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Comparison of Malaria Control Interventions in Angola

Ferdinand Nsengimana*

Kajo-Keji Health Sciences Institute, Juba, South Suda
*Corresponding author: ferdinand.nsengimana@gmail.com

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Abstract **Background:** There is lack of evidence on which of the two highly recommended malaria prevention methods, mosquito bednets and indoor residual spraying, is more effective than the other. **Objective**: To compare the effectiveness of mosquito bednets and indoor residual spraying in the prevention of malaria. Based on the Health Belief Model, the research questions tested whether there is any relationship between the use of mosquito bednet or the use of indoor residual spraying and contracting malaria. **Materials and Methods:** Using a quantitative research design, secondary data from the 2011 Angola malaria indicator survey were analyzed using IBM/SPSS version 24. Chi-square for association, logistic regression, and multinomial logistic regression tests were conducted with significance level set at p value of ≤ .05. **Results:** From 578 children who slept under mosquito bednet the night before data collection 9.2% (n = 28) had malaria compared to 5.7% (n = 31) of 331 children who did not sleep under mosquito bednet. However, there was no statistically significant association between the use of mosquito bednet and having malaria x^2 (1) = 3.324, p = .068, odds = .613, 95% CI [.361, 1.042]. From 2139 children who lived in dwellings that were not sprayed against mosquito 13.2% (n = 250) had malaria compared to 5.6% (n = 7) of 133 children who lived in sprayed dwellings. Furthermore, there was a statistically significant association between the use of indoor residual spraying and having malaria, x^2 (1) = 5.152, p = .023, odds = 2.382, 95% CI [1.100, 5.158]. **Conclusion:** The malaria prevention programs in Angola should focus on indoor residual spraying. It is recommended that all households in Angola malaria prone areas should be regularly sprayed.

Keywords: *malaria, mosquito bednet, indoor residual spraying*

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1. Introduction

Some successes in malaria reduction can be seen. Globally, there has been a decrease of 17% of malaria cases and 26% of malaria specific deaths between 2000 and 2010 [1]. The number of malaria cases in Africa decreased by 30% between 2004 and 2010 [2]. However, this decrease is unlikely to be due to the newly tested malaria vaccine as this vaccine's effect tends to decline over time and with increased malaria exposure [3] or the vaccine seems to offer only modest protection against malaria [4]. Some researchers have attributed the decrease in malaria cases to the increased use of insecticide treated bednets, indoor residual spraying, and anti-malaria drugs [5,6].

Despite the decrease in malaria cases, almost half of the world's population is at risk of malaria [7]. In 2013 alone, 198 million people got infected with malaria and half a million people died due to malaria [8]. Sub-Saharan Africa seems to be the most affected region with 89% of all malaria cases and 91% of all malaria deaths coming from this region [7,9].

The two highly recommended malaria prevention methods are insecticide-treated mosquito nets and indoor residual spraying [7]. It seems to be unclear whether it would be more beneficial to use insecticide treated bednets and indoor residual spraying in combination or separately [10]. While some researchers did not find any benefit in combining insecticide treated bednets and indoor residual spraying [11,12,13,14] other researchers have recommended using both methods [15] while others have concluded that combining both methods was beneficial [16]. There are other factors that may be worth considering such as the cost of each method, usability, and side effect.

The median cost of protecting one person for one year against malaria is three times higher for indoor residual spraying ($6.70), than insecticide treated bednets, ($2.20) [17]. On one hand, treated bednets are only effective when people in areas at risk for malaria sleep under a bednet [7]. This may not be always a case. In fact, some researchers found that only a quarter of pregnant women who own mosquito nets slept under a net [18]. Furthermore, people do not use mosquito nets because they do not know how to use them but because they do not fear malaria as result of lived experience [19]. Other people may use mosquito nets just to avoid the nuisance of mosquito bites [20]. On the other hand, indoor residual spraying may require several spraying during malaria seasons and is only effective if at least 80% of houses have been sprayed [7]. While mosquitoes are likely to become resistant to chemicals used to treat mosquito nets [21,22,23]

individuals who applied the indoor residual spraying as well as inhabitants of sprayed houses were having higher plasma levels of the sprayed chemicals that are potentially harmful to human health [24].

