., 2015).

Globally, regardless of diabetes type, people treated with insulin struggle with regimen adherence and persistence. A 2012 international survey of insulin-treated persons with diabetes (88% T2DM) found one in three omitted insulin or were non-adherent in the past month, with 3.3 average nonadherent days during that time (Peyrot et al., 2012b). Some report 41–57% of insulin-treated persons are non-adherent (Lerman et al., 2009; Peyrot et al., 2010), with an estimated 20% omitting insulin routinely (Peyrot et al., 2010). These studies highlight the magnitude of insulin non-adherence among adults with T2DM, but rely on self-report measures of unknown reliability and validity created for the study.

All measures of medication adherence have strengths and limitations. Self-reported adherence is subject to social desirability bias, but strongly correlated with more objective measures (e.g., pharmacy claims data, medication event monitoring systems), which cannot assess the timing and accurate dosing of medications. While both subjective and objective measures predict clinical outcomes, self-report is more feasible for research purposes and clinical administration, especially for adjustable-dose regimens (Gonzalez et al., 2011). Current self-report measures of medication adherence in diabetes include the Adherence to Refills and Medications Scale for Diabetes (ARMS-D) (Mayberry et al., 2013), the Summary of Diabetes Self-Care Activities Medication Subscale (SDSCA-MS) (Toobert et al., 2000), and the Morisky Medication Adherence Scale (MMAS) (Al-Qazaz et al., 2010;

Chung et al., 2015; DiBonaventura et al., 2014; Wong et al., 2014). A major drawback of these measures is having respondents consider their entire glucose-lowering regimen (orals and insulin) when responding to items rather than distinguishing between adherence to orals versus adherence to insulin.

To our knowledge, there is no gold standard self-report measure of insulin adherence, so we adapted the MMAS to specify insulin adherence (MIAS), examined its psychometric properties, and compared it to the ARMS-D and SDSCA, which are both correlated with objective adherence measures (Gonzalez et al., 2013; Kripalani et al., 2009) and glycemic control (Houle et al., 2015; Mayberry et al., 2013). We also explored relationships between the MIAS and glycemic control, emergency room visits, and self-rated health, and tested if it explains unique variance in these outcomes above and beyond the ARMS-D and SDSCA.

Methods

Sample and Recruitment

From July 2010 through November 2012, we recruited 314 English- or Spanish-speaking adults (≥18 years) prescribed medications for T2DM (i.e., insulin, insulin and oral agents, or oral agents only) at a Federally Qualified Health Center (FQHC) in Nashville, TN. Trained research assistants (RAs) worked with clinic personnel to identify eligible participants with a scheduled appointment (Mayberry et al., 2013; Mayberry et al., 2014). For this paper, we have restricted the sample to only those participants prescribed insulin alone or in combination with oral agents (i.e., 144 participants).

Data and Procedure

Data collection and study procedures have been previously described (Mayberry et al., 2013; Mayberry et al., 2014), and approved by the Vanderbilt University Institutional Review Board. Informed consent and data collection occurred before or after participants' scheduled clinic appointment. Given high rates of limited literacy skills in FQHC patient populations, RAs read self-report items and response options aloud to all participants. To reduce social desirability bias and maximize accurate reporting, RAs told participants their self-report data would not be shared with healthcare providers and, consistent with instructions, normalized non-adherence prior to the administration of each adherence measure. Finally, RAs obtained medical record information, and compensated participants $20. A clinic nurse administered a point-of-care glycated hemoglobin A_{1C} (HbA_{1C}) test to assess glycemic control.

Measures

Demographic and diabetes characteristics—We asked participants their date of birth and age, reconciling discrepancies with what was recorded in the medical record, as well as their gender, race, ethnicity, income, education, insurance status, and duration of diabetes. RAs collected body mass index (BMI) and the type of prescribed medications from the medical record.

Morisky Insulin Adherence Scale (MIAS)—With permission from Morisky (Morisky, personal communication), we adapted the eight-item Morisky Medication

Adherence Scale (MMAS (Morisky et al., 2008) to assess insulin adherence by replacing condition-specific language like “blood pressure medicine” with “insulin,” but retaining each item’s meaning and scoring. Consistent with the MMAS (Morisky et al., 2008), the MIAS includes seven yes/no questions and one question on a 5-point Likert scale. Respondents answering “no” to all questions, but “yes” to item 5 (reverse coded) and “never/rarely” to item 8 obtain the maximum 8 points and are classified as having perfect adherence. Respondents answering differently obtain a lower score, indicating less than perfect adherence (<8).

