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Factors associated with physical condition of insecticide treated bed nets in Senegal

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Epidemiology

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# Factors associated with physical condition of insecticide treated bed nets in Senegal

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Bachelor of Science

The Ohio State University

2012

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An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

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## Abstract

Factors associated with physical condition of insecticide treated bed nets in Senegal

By Emily B. Cason

**Background:** Insecticide treated nets (ITNs) are widely used to prevent malaria transmission. Net integrity decreases over time with use, and nets with holes are less effective at preventing malaria transmission. There is a need to better understand what factors contribute to the deterioration of nets so that strategies can be implemented to prevent a loss in protection from malaria.

**Methods:** A dataset collected by a Peace Corps Volunteer in Senegal during activities to promote net care and repair was used to examine the associations between several ITN care and use practices and five measures of ITN integrity. Multivariate linear and logistic models were constructed and estimates for the associations between the care and use factors and the ITN integrity outcomes were obtained.

**Results:** In three of the five models, prior repairs to the net were significantly associated with worse ITN integrity. Greater numbers of children under the age of five and greater numbers of children between the ages of 6 and 14 sleeping under the net were both associated with increased odds of having at least one hole in the net. Frequency of net washing was not significantly associated with net integrity in any of the final models.

**Conclusions:** The strong associations between prior repairs to the net and poor ITN condition may be indicative of a potential lack of proper net repair practices. ITN repair should be encouraged in order to maintain net effectiveness for as long as possible. Some factors that were expected to be strongly associated with ITN integrity outcomes were not significantly associated in this study. Further research is needed to better understand the ways in which net integrity can be maintained.

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# INTRODUCTION

Mosquito-borne diseases cause high levels of morbidity and mortality worldwide (1). Diseases transmitted by a mosquito vector include malaria, yellow fever, West Nile virus, Chikungunya, Dengue fever, Rift Valley fever, and Japanese encephalitis (2-4). In Senegal, malaria is an important cause of death, especially for children under the age of five (5, 6). All of Senegal's population, or approximately 13,200,000 people, are at risk for malaria transmission (7). In addition to the health effects from malaria, it has a substantial economic impact in affected countries. Countries with malaria had income levels only one third of countries without malaria, and researchers found a that 10% reduction in malaria was associated with a 0.3% increase in growth (8). This physically and economically devastating disease is the target of many health programs in Senegal and other affected areas throughout the world. The President's Malaria Initiative (PMI), which is jointly managed by Centers for Disease Control (CDC) and USAID, the World Health Organization (WHO), and other partners are all working with the Ministry of Health on malaria related projects in Senegal. (6, 7).

Many malaria control projects use insecticide treated nets (ITNs) as a main component of their strategy to prevent malaria transmission. The PMI for example, has distributed over 75 million ITNs since 2006 (9). The percent of households in Senegal who own an ITN has increased from 20% in 2005 to 73% in 2012, and all cause under five morality in Senegal has decreased by 40% from 2002 to 2011 (9-11). In June 2009, there was a campaign in the Kolda region to distribute long-lasting insecticidal nets (LLINs) to all children under the age of 5, and a universal coverage campaign was undertaken in Senegal in 2010 to distribute a bed net for every sleeping space (12). ITNs are provided for free to pregnant women, and at a discounted rate to others who visit health clinics, but malaria mortality is still high (9, 13). This project seeks to provide information for malaria control programs and educators on how to make ITN programs as successful as possible by increasing the useful life of ITNs. This study aims to assess whether ITN care and use practices are associated with increased number and size of holes in a cross-sectional study of 746 insecticide treated nets owned by villagers in Kolda Region, Senegal.