Despite the cost differences, usability, resistance, and possibility of used chemicals being potentially harmful to human health, insecticide treated bednets and indoor residual spraying have been in use either separately or in combination without evidence of which of these two methods is more effective in preventing malaria. Some researchers assessed the effectiveness on indoor residual spraying but did not compare this method with any other malaria prevention methods [25]. Therefore, there is a need to compare the effectiveness of mosquito bednets and indoor residual spraying in the prevention of malaria. Knowing which of the two malaria prevention methods is more effective would ensure efficient interruption of the chain of infection and thus reducing the burden of malaria to individuals in particular and to the community in general.

2. Materials and Methods

2.1. Study Design

This was a cross-sectional quantitative study that used secondary data of 2011 Angola malaria indicator survey from Demographic and Health Surveys (DHS) Program.

2.2. Population

The target population for this study comprised of all households in Angola. There were about 2,769,000 privately owned households [26].

2.3. Sampling Procedure

Four regional domains namely hyperendemic region, mesoendemic stable region, mesoendemic unstable region, and Luanda province were identified. In each domain 60 clusters were selected with a total of 96 urban clusters and 144 rural clusters. Clusters were selected in three stages using a stratified design. In first stage communes in each province were stratified as urban or rural and then selected with a probability proportional to each domain's population size. In second stage clusters were selected with a probability proportional to the selected communes' size while in the third stage about equal number of households from each cluster's household listing was selected to be interviewed. In total, 8,806 households were selected of which 8,030 were interviewed. In each selected household, all women aged 15 to 49 years were selected for personal interview and all children aged 6 to 59 months were selected for malaria and anemia testing. Field work started in January 2011 and ended in May 2011 [27].

2.4. Sample Size

The required sample size for this research was determined using a freely online accessible software G*Power 3.0.10. For this study the test family was x^2 *tests*, the statistical test was *goodness-of-fit tests: Contingency tables*, and the types of power analysis was *A priori: Compute required sample size – given α, power, and effect size*. G*Power gives three options about the effect size: small (0.1), medium (0.3), and large (0.5). Large effect can be easily identified even with a small sample size whereas small effect is not only difficult to identify but could also be of little scientific importance [28]. However, considering the seriousness of malaria and its impact on the population, the effect size was set to small (0.15). If a small effect cannot be detected, then this would be close to there being no effect at all, unlike when failure to detect larger effect would not exclude the possibility of there being a smaller effect. Alfa and power were set at .5 and .95 respectively. Type I error was less likely as the effect in malaria prevention exists when mosquito nets are used [29], or indoors are sprayed [30] or a combination of both mosquito nets and indoor residual spraying [16]. In such a case, the power could be set higher to minimize the chances of the only highly possible type II error [31]. The degree of freedom was computed using the formula *df = number of columns – 1 multiplied by the number of rows – 1* [32]. There were three columns and two rows and thus *df = 2*. Using these data G*Power calculated a total sample size of 687.

2.5. Archival Data

Secondary data from Demographic and Health Surveys database were used. This database stores and provides on request data from nationally-representative household surveys from several countries in areas such as population, health, and nutrition [33]. To have access to and use data from this database, one needs to register online with the Demographic and Health Surveys Program. The registration process requires providing information such as researcher's names, address, associated institution, and personal contact numbers as well as the title, purpose, and brief description of the study for which data are being requested. Access and permission to access the needed data was granted on November 23, 2015.

2.6. Variables and Data Manipulation

The original data set consisted of 317 variables of which only seven variables were relevant for this study. The dataset was filtered using as inclusion criteria the availability of information on final result of malaria from blood smear test. Furthermore, all cases with missing value on any of the variables were deleted listwise. This left a sample size of 909 respondents for research question (RQ) 1 and 2272 respondents for RQ 2.

2.7. Data Analysis Plan

The Statistical Program for the Social Sciences (SPSS) version 24, a statistical application developed by IBM, was used to analyze the study data. Summary statistics were computed for the variables being analyzed. Considering that the intention was to identify the association or relationship between variables in order to refute or validate the research hypotheses, Chi-square was used with cross-tabulation to test the association between

the independent variable use of bednet in RQ 1 and the use of indoor residual spraying in RQ 2 and the dependent variable final result of malaria from blood smear test. The logistic regression tested the predictive effect of the independent variables on the dependent variable. To facilitate the interpretation of the logistic regression values, odds ratio were computed. The multinomial logistic regression allowed testing the association between three or more variables. All statistical tests were conducted at 5% significance level, 95% Confidence Interval, and a *p*- value of .05.