Adherence to Refills and Medications Scale for Diabetes (ARMS-D)—The 11-item ARMS-D asks respondents to think about all the diabetes medications they are taking (i.e., oral agents, insulin, or insulin plus oral agents) when responding to items assessing problems with filling and taking diabetes medications, including insulin (Mayberry et al., 2013). We elected to administer the ARMS-D ‘as is’ rather than adapt it for insulin only to see if the MIAS does better than currently used measures that take insulin into account. Furthermore, while the ARMS-D is not an insulin-specific adherence measure, per se, insulin-treated participants completed the ARMS-D and their responses account for their problems taking insulin. We reversed the ARMS-D scores to be consistent with the direction of MIAS scores, so higher ARMS-D scores indicate better adherence.

Summary of Diabetes Self-Care Activities medications subscale (SDSCA-MS)—The two-item SDSCA-MS is one of the most widely used self-report measures of medication adherence in diabetes (Mayberry et al., 2013; Toobert et al., 2000). Respondents are typically asked to think about *all* of their diabetes medications when answering two questions, but because adherence may be medication-specific, we administered both items separately for each diabetes medication in the regimen. RAs asked insulin-treated participants to list each insulin and oral diabetes medication in their regimen, separately, and then the RA asked (1) “On how many of the last seven days did you take this medication?” and (2) “On how many of the last seven days did you take the correct number of (pills/injections) for this medication?” Response options range from 0–7. We averaged these items as recommended (Toobert et al., 2000), and then calculated the average of the averages (i.e., across insulin[s] and orals for those on both) to generate the typically calculated diabetes medication adherence score, with higher scores indicating better adherence (Mayberry et al., 2013). We also calculated a separate score, representing participants’ adherence to only their insulin(s), which we are calling the SDSCA-IS, with higher scores indicating better insulin adherence.

Self-rated health—RAs asked on a 5-point response scale, ranging from 1=“poor” to 5=“excellent,” “In general, your overall health is?”

Emergency room (ER) visits—RAs asked, “How many times have you been to the emergency room in the past year?” The response was open-ended.

Glycemic control (HbA_{1C})—A nurse administered a point-of-care HbA_{1C} (%) test (Kennedy et al., 2005). The HbA_{1C} test measures one’s average blood glucose control over the past two to three months, and is the gold standard for assessing glycemic control.

MMAS-assessed medication adherence is highly sensitive, with 88.9% of non-adherent patients also having suboptimal glycemic control (Chung et al., 2015).

Analyses

We used SPSS 21 for all analyses, and restricted our analyses to include only those participants prescribed insulin or insulin plus oral glucose-lowering agents (N=144). Cronbach's α and item-total correlations assessed the MIAS' internal consistency reliability. Item-rest correlations ≥0.30 indicate items are conceptually similar to other items, and Cronbach's α ≥0.70 indicates good internal consistency reliability (DeVellis, 1991; Nunnally et al., 1994). We performed a principal components factor analysis with a forced one-factor solution to test comparability with the MMAS (Morisky et al., 2008). Items with loadings ≥0.40 share substantial variance with other items (Loehlin, 2012). To examine convergent validity, Spearman's rho correlations tested the MIAS' association with overall diabetes medication adherence according to the ARMS-D and the SDSCA-MS, and insulin-specific adherence according to the SDSCA-IS.

Data were missing on three variables included in multivariable models; one participant did not know duration of diagnosed diabetes, three participants had missing BMI in the medical record, and 10 participants (6.9%) did not report income. Casewise deletion biases estimates (Ware et al., 2012) and requires more assumptions about the missing data than multiple imputation, so we used multiple imputation using chained equations (Raghunathan et al., 2001; van Buuren et al., 1999) to impute 10 datasets (Graham et al., 2007) following Graham's guidelines (Graham, 2009; Graham et al., 1999).

To explore criterion validity, we related the MIAS to self-rated health, ER visits in the past year, and glycemic control. Linear regression models assessed the unadjusted and adjusted relationships between the MIAS and each outcome variable. Adjusted models included a priori covariates entered at the same time, including participants' age, gender, race, income, education, insurance status, duration of diabetes diagnosis, and BMI. Linear models assessed both the independent relationship between the MIAS and the outcome variable and the proportion of variance the MIAS explained in the outcome.

We also conducted three hierarchical linear regression models to test the unique contribution of the MIAS in predicting HbA_{1C} above and beyond each existing medication adherence measure. One model asks, "Does the MIAS explain unique variance in A1c compared to the ARMS-D (i.e., the medication adherence measure endorsed by the National Diabetes Education Program) before and after adjusting for age, gender, race, income, education, insurance status, duration of diabetes diagnosis, and BMI?" Another model asks, "Does the MIAS explain unique variance in A1c compared to the SDSCA-MS (i.e., the most widely used medication adherence measure in diabetes) before and after adjusting for a priori covariates?" The final model asks, "Does the MIAS explain unique variance in A1c compared to the SDSCA-IS (i.e., asking respondents to think of insulin only when responding to SDSCA items) before and after adjusting for covariates?" Support for unique variance suggests the MIAS is assessing something above and beyond what is captured by existing measures of diabetes medication adherence.