# BACKGROUND

Insecticide treated nets (ITNs) have been shown to be an effective means of reducing rates of malaria (14). In Senegal, 73% of households own insecticide treated nets, and the majority of the expenditures for malaria programs in Senegal went to ITNs in 2011 (6, 7, 11). When nets are in use the physical integrity and insecticidal properties deteriorate over time and the net loses effectiveness (15). A study conducted in Kenya found that 100% of nets still in use five years after distribution had holes, and other studies noted high prevalence of holes in the net as little as 14 months after distribution (16-19). The presence of holes in an ITN reduces its ability to protect the user from mosquitoes (20, 21). Kweka et al. noted that education on the use and maintenance of ITNs should be incorporated into bed net distribution programs in order to ensure that the nets provide long-lasting protection, and in order to provide appropriate education a greater understanding of what factors contribute to net deterioration is needed (16). There is abundant evidence that repeated washing of nets reduces the net's insecticidal properties and many noted holes in the net after several years of use (16, 22-27). Erlanger et al. reported results of a questionnaire on net care in Tanzania, and found that their respondents washed their nets 4-7 times per year, usually with soap. The nets were of varying ages, and none had rubbed the net against a washboard or a piece of stone or wood during washing, but 45% of the nets observed in their study were considered to be in bad condition (18). There is also some variation in net durability by brand and by the design and type of fiber used to construct the net (19, 28, 29). Studies in Kenya and Tanzania found that older children were more likely to be sleeping under nets of poor quality than other age groups, and that the nets used by young children and women of childbearing age were in the best condition (30, 31). There is evidence that the physical barrier to mosquitos provided by sleeping under an ITN is more important than the protection provided by the insecticide, as well as evidence that mosquitos may be developing resistance to the insecticides being used on ITNs (16, 32). Given these known limitations of the insecticidal ability of ITNs, it is important to understand what factors contribute significantly to the physical deterioration of the net. It is especially important to examine factors that are within the control of the net owners, such as washing, repair, and the number of people sleeping under the net, rather than factors that may be outside their control such as the brand of net provided to them. A study in coastal Kenya found significant associations between washing frequency and age of net users and the proportionate hole index (PHI) (33). This study will examine those and other factors in a different setting, using data collected at bed net care and repair events held by a Peace Corps Volunteer in rural Senegal to model the association between several care and use factors and the presence and size of holes in the ITN. This study may provide a basis by which ITN users and promoters can prioritize the changes made to net use practices in order to best preserve the effectiveness of ITNs.

# METHODS

*Data source*

The dataset was obtained from a Peace Corps Volunteer who conducted a series of bed net care and repair events in several villages in Kolda Region, Senegal in October 2012. The coordinating Volunteer collaborated with other Peace Corps Volunteers in the region to create a questionnaire based on an existing survey. The events were conducted in villages of varying sizes, up to 20 kilometers from a main road, and in an area with high malaria transmission. The event attendees were asked about their bed net care and use practices, the net condition was assessed and the nets were repaired. The data from this cross-sectional survey will be used to conduct an analysis of factors affecting net integrity. This secondary data analysis was considered exempt from review by the Emory Institutional Review Board.

*Hypothesis*

Nets with greater numbers of children sleeping under the net are more likely to be in worse physical condition than nets with fewer children sleeping under them, and nets that are washed more frequently are more likely to be in worse physical condition than nets that are not washed as often.

*Variable specification*

The condition of the nets was reported as the number of holes present in the net in various size ranges. The area of holes in the net was calculated by assuming that the holes were circular with a diameter at the midpoint of each size range. The total area of all holes in the net is the primary outcome variable, from which other outcome variables were calculated. A binary variable was created to indicate the presence of any holes in the net, as compared to a completely intact net. Two net quality variables were created to separate nets into categories of good and poor quality, one in which nets with a total hole area less than or equal to $500cm^2$ were considered good quality, and one in which nets with a total hole area less than or equal to $1{,}000cm^2$ were considered good quality. Since there are no widely accepted net quality criteria in the field, $500cm^2$ was chosen based on a previous published study and $1{,}000cm^2$ was chosen for the purposes of sensitivity analysis (33, 34). The total number of holes in the net, regardless of size, was also calculated and used as a continuous outcome variable. The two continuous outcome variables, total hole area and number of holes, were not normally distributed and were log transformed prior to analysis. These five variables (presence of holes, two net quality variables with different cutoffs, number of holes, and total hole area) are all measures of the physical condition of ITNs, and are used in this study to represent ITN integrity.

The responses to the questions asked at the net care and repair events were used to code several binary and continuous predictor variables. The net owner's responses to questions as to whether the household had enough nets, whether a net was used when sleeping outside, whether the net was used all year, and whether there were any previous repairs to the net were coded as binary yes or no variables. Event participants were also asked about what soap they used when washing their nets and how they dried their nets, and the volunteers marked these as correct or incorrect methods. If the respondent reported using a gentle on-detergent soap to wash the nets this was considered correct washing practices, and correct drying practices were indicated if the respondents reported drying their net in the shade and not on something sharp likely to tear the net. These two variables were also recoded as binary yes or no variables. Number of nets a person brought to the event, years a person had been using nets, months of the year sleeping under a net, the age of the net, how many times per year the net was washed, and how long ago the net was washed were coded as continuous numeric variables. If a person answered that they did not own enough nets for their household, did not sleep under a net year round, or did not sleep under a net the previous night, a multiple choice follow up question was asked about why. Their responses to these questions were recorded as categorical variables.