2.8. Threat to Validity

This study was not about establishing a causal relationship, thus threats to internal validity might not have been an issue. Furthermore, external validity might not be an issue either considering that the study was cross sectional and therefore the researcher aimed at providing a correlational and predictive relationship among variables. In this study there were no related survey instruments as secondary data was used. Construct validity was therefore established through hypothesis testing. However, threats to validity include human error that might have existed during the capture and recording of results and demographic and other information. There is also the possibility of information bias.

3. Results

The first RQ was "What is the relationship between the use of mosquito bednet and contracting malaria?" To answer this question all cases for variable *final result of malaria from blood smear test* with values other than *0 = Negative* or *1 = Positive* as well as all cases for variable *children under 5 slept under bednet last night* with values other than *0 = No* or *1 = All children* were deleted. Furthermore all cases for variable *someone sprayed interior walls* with values other than *0 = No* were deleted. This deletion resulted in a sample size of 909 subjects, which is still good enough to run statistical tests since G*Power 3.0.10 estimates a sample size of 903 at an effect size of .12 with a degree of freedom equal to 1. When assessing for confounders in the logistic regression, variable *Highest educational level* had 11.3% missing data and was entirely excluded from analysis. Variable *Number of household members* was recoded to variable *Number of household members CAT*, with categories *1 = Low* for household with 2 to 4 members, *2 = Medium* for households with 5 to 7 members, and *3 = High* for households with 8 or more members.

The sample comprised of under-fives whose malaria blood test results were available. There was no specification of particular subjects' age or sex. A chi-square test for association between children sleeping under a mosquito bednet and final result of malaria from blood smear test was performed using a sample size of $n = 909$. No cell had expected count less than 5. As shown in Table 1, there was no statistically significant association between children sleeping under a mosquito bednet and final result of malaria from blood smear test, x^2 (1) = 3.324, $p = .068$, odds = .613, 95% CI [.361, 1.042]. The measure of effect between children sleeping under a mosquito bednet and final result of malaria from blood smear test further shows the lack of statistically significant association, $V = .060$, $p = .068$.

There were 331 children who did not sleep under mosquito bednet while 578 did sleep under mosquito bednet the night prior to data collection. From those who did not sleep under a mosquito bednet 28 (9.2%) had malaria positive blood result compared to 31 (5.7%) from those who slept under bednet, a difference of 3.5%.

Table 1. Chi-Square Results for Sleeping under Mosquito Net and Final Malaria Result

	Value	*P*	95%CI	
			Lower	Upper
Pearson x^2	3.342	.068		
Df	1			
V	.060	.068		
Odds Ratio	.613		.361	1.042

The first model in the logistic regression included variable *Children under 5 slept under bednet last night Yes No*, as a predictor. This model was not statistically significant, $x^2(1) = 0.322$, $p = .073$. The model could explain 0.9% (Nagelkerke R^2) of the variances, in having malaria. Overall, the model could correctly classify 93.5% of cases. As shown in Table 2, the Wald statistics, Wald = .327, $p = .071$, also support these results showing that sleeping under a mosquito bednet the previous night does not predict having malaria.

The second model, which included variable *Types of place of residence,* as predictor was statistically significant, $x^2(2) = 48.153$, $p = <.001$. The model could explain 13.5% (Nagelkerke R^2) of the variances in having malaria. Overall, the model could correctly classify 93.5% of cases. As shown in Table 3, the Wald statistics, Wald = 20.701, $p = <.001$, also support these results showing that the place of residence does predict having malaria.

The third model, which included variable *wealth index* as predictor was statistically significant, $x^2(6) = 68.708$, $p = <.001$. The model could explain 19.1% (Nagelkerke R^2) of the variances in having malaria. Overall, the model could correctly classify 93.5% of cases. As shown in Table 4, the Wald statistics of some categories in the wealth index does not predict reporting having malaria while others do.