Results

Sample characteristics for the 144 participants prescribed insulin are presented in Table 1. These participants were on average 50.7 (SD=11.9) years old; 38.9% male; 58.3% African American/Black; 31.9% had less than a high school diploma or equivalent; 73.6% had annual incomes less than $15K; and 47.2% were uninsured. The average participant had been diagnosed with diabetes for 10.0 (SD=7.6) years, and presented with an HbA1c of 9.0% (SD=2.1%).

The mean score for the MIAS was 5.35 (SD=1.92). The MIAS item-total correlations were ≥ 0.30 for each item. Internal consistency reliability was α=0.69, and did not improve with item deletion. The MIAS produced acceptable item loadings ranging from 0.48–0.68 that loaded onto a single factor (Table 2). Better insulin adherence on the MIAS was associated with better diabetes medication adherence on the ARMS-D total (ρ=0.66, p<.001), ARMS-D refill adherence subscale (ρ=0.35, p<.001), ARMS-D medication taking subscale (ρ=0.70, p<.001), and SDSCA-MS (ρ=0.51, p<.001). Insulin adherence on the MIAS was associated with insulin adherence on the SDSCA-IS (ρ=0.48, p<.001).

The proportion of participants reporting *perfect adherence* (i.e., the highest level of adherence measured by a scale) was 12.5% on the MIAS, as compared to 0% on the ARMS-D total, 54.2% on the SDSCA-MS, and 58.3% on the SDSCA-IS. Of participants reporting perfect adherence on the SDSCA-MS and SDSCA-IS, 82.1% and 83.3% reported less than perfect adherence on the MIAS, respectively. Of participants reporting perfect adherence on the MIAS (n=18), 22% reported less than seven days adherence on the SDSCA-MS and the SDSCA-IS.

The MIAS was not significantly related to participants' age, gender, race, years of education, income, health insurance status, duration of diagnosed diabetes, or BMI, but was significantly associated with favorable health ratings, fewer ER visits in the past year, and lower HbA_{1C} (Table 3). In adjusted regression models, the MIAS was marginally associated with favorable health ratings, but remained significantly associated with fewer ER visits in the past year and lower HbA_{1C} (Table 3). The MIAS explained a marginally significant amount of unique variance in self-rated health, but explained a significant and substantial amount of unique variance in ER visits and $HbA_{1C.}$ The MIAS explained 11% of the variance in ER visits, representing a 69.5% increase over the amount of variance explained by the covariates alone. While the MIAS explained 6.6% of the variance in HbA_{1C}, representing a 41.3% increase in variance explained by the covariates, participants with controlled HbA_{1C} (<7%, n=22) were only marginally more adherent on the MIAS (M=6.0 ± SD=1.51) compared to participants with uncontrolled HbA_{1C} (≥7%, n=122; M=5.23 ± SD=1.96), p=.09.

Three hierarchical linear regression models tested the unique contribution of the MIAS in predicting HbA_{1C}, independent of the ARMS-D, SDSCA-MS, and SDSCA-IS, and prior to and after adjusting for age, gender, race, income, education, insurance status, duration of diagnosed diabetes, and BMI. Table 4 presents the three-step models in which HbA_{1C} was regressed on one of the three validated measures of diabetes medication adherence (in Step

1), the MIAS (in Step 2), and covariates (in Step 3). In the first model, the ARMS-D was significantly associated with lower HbA_{1C} in Step 1 (β=−.30, p<.001), but this effect was reduced (β=−.21, p=.049) with the MIAS. In Step 2, the MIAS was not associated with lower HbA_{1C} (β=−.13, p=.225), but was marginally associated with lower HbA_{1C} in Step 3 (β=−.20, p=.057). In the second model, the SDSCA-MS was marginally associated with lower HbA1c in Step 1 (β=−.16, p=.05), but was not associated with HbA_{1C} in Steps 2 and 3, whereas the MIAS was significantly associated with lower HbA_{1C} in Steps 2 (β=−.25, p=.006) and 3 (β=−.22, p=.013). Finally, in the third model, the SDSCA-IS was marginally associated with lower HbA_{1C} in Step 1 (β=−.15, p=.063), but this trend was attenuated (β=−.07, p=.434) with the MIAS. In Steps 2 and 3, the MIAS was significantly associated with lower HbA_{1C} (β=−.25, p=.004 and β =−.22, p=.007, respectively).