*Statistical analysis*

Statistical analyses were conducted using SAS version 9.3 (Cary, NC). The mean and standard deviation for each group was calculated for continuous variables, and the number and percent in each group was calculated for categorical variables. For each binary outcome variable, two sample t-tests were performed to determine if the groups had significantly different mean values for continuous predictor variables or a chi-square test was performed to determine if the two groups had significantly different distributions for a categorical predictor variable. For the two continuous outcome variables, two sample t-tests were conducted for categorical predictors and the Pearson's correlation coefficient was calculated for continuous predictors to determine if there was a significant association between the predictors and the outcomes. The odds ratio and 95% confidence interval for the univariate association between predictor and outcome was calculated using either a logistic or linear regression model. Variance inflation factors were used to assess multicollinearity between predictor variables, and variables or product terms that caused multicollinearity problems were removed. Multivariate logistic models were built for each of the binary outcome variables and multivariate linear models were built for the continuous outcomes. In each of the models, the dependent variable was one of the net integrity variables and all of the net user characteristics, net use patterns, and net care patterns from the survey were considered for inclusion as potential predictors of ITN integrity. Interaction and confounding were assessed in each of the logistic and linear models. Final models were those that included all of the potential predictors and had been adjusted for confounding. The final models were used to calculate adjusted odds ratios, parameter estimates and 95% confidence intervals for the association between each predictor and the net integrity outcomes.

# RESULTS

*ITN integrity and use*

Of the 746 ITNs included in this study, 497 (67%) had at least one hole. When the nets were categorized according to their quality using 500 square cm of holes as the cutoff between good and poor quality, 635 (85%) were good quality. Using a cutoff of 1,000 square cm for net quality, 691 (93%) of the nets were considered good quality. The mean hole area in the nets included in this study was 258 square centimeters, with a range of hole areas from zero to 5,591 square centimeters (Figure 1). The mean number of holes was four, with the number of holes observed ranging from zero to 40. The mean age of ITNs in the study was 3.2 years (standard deviation: 1.7 years). The mean number of children under the age of 5 sleeping under a net was 0.9, and the mean number of children between the ages of 6 and 14 sleeping under the net was 0.7 (Table 1). Only 14% of nets had been repaired previously, and the average number of washes per year was 3.6.

*Model 1: Presence of holes in ITNs*

Model 1 was a logistic model predicting the odds of the presence of at least one hole in the net. All of the interaction terms were non-significant, and none were included in the final models. The final model included all net user characteristics, net care practices, and net repair practices as independent variables and controlled for age. Nets with holes had significantly higher numbers of children less than 5 years ($p=0.0024$) and between the ages of 6 and 14 years ($p=0.0379$) sleeping under them the previous night than nets with no holes (Table 1). Owners of nets with holes reported that they had been using nets for significantly longer than owners of nets with no holes ($p=0.0086$). Nets with holes were significantly more likely to have been repaired previously ($p<0.0001$) and were also washed more times per year than nets with no holes ($p<0.0001$).

In an unadjusted analysis, a greater number of children less than 5 years of age sleeping under the net was significantly associated with higher odds of having holes in the net (OR: 1.27, 95% CI: 1.08-1.50), as was a greater number of children aged 6 to 14 years using the net (OR: 1.20, 95% CI: 1.01-1.40). There was no association between greater numbers of adults sleeping under the net and the presence of holes in the net. A statistically significant association was observed between the number of times per year a net was washed and the presence of holes, as well as between the number of years the net owner had been using ITNs and the presence of holes in the net (Table 2). A net with holes had 5.24 times greater odds of having been repaired before than a net with no holes present.

When adjusted for the net owner's sex, user characteristics, and all care and use factors, the associations between number of children sleeping under the net and years the owner had been using nets with presence of holes remained significant (Table 2). Nets with more users between the ages of 6 and 14 years had 3.12 times higher odds of having holes, while nets with more users under the age of 5 had 2.12 times higher odds of having holes. Nets that had previously been repaired had 6.59 times higher odds of having holes, although this association was not statistically significant and was imprecise after adjustment (95% CI: 0.61-70.87).