The fourth model included variable *Number of households members CAT*. Although the model was statistically significant, $x^2(8) = 73.170$, $p = <.001$, adding this variable to the model had no significant effect, $x^2(2) = 4.462$, $p = .107$. The model could explain 20.3% (Nagelkerke R^2) of the variances in having malaria. Overall, the model could correctly classify 93.5% of cases. As shown in Table 5, the Wald statistics of different categories also supported these results showing that the number of household members does not predict having malaria. However, this model indicates that the odds of a person living in rural area having malaria are 9.49 times higher than a person living in urban area.

These logistic regression results indicate that the type of place of residence and being in the richer or richest wealth index categories are the only significant confounders. When these confounding variables were analyzed together

with the predictor variable Children under five slept under bednet last night Yes No, adding interaction terms such as using a mosquito bednet by type of place of residence, using a mosquito bednet by wealth index, or using a mosquito bednet by place of residence by wealth index had no significant effect to the models.

The second RQ was "What is the relationship between the use indoor residual spraying and contracting malaria?" To answer this question all cases for variable *Someone sprayed interior walls,* with values other than *0 = No* or *1 = Yes* were deleted while all cases with values other than *3 = No bednet in household* for variable *children under 5 slept under bednet last night*, were deleted. When assessing for confounders in the logistic regression, variable *Highest educational level* had about 18% missing data and was entirely excluded from analysis. Variable *Number of household members* was recoded as for RQ 1.

The sample comprised of under-five children. There was no specific age or sex for subjects. A chi-square test for association between the use of indoor residual spraying and having malaria was performed using a sample size of n = 2272. No cell had expected count less than 5. As shown in Table 6, there was a statistically significant association between the use of indoor residual spraying and having malaria, x^2 (1) = 5.152, p = .023, odds = 2.382, 95% CI [1.100, 5.158]. The measure of effect between the use of indoor residual spraying and having malaria shows the presence of statistically significant association, V = .048, p = .023. Furthermore, 2139 children lived in dwellings that were not sprayed against mosquitoes while 133 children lived in sprayed dwellings. From those who lived in non-sprayed dwellings, 250 (13.2%) had malaria compared to 7 (5.6%) from those who lived in sprayed dwellings.

As for RQ 1, a regression test was conducted to control for confounding factors such as area of residence, wealth index, and number of household members. The first model in the logistic regression included variable *Someone sprayed interior walls*, as a predictor. This model was statistically significant, x^2 (1) = 6.213, p = .013. The model could explain 0.5% of the variances (Nagelkerke R^2) in having malaria. Overall, the model could correctly classify 88.7% of cases. As shown in Table 6, the Wald statistics, Wald = 4.851, p = .028, also support these results showing that living in a dwelling that was sprayed predicted having malaria.

Variable *Type of place of residence* was added as predictor in the second model. This model was statistically significant, x^2 (2) = 120.072, p = <.001. The model could explain 10.2% (Nagelkerke R^2) of the variances in having malaria. Overall, the model could correctly classify 88.7% of cases. However, as shown in Table 7, only the Wald statistic for the place of residence variable remained statistically significant.

Variable *Wealth index* was added as predictor in the third model. This model was statistically significant, x^2 (6) = 142.772, p = <.001. The model could explain 12% (Nagelkerke R^2) of the variances in having malaria. Overall, the model could correctly classify 88.7% of cases. However, the Wald statistics for the different categories of wealth index were not statistically significant. This indicates that wealth index is not a statistically significant predictor of having malaria.

Variable *Number of household members* was added as predictor in the fourth model. Although this model was statistically significant, x^2 (8) = 143.772, p = <.001 adding this variable to the model did not make significant contribution, x^2 (2) = .679, p = .712. The model could explain 12.1% (Nagelkerke R^2) of the variances in having malaria. Overall, the model could correctly classify 88.7% of cases. Furthermore, the Wald statistics for the different categories in number of household members as well as the other predictors were not statistically significant. This indicates that the number of household members is not a statistically significant predictor of malaria.