Discussion

Studies assessing insulin adherence often rely on single-item self-reports with unknown reliability and validity, use arbitrary cut-offs for non-adherence, or combine adherence to insulin and oral medications in a single assessment. To establish a self-report measure of insulin adherence, we adapted a widely used measure of medication adherence in clinical settings, the MMAS (Morisky et al., 2008), to be insulin-specific (i.e., the MIAS), administered it to a sample of high risk patients, and assessed its psychometric properties. We found the MIAS to be a reliable and valid measure of insulin adherence, and that nearly half (45.8%) of our sample reported episodes of insulin non-adherence during the previous two weeks and 21% were non-adherent on the previous day.

Chronbach's alpha assesses the degree to which items measure the same general construct. The MMAS has produced an acceptable >0.80 alpha (Morisky et al., 2008), whereas the MIAS produced an adequate alpha of 0.69. This might be due to patients on short-acting adjustable insulin versus long acting insulin responding differently to items 2, 3, and 5 on the MIAS. These items ask about not taking all of your insulin or cutting back insulin, which might indicate adherence for patients on adjustable insulin, but non-adherence for patients on long-acting insulin. Future studies should examine item performance by insulin type to account for this possibility.

Convergent validity was supported by significant correlations between the MIAS and the ARMS-D, a general diabetes medication adherence scale, and the SDSCA-MS, which estimates taking diabetes medications and correct dosing of these medications in the past seven days. Discriminant validity was partially supported, as the MIAS was more closely related to the ARMS-D's medication taking subscale than the refill adherence subscale, but it was equally related to the number of days of taking diabetes medications and doses for both the overall SDSCA medications subscale and an insulin-specific version.

Criterion validity was strongly supported. The MIAS was significantly related to favorable health ratings, fewer ER visits in the past year, and better glycemic control. The MIAS accounted for 70% more variance in ER visits and over 40% more variance in HbA_{1C} than could be accounted for by demographic and clinical covariates alone. Moreover, the MIAS accounted for additional variance in HbA_{1C} (of marginal significance) over and above what

could be predicted by the ARMS-D that assesses overall diabetes medication adherence. The MIAS also accounted for significantly more variance in HbA_{1C} than asking about days having taken diabetes medications and doses in general, or days having taken insulin and insulin doses, specifically, over the past seven days (SDSCA-MS and SDSCA-IS). Although the magnitude of the relationship between insulin adherence and HbA_{1C} was statistically significant, analyses indicated approximately 7% shared variance. This is somewhat better than what is typical for studies assessing the relationship between adherence and glycemic control in T2DM, even when adherence is objectively measured. Medication adherence based on prescription refill data accounted for 4% of the variance in concurrently measured HbA1c and only 1.7% in HbA1c change over time in a prior study of 810 low-income African American/Black and White adults with diabetes (Schectman et al., 2002). An Israeli population-based study of 228,846 adults with diabetes indicated approximately 4.5% shared variance between medication possession ratio and glycemic control (Feldman et al., 2014). Another study found shared variance between various self-reports for medication adherence and glycemic control ranging from 3–8% (Kripalani et al., 2009). Our results suggest the MIAS shares some overlap with existing measures of medication adherence, but accounts for additional information relevant to understanding the risk of suboptimal outcomes among racially/ethnically diverse, low SES insulin users with T2DM.

Prior studies of insulin adherence have used self-report scales of unknown psychometric properties, often using a single item that asks patients give an overall estimate of the frequency of intentionally taking less insulin than prescribed or unintentionally missing prescribed doses (Peyrot et al., 2012a, 2012b; Peyrot et al., 2010). Unlike the SDSCA (Toobert et al., 2000), but similar to the ARMS-D, the MIAS has the advantage of using multiple items to identify common reasons for non-adherence that can be addressed in clinical practice or in interventions to improve adherence. Forgetting to take insulin doses was the most frequently endorsed MIAS item (59%), but nearly half (47.9%) felt hassled by insulin, whereas one in five reported intentional non-adherence to avoid negative consequences of insulin (23.6%) or because they felt diabetes was under control (21.5%). These rates differ from the 2012 U.S. National Health and Wellness Survey (NHWS) that reported overall medication adherence for adult T2DM patients taking insulin (DiBonaventura et al., 2014). Among 1,198 respondents taking insulin glargine or detemir, 20% reported forgetting to take their medication, 29% felt hassled by their medication regimen, and less than 7% reported each type of intentional non-adherence (DiBonaventura et al., 2014). The NHWS did not assess insulin-specific adherence, so our higher rates of insulin non-adherence problems might reflect differences in adherence to insulin versus oral medications, differences in samples, or a combination of both. Our sample was younger, included more African American/Black participants, with lower SES who had worse glycemic control in comparison. The relatively high rates of insulin non-adherence and perceived hassles related to insulin in our sample of low SES patients underscore the importance of assessing insulin-specific adherence in this population.