*Model 2: ITN quality (500cm$^2$ cutoff)*

Model 2 was a logistic model predicting the odds of poor net quality, defined as more than 500cm$^2$ of holes in the net. All of the interaction terms were non-significant, and none were included in the final models. The final model included all net user characteristics, net care practices, and net repair practices as independent variables and controlled for age. Poor quality nets had significantly greater number of users in the younger age categories than did good quality nets (Table 3). Poor quality nets also had significantly smaller numbers of adults users aged 18 years and over ($p=0.0214$). There was a statistically significant difference in mean ages of good and poor quality nets, with poor quality nets averaging 3.8 years in use and good quality nets averaging 3.1 years in use ($p=0.0014$). Poor quality nets were also significantly more likely to have been repaired before than good quality nets ($p<0.0001$).

In an unadjusted analysis, significant associations were found between the number of users less than 5 years of age, number of users between the ages of 6 and 14 years, the age of the net, and prior repairs and net quality (Table 4). Number of children under the age of five and number of children between the ages of 6 and 14 were associated with 1.33 and 1.36 times higher odds poor quality, respectively. The odds ratio for net age was 1.22, with a 95% CI of (1.10, 1.36), indicating a small but significant increase in odds of poor quality with increasing net age. There was a strong crude association between prior repairs to the net and net quality; nets that had been repaired before had 4.29 times higher odds of being poor quality, compared to nets that had not been repaired before (95% CI: 2.66-6.90).

When adjusted for net owner’s sex and other net user characteristics, net use patterns, and net care patterns, there were no significant associations between net user characteristics and net quality. The adjusted association between prior repairs and net quality remained strong (Table 4). Nets that had been repaired before had 4.71 times the odds of being poor quality than nets that had not been repaired before.

*Model 3: ITN quality (1,000 $cm^2$ cutoff)*

Model 3 was a logistic model predicting the odds of poor net quality, defined as more than 1,000$cm^2$ of holes in the net. All of the interaction terms were non-significant, and none were included in the final models. The final model included all net user characteristics, net care practices, and net repair practices as independent variables and controlled for age. Poor quality nets had significantly higher number of users less than five years of age (p=0.0005) and between the ages of 6 and 14 years (p=0.0342) than good quality nets. Poor quality ITNs were significantly more likely to have been repaired previously as compared to good quality ITNs (p<0.0001). There were no significant differences in the number of users in older age groups between good and poor quality nets, and also no differences between the net use patterns of good and poor quality ITNs (Table 5).

In an unadjusted analysis, there were significant associations between net quality and the number of people under the age of five sleeping under the net (OR: 1.54, 95% CI: 1.20-1.99) and the number of people aged 6 to 14 years sleeping under the net (OR: 1.43, 95% CI: 1.08-1.88). There was also a strong significant association between previous repairs to the net and net quality (Table 6). Nets that had been repaired before had 5.67 times higher odds of being poor quality compared to nets that had not been repaired before.

After adjusting for the net owner's sex and all other net user characteristics, net use patterns, and net care patterns, only the association between prior repairs and ITN quality remained significant (Table 6). Nets that had been repaired previously had 13.45 times higher adjusted odds of poor quality than nets that had not been repaired previously, although this estimate was imprecise (95% CI: 2.14-84.82).

*Model 4: Number of holes*

Model 4 was a log linear model predicting the number of holes in the net. All of the interaction terms were non-significant, and none were included in the final models. The final model included all net user characteristics, net care practices, and net repair practices as independent variables. There was a significant correlation between number of holes in the net and the presence of prior repairs (p=0.0007). There was also a significant correlation between use of the correct soap when washing the net and the number of holes in the net (p=0.0361). Interestingly, there were no significant correlations between number of holes in the ITN and number of users in any of the age categories (Table 7).

When unadjusted for other parameters, the presence of prior repairs in the net is associated with a 0.36 log increase in number of holes in the net, equivalent to an increase in 1.4 holes on average. Use of the correct soap when washing the net was associated with, on average, a 0.68 log decrease in number of holes, or 2.0 fewer holes (Table 8).

When adjusted for net user characteristics, net use patterns, and net care patterns, none of the predictors were significantly associated with the number of holes in the net (Table 8).