Table 2. Predicting Malaria based on Bednet Use

							95% C.I. for Exp(B)	
	B	S.E.	Wald	Df	Sig.	Exp(B)	Lower	Upper
Slept under bednet last night Yes No(1)	-.486	.270	.327	1	.071	.613	.361	1.042
Constant	-2.382	.198	145.373	1	.000	.092		

Table 3. Predicting Malaria based on Place of Residence

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for Exp(B)	
							Lower	Upper
Place of residence(1)	2.716	.597	20.701	1	.000	15.126	4.694	48.744
Constant	-4.531	.596	57.816	1	.000	.011		

Table 4. Predicting Malaria based on Wealth Index and Bednet Use

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for Exp(B)	
							Lower	Upper
Place of residence(1)	2.221	.620	12.818	1	.000	9.219	2.733	31.101
Wealth index			17.264	4	.002			
Wealth index(1)	-.576	.453	1.617	1	.203	.562	.232	1.365
Wealth index(2)	-.082	.388	.045	1	.832	.921	.431	1.969
Wealth index(3)	-1.111	.457	5.896	1	.015	.329	.134	.807
Wealth index(4)	-1.869	.551	11.526	1	.001	.154	.052	.454
Constant	-3.510	.700	25.180	1	.000	.030		

Table 5. Predicting Malaria based on Number of Household Members, Wealth Index, and Bednet Use

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for Exp(B)	
							Lower	Upper
Place of residence(1)	2.250	.621	13.114	1	.000	9.486	2.807	32.057
Wealth index			18.410	4	.001			
Wealth index(1)	-.586	.459	1.634	1	.201	.556	.226	1.367
Wealth index(2)	-.090	.393	.052	1	.820	.914	.423	1.975
Wealth index(3)	-1.098	.460	5.707	1	.017	.334	.136	.821
Wealth index(4)	-1.989	.556	12.811	1	.000	.137	.046	.407
Number of household members CAT			4.048	2	.132			
Number of household members CAT(1)	.707	.375	3.554	1	.059	2.028	.972	4.231
Number of household members CAT(2)	.777	.446	3.041	1	.081	2.175	.908	5.208
Constant	-4.159	.777	28.618	1	.000	.016		

Table 6. Chi-Square Results for Using Indoor Residual Spraying and Having Malaria

	Value	P	95% CI	
			Lower	Upper
Pearson x^2	5.152	.023		
Df	1			
V	.048	.023		
Odds Ratio	2.382		1.100	5.158

Table 7. Predicting Malaria based on Place of Residence and Sprayed Dwelling

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for Exp(B)	
							Lower	Upper
Dwelling sprayed (1)	-.729	.400	3.331	1	.068	.482	.220	1.055
Type of place of residence(1)	2.158	.270	63.775	1	.000	8.656	5.096	14.700
Constant	-3.815	.261	212.913	1	.000	.022		

Table 8. Predicting Malaria based on Dwelling Sprayed and Place of Residence

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for Exp(B)	
							Lower	Upper
Type of place of residence (1)	2.189	.279	61.432	1	.000	8.927	5.164	15.432
Dwelling sprayed (1)	-.181	1.044	.030	1	.862	.834	.108	6.461
Type of place of residence(1) by Dwelling sprayed (1)	-.620	1.130	.301	1	.583	.538	.059	4.925
Constant	-3.844	.270	202.538	1	.000	.021		

These logistic regression results indicate that type of place of residence, as was in *RQ 1*, is the only significant confounder. When this confounding variable was analyzed together with the predictor variable *Dwelling sprayed*, the model was statistically significant, x^2 (3) = 120.337, p = <.001. The model could explain 10.2% (Nagelkerke R^2) of the variances in having malaria. Overall, the model could correctly classify 88.7% of cases. As shown in Table 8, this model indicated that only the type of place of residence, Wald = 61.432, p = <.001, odds = 8.927, 95% CI [5.164, 15.432], could predict having malaria. The odds of a person living in rural area having malaria are 8.93 times higher than a person living in urban area.

4. Discussion

About the use bed net, both the chi-square test for association and the logistic regression test revealed no statistically significant association between children sleeping under a mosquito bed net and the result of malaria from blood smear test. Other researchers have reported that the risk of contracting malaria is not less for children who own a mosquito bednet than those who do not [34] while others found a double mean malaria prevalence rate among those who used insecticide treated bednets alone compared to those who used both insecticide treated bednets and indoor residual spraying [13,35]. However, while other researchers found no significant difference in clinical malaria among children who used mosquito bednets alone and those who combined indoor residual spraying and mosquito bednets [36] some research findings indicate that bednet users report lower incidence of malaria compared to non-users [37].