There are study limitations. Our cross-sectional design precluded testing if the MIAS, ARMS-D, SDSCA-MS and SDCSA-IS predicted future health ratings, ER visits, and glycemic control. We were also unable to assess test-retest reliability, compare these measures' concordance with objective adherence measures, test the MIAS' divergent

validity with unrelated measures, explore between group differences in the MIAS by duration and type of insulin therapy, or assess social-desirability bias. Furthermore, results may differ from those presented here if measurement administration is done by a non-RA (e.g., clinician) or does not include a statement normalizing non-adherence, or if the SDSCA-MS and SDSCA-IS are not administered for each medication or insulin, separately. While we achieved the absolute minimum number of cases per predictor in regression models (Wilson VanVoorhis et al., 2007), our sample size was small, limiting statistical power. The sample was also racially/ethnically diverse, and the MIAS' acceptability and psychometric properties might vary by racial/ethnic subgroup. Finally, our results may not generalize to less diverse, higher SES populations.

Clinicians and researchers often do not assess medication adherence, perhaps because all methods have limitations (Gonzalez et al., 2011). Although technological advances may improve this (Driscoll et al., 2014), a single method is unlikely to overcome measurement error, and self-report will remain the most feasible option in most settings. It is also particularly well-suited for insulin self-administration where objective monitoring is difficult and cannot easily account for sliding-scale regimens. Self-reported adherence can also be as valid and can predict outcomes such as glycemic control as well as objective adherence measures (Gonzalez et al., 2013). Thus, reservations about the accuracy of self-report should not deter adherence assessment in clinical and research settings. Our results highlight benefits to assessing insulin adherence while providing a tool for future research on insulin adherence.

Acknowledgments

This research was funded with support from the Vanderbilt Clinical Translational Scientist Award (UL1TR000445) from the National Center for Advancing Translational Sciences. Dr. Osborn is supported by the National Institute of Diabetes and Digestive and Kidney Diseases (K01 DK087894 and R01 DK100694), as is Dr. Gonzalez (R18 DK098742 and R01 DK104845).

All authors are responsible for the reported research and approve the final submitted version. Author Chandra Y. Osborn is the grantor of this work and, as such has full access to all the data in the study and takes responsibility for the integrity of the data, the accuracy of the data analysis, and the decision to publish the manuscript. Dr. Osborn supervised all aspects of data collection, cleaning, and management, conducted analyses, interpreted the data, wrote the methods and results sections, and reviewed and edited the manuscript. Dr. Gonzalez guided the analyses, interpreted the data, wrote the abstract, introduction and discussion sections, and reviewed and edited the manuscript. The authors would like to acknowledge Cecilia C. Quintero, Lindsay S. Mayberry, Sahbina Ebba, Karen Calderon, Leo Cortes, Anne Crook, Carmen Mekhail, the Vine Hill Community Clinic personnel, and the patients for their contributions to this research.

References

Al-Qazaz H, Hassali MA, Shafie AA, et al. The eight-item Morisky Medication Adherence Scale MMAS: translation and validation of the Malaysian version. Diabetes Res Clin Pract. 2010; 90(2): 216–221. [PubMed: 20832888]

Baek RN, Tanenbaum ML, Gonzalez JS. Diabetes burden and diabetes distress: the buffering effect of social support. Ann Behav Med. 2014; 48(2):145–155. [PubMed: 24550072]

Balkrishnan R, Rajagopalan R, Camacho FT, et al. Predictors of medication adherence and associated health care costs in an older population with type 2 diabetes mellitus: a longitudinal cohort study. Clin Ther. 2003; 25(11):2958–2971. [PubMed: 14693318]

Chung WW, Chua SS, Lai PS, et al. The Malaysian Medication Adherence Scale (MALMAS): Concurrent validity using a clinical measure among people with type 2 diabetes in Malaysia. PLoS One. 2015; 10(4):e0124275. [PubMed: 25909363]

Cramer JA. A systematic review of adherence with medications for diabetes. Diabetes Care. 2004; 27(5):1218–1224. [PubMed: 15111553]

Cramer JA, Pugh MJ. The influence of insulin use on glycemic control: How well do adults follow prescriptions for insulin? Diabetes Care. 2005; 28(1):78–83. [PubMed: 15616237]

Davies MJ, Gagliardino JJ, Gray LJ, et al. Real-world factors affecting adherence to insulin therapy in patients with Type 1 or Type 2 diabetes mellitus: a systematic review. Diabet Med. 2013; 30(5):512–524. [PubMed: 23323988]

DeVellis, R. Scale Development. Theory and Applications. Newbury Park, CA: Sage Publications, Inc; 1991.