*Model 5: Total area of holes in the net (square centimeters)*

Model 5 was a log linear model predicting the total area of holes in the net in square centimeters. All of the interaction terms were non-significant, and none were included in the final models. The final model included all net user characteristics, net care practices, and net repair practices as independent variables. There were significant positive correlations between the total area of holes in the ITNs and the number of children under 5 years of age sleeping under the net (p=0.0008) and the number of children between the ages of 6 and 14 years sleeping under the net (p=0.0098). There was also a significant positive correlation between the number of months per year a net is used and the total hole area (p=0.0166), as well as between the age of the net in years and the total hole area (p=0.0011). Significant correlations were also observed between the presence of prior repairs to the net and the number of months ago that the net was last washed (Table 9).

Prior to adjustment, an increase in one child less than five years of age and an increase in one child between 6 and 14 years of age was associated with a 0.32 and 0.28 log increase in hole area, respectively (Table 10). This is equivalent to an average increase of 1.4$cm^2$ in hole area for an additional child under the age of five and an increase of 1.3$cm^2$, on average, for an additional child between the ages of 6 and 14. A one month increase in net use per year was associated with an increase of 1.1$cm^2$ hole area on average, and each additional year of net age was associated with an average increase in hole area of 1.2$cm^2$. The presence of prior net repairs was strongly associated with net holes, predicting a 0.93 log increase in hole area, or 2.5$cm^2$ on average. There was also a statistically significant association between how long ago the net was last washed and the total hole area, where an increase in 1 month since the net was washed predicted, on average, a 1.1$cm^2$ increase in hole area.

After adjustment for all other net user characteristics, net use patterns, and net care patterns, the only factor that significantly predicted the total hole area was prior repairs to the net (Table 10). Prior repairs to the net was associated with, on average, a 1.31 log increase in total hole area, or an increase of 3.7$cm^2$.

# DISCUSSION

The most consistently significant and strong association in this study was that between prior repairs to the net and poor ITN integrity (Tables 4, 6, 10, and 11). This finding is interesting because it is expected that repairs to the net, if done effectively, would decrease the number and size of holes in the net. Of the 497 ITNs in this study that had at least one hole, only 97 had been previously repaired (data not shown). For the other 400 ITNs containing holes, no repairs had been attempted. Nets that had been previously repaired were, on average, slightly older than nets that had never been repaired. It is possible that people were most likely to attempt to repair the ITNs that were older or in the worst condition, but repairs were incomplete. While data is not available from this study to indicate whether the nets that are in good condition are so because they are completely undamaged or have been effectively repaired, the strength of the association between prior repairs and poor ITN integrity indicates that when nets are repaired the repairs are not adequate or complete. Promoting effective net repair is an area of possible improvement that could have a big impact on the physical condition of ITNs and their effectiveness. Even when people understand the importance of repairing ITNs and have access to a needle and thread for repairs, reasons for inadequate net repair include not repairing all holes in the net, not having enough time for effective repair, the cost of taking a net to a tailor to repair larger holes, and choosing not to repair holes that are in the parts of the net that would be tucked under the mattress (33, 35). Panter-Brick et al. describe a community-led intervention in rural Gambia that used songs and posters to reinforce and remind people of the importance and urgency of ITN repairs, which led to a significant increase in net repairs (35). Their approach takes into account the context in which the intervention will be conducted, and since it is led by community members it provides a "culturally compelling" message (35). This type of approach may also be effective in Senegal, where evidence from this study indicates that net repair may be incomplete and ineffective.

A recent similar study conducted in coastal Kenya found that there were significant associations between washing frequency and ITN integrity, as well as between age of net users and ITN integrity (33). While both of these factors were investigated as potential predictors of ITN integrity in this study, frequency of washing was not significantly associated with any of the five ITN integrity outcomes and the net user's age was only significantly associated with the presence of holes in the net (Table 11). Mutuku et al. reported significant associations between ITN effectiveness and number of young children and older children using the net (33). There are also several other previous studies that indicate that children in certain age groups may be more likely than adults to be sleeping under ITNs in poor physical condition (30, 31). While this study only found significant associations between net user's age and the presence of holes in ITNs, this data indicates that there is a relationship between the number of children sleeping under the net and the ITN integrity (Table 2). This may be because children cause holes in the nets by handling them roughly (36). Mutuku et al. also found significant associations between ITN effectiveness and frequency of washing (33). Other previous studies also noted that repeated washing of ITNs leads to a reduction in the insecticidal properties of the net, and may also lead to the creation of holes in the net (16, 22, 25). The findings from this study did not indicate a significant relationship between frequency of washing and ITN integrity. The differing results from this study and previous studies on the impact of washing nets on ITN integrity may be due to the fact that with the limited data on drying and soap use practices, this study cannot fully determine the extent to which washing practices are associated with ITN integrity. It is also possible that survey respondents misreported the frequency with which they wash their nets. People may feel social pressure to report that they washed their nets more frequently than they did, which would lead to inaccuracy in the measures of washing frequency. Given these challenges and the fact that detailed data on washing practices was available for only one village of 24 in the study, and that previous studies have reported associations between ITN integrity and washing frequency, future studies should continue to consider washing frequency to have a potential impact on ITN integrity.