One factor that could have led to current findings could be the way the original variables were constructed. The independent variable was: Children under 5 slept under bednet last night; while the dependent variable was: Final result of malaria from blood smear test. The incubation period for malaria is 7 days or longer [8,38]. It could be that a child did not sleep under a bednet last night but has been sleeping under one all the other previous nights, or slept under bednet only last night but not before. In the former, a child with malaria could be classified as non-user while they were using bednet at the time of infection. In the later situation, one could be classified as having fever in the last previous two weeks and as a bednet user while the infection happened before the person starts using a bednet.

Another factor could be the biting behavior of mosquitoes. Bednet could be protective for people who

sleep under one but this protection is only limited to the sleeping time. It is a common practice to find people socializing whether inside or outside the house for some time in evening before going to bed and mosquito bites can happen during this time. A study on mosquito bites indicates that 72% of bites on humans occurred in the outdoors while 76% of these bites occurred before 21h00 (9:00 PM) [39]. Some of the bites can even happen during broad daylight [40]. However, there seem to be no clarity on whether outdoor bites are associated with malaria transmission or not. Some researchers found no association between having malaria and outdoor mosquito bites [41] while others concluded that the outdoor transmission level was considerably high [42].

About the use of indoor residual spraying, both the chi-square test for association and the logistic regression test revealed a statistically significant association between children living in sprayed dwelling and having malaria. In a mathematical modeling study, indoor residual spraying alone was found to be up to ten times more effective than bednet use alone [43]. Other researchers have reported low malaria prevalence in sprayed compared to non-sprayed areas [30,44,45,46,47]. The low malaria prevalence rate in sprayed areas could be associated to the fact that the sprayed chemicals will remain effective for some period without the household occupants being required to do anything further. However, indoor residual spraying does not prevent mosquitoes from entering the sprayed house [48] and eventually taking a bite, nor does it prevent the outdoor biting. This could explain the small though significant difference of malaria prevalence among those living in sprayed dwellings (5.6%) to those living in non-sprayed dwellings (13.2%).

Limitations of the Study: Since secondary data were used, limitations associated with the use of secondary data may apply to this study. For instance, some subjects had incomplete or missing data for the current study. Some data format, level of measurement, and labelling were different from what was suitable for this study. This required additional data manipulation which could lead to errors and therefore jeopardizing the validity of the study results. To mitigate this possibility of errors, the researcher dropped all cases which used both methods or had missing or incomplete data. The data used in this study were collected in 2011. Although these were the latest available data, it could be that the current prevalence of malaria has varied during this time interval. One of the variables was *Children under 5 slept under mosquito bed net last night*. The way this variable is constructed does not consider the fact that malaria incubation period goes up to 14 day, thus, possibility of misclassifying cases as bednet users where in fact the infection happened before they start using bednets or as non-bednet users while the infection happened when in fact they were using a bednet.

5. Conclusions

Malaria is a common problem in Angola as well as in other parts of the world. Among several malaria prevention methods the two highly recommended methods are the use of mosquito bednets and indoor residual spraying. This study aimed at comparing these two highly recommended malaria prevention methods. The results of this study indicate that indoor residual spraying is more effective than mosquito bednets when used separately. Thus, households in malaria prone areas should be sprayed in addition to any other preferred malaria prevention method if any.

Ethical Consideration

Secondary data from Demographic and Health Surveys Program were used for this study. Although the datasets were publicly available, registration had to be made on the program's website and full name, associated institution, address, and contact details as well as the proposed research title, purpose, and a brief description of the study were provided. An assurance that the data will not be used for purpose other than the one stated and that the data will not be shared with other researchers without prior authorization had to be guaranteed. A written authorization to use the requested dataset was given on November 23, 2015. The data sets did not contain any identifier of study subjects. A study proposal was submitted to and approved by the Institutional Review Board at Walden University.

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Conflict of Interest Statement

The author has no competing interests.

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