DiBonaventura M, Wintfeld N, Huang J, et al. The association between nonadherence and glycated hemoglobin among type 2 diabetes patients using basal insulin analogs. Patient Prefer Adherence. 2014; 8:873–882. [PubMed: 24971002]

Driscoll KA, Young-Hyman D. Use of technology when assessing adherence to diabetes self-management behaviors. Curr Diab Rep. 2014; 14(9):521. [PubMed: 25023214]

Egede LE, Gebregziabher M, Hunt KJ, et al. Regional, geographic, and ethnic differences in medication adherence among adults with type 2 diabetes. Ann Pharmacother. 2011; 45(2):169–178. [PubMed: 21304026]

Feldman BS, Cohen-Stavi CJ, Leibowitz M, et al. Defining the role of medication adherence in poor glycemic control among a general adult population with diabetes. PLoS One. 2014; 9(9):e108145. [PubMed: 25259843]

Gonzalez JS, Safren SA, Cagliero E, et al. Depression, self-care, and medication adherence in type 2 diabetes: relationships across the full range of symptom severity. Diabetes Care. 2007; 30(9): 2222–2227. [PubMed: 17536067]

Gonzalez JS, Schneider HE. Methodological issues in the assessment of diabetes treatment adherence. Curr Diab Rep. 2011; 11(6):472–479. [PubMed: 21956675]

Gonzalez JS, Schneider HE, Wexler DJ, et al. Validity of medication adherence self-reports in adults with type 2 diabetes. Diabetes Care. 2013; 36(4):831–837. [PubMed: 23204245]

Gonzalez JS, Shreck E, Psaros C, et al. Distress and type 2 diabetes-treatment adherence: A mediating role for perceived control. Health Psychol. 2015; 34(5):505–513. [PubMed: 25110840]

Graham J. Missing data analysis: making it work in the real world. Annu Rev Psychol. 2009; 60:549–576S. [PubMed: 18652544]

Graham J, Olchowski A, Gilreath T. How many imputations are really needed? Some practical clarifications of multiple imputation theory. Prev Sci. 2007; 8:206–213. [PubMed: 17549635]

Graham, J.; Schafer, J. On the performance of multiple imputation for multivariate data with small sample sizes. In: Hoyle, R., editor. Statistical Strategies for Small Sample Research. Thousand Oaks, CA: Sage; 1999. p. 1-29.

Ho PM, Rumsfeld JS, Masoudi FA, et al. Effect of medication nonadherence on hospitalization and mortality among patients with diabetes mellitus. Arch Intern Med. 2006; 166(17):1836–1841. [PubMed: 17000939]

Houle J, Beaulieu MD, Chiasson JL, et al. Glycaemic control and self-management behaviours in Type 2 diabetes: results from a 1-year longitudinal cohort study. Diabet Med. 2015; 32(9):1247–1254. [PubMed: 25581545]

Kennedy L, Herman WH. Glycated hemoglobin assessment in clinical practice: comparison of the A1cNow point-of-care device with central laboratory testing (GOAL A1C Study). Diab Tech Ther. 2005; 7:907–912.

Kripalani S, Risser J, Gatti ME, et al. Development and evaluation of the Adherence to Refills and Medications Scale (ARMS) among low-literacy patients with chronic disease. Value Health. 2009; 12(1):118–123. [PubMed: 19911444]

Lerman I, Diaz JPM, Ibarguengoitia MER, et al. Nonadherence to insulin therapy in low-income, type 2 diabetic patients. Endocrine Practice. 2009; 15(1):41–46. [PubMed: 19211396]

Loehlin, JC. Latent variable models: An introduction to factor, path, and structural equation analysis. Psychology Press; 2012.

Mayberry LS, Gonzalez JS, Wallston KA, et al. The ARMS-D out performs the SDSCA, but both are reliable, valid, and predict glycemic control. Diabetes Res Clin Pract. 2013; 102(2):96–104. [PubMed: 24209600]

Mayberry LS, Osborn CY. Empirical validation of the information-motivation-behavioral skills model of diabetes medication adherence: a framework for intervention. Diabetes Care. 2014; 37(5):1246–1253. [PubMed: 24598245]

Morisky DE, Ang A, Krousel-Wood M, et al. Predictive validity of a medication adherence measure in an outpatient setting. J Clin Hypertens (Greenwich). 2008; 10(5):348–354. [PubMed: 18453793]

Nunnally, JIB. Psychometric Theory. 3. New York: McGraw-Hill; 1994.

Osborn CY, Cavanaugh K, Wallston KA, et al. Health literacy explains racial disparities in diabetes medication adherence. J Health Commun. 2011; 16(Suppl 3):268–278. [PubMed: 21951257]

Osborn CY, Mayberry LS, Wagner JA, et al. Stressors may compromise medication adherence among adults with diabetes and low socioeconomic status. West J Nurs Res. 2014; 36(9):1091–1110. [PubMed: 24569697]

Osborn CY, Patel KA, Liu J, et al. Diabetes and co-morbid depression among racially diverse, low-income adults. Ann Behav Med. 2011; 41(3):300–309. [PubMed: 21104461]

Peyrot M, Barnett AH, Meneghini LF, et al. Factors associated with injection omission/non-adherence in the Global Attitudes of Patients and Physicians in Insulin Therapy study. Diabetes Obes Metab. 2012a; 14(12):1081–1087. [PubMed: 22726104]

Peyrot M, Barnett AH, Meneghini LF, et al. Insulin adherence behaviours and barriers in the multinational Global Attitudes of Patients and Physicians in Insulin Therapy study. Diabet Med. 2012b; 29(5):682–689. [PubMed: 22313123]

Peyrot M, Rubin RR, Kruger DF, et al. Correlates of insulin injection omission. Diabetes Care. 2010; 33(2):240–245. [PubMed: 20103556]

Piette JD, Wagner TH, Potter MB, et al. Health insurance status, cost-related medication underuse, and outcomes among diabetes patients in three systems of care. Med Care. 2004; 42(2):102–109. [PubMed: 14734946]

Raghunathan T, Lepkowski J, van Hoewyk J, et al. A multivariate technique for multiply imputed mising values using a sequence of regression models. Surv Methodol. 2001; 27:85–95.

Ross SA, Tildesley HD, Ashkenas J. Barriers to effective insulin treatment: the persistence of poor glycemic control in type 2 diabetes. Curr Med Res Opin. 2011; 27(Suppl 3):13–20. [PubMed: 21942467]

Rubin RR, Peyrot M, Kruger DF, et al. Barriers to insulin injection therapy: patient and health care provider perspectives. Diabetes Educ. 2009; 35(6):1014–1022. [PubMed: 19934459]

Schectman JM, Nadkarni MM, Voss JD. The association between diabetes metabolic control and drug adherence in an indigent population. Diabetes Care. 2002; 25(6):1015–1021. [PubMed: 12032108]

Toobert D, Hampson S, Glasgow R. The Summary of Diabetes Self-Care Activities measure: results from 7 studies and a revised scale. Diabetes Care. 2000; 23:943–950. [PubMed: 10895844]

van Buuren S, Boxhuizen H, Knook D. Multiple imputation of missing blood pressure covariates in survival analysis. Stat Med. 1999; 18:681–694. [PubMed: 10204197]

Ware J, Harrington D, Hunter D, et al. Missing data. New Engl J Med. 2012; 367(14):1353–1354.

Wilson VanVoorhis CR, Morgan BL. Understanding power and rules of thumb for determiing sample sizes. Tutorials in Quantitative Methods for Psychology. 2007; 3(2):43–50.

Wong MC, Wu CH, Wang HH, et al. Association between the 8-item Morisky medication adherence scale (MMAS-8) score and glycaemic control among Chinese diabetes patients. J Clin Pharmacol. 2014

Table 1

Participant Characteristics

N=144	M ± SD or n (%)
DEMOGRAPHIC CHARACTERISTICS	
Age, years	50.7 ± 11.9
Gender	
Male	56 (38.9)
Female	88 (61.1)
Race	
Caucasian/White	49 (34.0)
African American/Black	84 (58.3)
Other race	11 (7.6)
Hispanic ethnicity	10 (6.9)
Education, years	12.0 ± 2.9
Income	
≤$10,000	67 (46.5)
$10,000 – $14,999	39 (27.1)
$15,000 – $19,999	21 (14.6)
≥$20,000	17 (11.8)
Insurance Status	
Private insurance	11 (7.6)
Public insurance	65 (45.1)
Uninsured	68 (47.2)
DIABETES CHARACTERISTICS	
Body mass index	36.4 ± 8.7
Duration of diagnosed diabetes, years	10.0 ± 7.6
Type of diabetes medications	
Insulin only	71 (49.3)
Insulin + oral agents	73 (50.7)
MEDICATION ADHERENCE	
MIAS	5.3 ± 1.9
ARMS-D total	38.9 ± 4.5
ARMS-D refill adherence	14.0 ± 2.2
ARMS-D medication taking	24.9 ± 3.1
SDSCA-MS	6.0 ± 1.7
SDSCA-IS	6.0 ± 1.9
GLYCEMIC CONTROL	
$HbA_{1C,}$ % (mmol/mol)	9.0 ± 2.1 (75 ± 23)
Suboptimal (≥7.0% or 53 mmol/mol)	122 (84.7)
Optimal (<7.0% or 53 mmol/mol)	22 (15.3)

Notes. M=mean, SD=standard deviation, MIAS=Morisky Insulin Adherence Scale, ARMS-D=Adherence to Refills and Medications Scale for Diabetes, HbA_{1C}=hemoglobin A1C, SDSCA-MS=Summary of Diabetes Self-Care Activities medications subscale, SDSCA-IS=Summary of Diabetes Self-Care Activities insulin score

Table 2

Factor loadings of the eight-item Morisky Insulin Adherence Scale (MIAS) and the percentage of participants who endorsed each item.

Item	Factor Loadings	% Endorsed
1. Do you sometimes forget to take your insulin?	0.57	59.0
2. People sometimes miss taking their insulin or take less than prescribed for reasons other than forgetting. Thinking over the past two weeks, were there any days when you did not take all your prescribed insulin?	0.59	45.8
3. Have you ever cut back or took less of your insulin without telling your doctor, because you felt worse when you took it or wanted to avoid other negative consequences of taking insulin?	0.52	23.6
4. When you travel or leave home, do you sometimes forget to bring along your insulin?	0.55	29.9
5. Did you take all your insulin as prescribed yesterday? (reverse-coded)	0.48	20.8[†]
6. When you feel like your diabetes is under control, do you sometimes take less of your insulin than prescribed?	0.48	21.5
7. Taking insulin every day is a real inconvenience for some people. Do you ever feel hassled about sticking to your insulin regimen?	0.60	47.9
8. How often do you have difficulty remembering to take all your insulin?	0.68	42.5

Notes.

[†]79.2% of participants did take all their insulin as prescribed yesterday. Use of the ©MMAS is protected by US copyright laws. Permission for use is required. A licensure agreement is available from: Donald E. Morisky, ScD, ScM, MSPH, Professor, Department of Community Health Sciences, UCLA School of Public Health, 650 Charles E. Young Drive South, Los Angeles, CA 90095–1772, dmorisky@ucla.edu.

Table 3

Predicting self-rated health, emergency room visits and HbA_{1C} with the Morisky Insulin Adherence Scale (MIAS).

	Morisky Insulin Adherence Scale (MIAS)									
	Unadjusted Models				***Adjusted Models[a]***					
Outcomes	**b**	**β**	***p***	**% variance explained (R^2)**	**b**	**β**	***p***	**% variance explained (R^2)**	**Incremental R^2 †**	**% increase in R^2 ††**
Self-rated Health	0.09	0.19	0.023	3.5	0.08	0.16	0.057	15.3	2.3 ‡	18.0
Emergency Room Visits	−0.21	−0.34	0.001	11.5	−0.21	−0.34	0.001	26.8	11.0 **	69.5
HbA_{1C}	−0.30	−0.27	0.001	7.4	−0.29	−0.26	0.001	22.7	6.6 ***	41.3

Notes.

[a]Covariates age, gender, race, income, education, insurance status, duration of diagnosed diabetes, and BMI; b=unstandardized regression coefficients, β=standardized regression coefficients, HbA_{1C}=hemoglobin A_{1C}, *p*=probability value,

‡ *p*=0.055,

* *p*<0.05,

** *p*<0.01,

*** *p*<0.001.

† Unique variance explained by the MIAS in adjusted models.

†† Percent increase in the variance explained by the MIAS measure in adjusted models; [(incremental R^2) / (covariates only R^2)].

Table 4

Hierarchical multiple regression models presenting the unique contribution of the MIAS on HbA_{1C}.

	ARMS-D			SDSCA-MS			SDSCA-IS		
Predictors	**Step 1 ARMS-D**	**Step 2 MIAS**	**Step 3 a priori covariates**	**Step 1 SDSCA-MS**	**Step 2 MIAS**	**Step 3 a priori covariates**	**Step 1 SDSCA-IS**	**Step 2 MIAS**	**Step 3 a priori covariates**
Step 1 ΔR^2	.09***			.03≠			.02≠		
Adherence Measure β	−.30***	−.21*	−.09	−.16*	−.05	−.10	−.15≠	−.07	−.11
Step 2 ΔR^2		.01			.05**			.05**	
MIAS β		−.13	−.20≠		−.25**	−.22**		−.25**	−.22**
Step 3 ΔR^2			.13**			.16**			.16**
Age β			−.27**			−.30***			−.29***
Gender β			−.002			−.02			−.02
Race β			.19*			.20*			.20**
Education β			.04			−.06			−.07
Income β			.005			.02			.02
Insurance (1=Public) β			−.09			−.09			−.08
Insurance (1=Private) β			.06			.07			.07
Duration of diagnosed DM β			.14			.15≠			.15≠
BMI β			−.14≠			−.16≠			−.17*
Total R^2	.09	.10	.23	.03	.08	.23	.02	.08	.23

Notes. MIAS=Morisky Insulin Adherence Scale, HbA_{1C}=hemoglobin A_{1C}, ARMS-D=Adherence to Refills and Medications Scale for Diabetes, SDSCA-MS=Summary of Diabetes Self-Care Activities medications subscale, SDSCA-IS=Summary of Diabetes Self-Care Activities insulin score, β =standardized regression coefficients, HbA_{1C}=hemoglobin A_{1C}, *p*=probability value,

≠ *p*<0.09,

* *p*<0.05,

** *p*<0.01,

*** *p*<0.001