The World Health Organization (WHO) has published guidelines for field and laboratory testing of ITNs, in which they state that there is no universally agreed-upon criteria for assessing fabric integrity in ITNs (34). There are also differing opinions among net users as to when a net has reached the end of its useful life, with decision-making factors usually including holes in the net, net age, and availability of new ITNs (13). In this study, two different variables were used for net quality, one that divided ITNs into good and poor quality with a cutoff of 500cm$^2$ and one that divided ITNs into good and poor quality with a cutoff of 1,000cm$^2$. This allowed for a sensitivity analysis to determine if the choice of cutoff for net quality variables has an effect on the results obtained from the models. After assessing multicollinearity, interaction, and confounding, the two final net quality models (Models 2 and 3) included the same variables. The odds ratio estimates were slightly different in the two models, but the variables that were significantly associated with increased odds of poor net quality were the same. In both ITN quality models, the only significant association was that between prior repairs to the net and poor quality. These identical results indicate that the findings from these models are not dependent on the way net quality is defined.

# LIMITATIONS AND STRENGTHS

There were several limitations to this study. Since the participants who took the survey were attending a bed net care and repair event, those members of the community who do not own any ITNs or who are disinterested in caring for and repairing their nets are not included in the study. This non-probability sample may lead to selection bias by excluding those people who are likely to have the least complete net care and repair practices and who might own nets that are in very poor condition from lack of care. The data collected in this study did not allow for analysis of some very important factors that may play a role in the deterioration of ITNs, including the brand of net and whether nets were completely intact or had no holes because the holes had been successfully repaired. Including these variables in the analysis would have allowed for a more detailed analysis of the factors associated with physical condition of ITNs. There were also some variables, particularly the soap type and drying method, which were missing for all but one village.

Despite these limitations, this study provides some useful information on the factors that are associated with ITN integrity. By evaluating the associations between net user characteristics, net care patterns, and net use patterns with five different outcomes related to ITN integrity, this study was able to determine whether different factors that are associated with different of net condition concerns. The consistent strong association between prior repairs and all of the net integrity outcomes strengthens the certainty with which it can be targeted as a potential intervention to lengthen the useful life of ITNs. This study also examined washing practices in more detail than previous studies. Rather than simply examining the relationships between frequency of washing and net integrity, this study was able to include the type of soap used, the drying method, and the time since the net was last washed. These factors added more specific information about what aspect of the washing process may be associated with poor ITN integrity. While neither correct soap use nor correct drying practices were statistically significant predictors of ITN integrity, it appears that correct drying practices may be related to better ITN integrity, while correct soap use may not. This potential relationship is an interesting area for further investigation because soap use and drying practices are both practices that could be changed to protect ITNs from deteriorating while in use.

# FUTURE DIRECTIONS

Future studies should focus on collecting data on the specifics of net care practices, including motivations for repairing or not repairing ITNs when they are damaged. Very few of the nets examined as part of this study had ever been repaired, indicating that motivation to repair damaged nets, ability to repair nets, or both are lacking in this region in Senegal. These issues could be easily addressed through education and awareness interventions. Examining the interactions between washing frequency, soap type and drying method with more complete data than was available here would be valuable in gaining a more in depth understanding of the association between washing practices and ITN integrity reported in other studies (33). More research into the potential relationship between the ages of net users and ITN integrity is also needed. Although the associations between number of children sleeping under the net and ITN integrity were not significant in most of the adjusted models in this study, other studies have noted that a person's age is related to the physical integrity of the ITN that person uses (30, 31). In a cross-sectional study it is impossible to determine whether ITNs in poor physical condition are more likely to be given to age groups perceived to be at a lower risk for malaria, or whether young children are rougher on the nets and create holes. Establishing the temporality of this association would provide support for making ITN distribution less targeted and instead striving to provide ITNs to all groups. More research into the factors and practices that may contribute to the creation of holes in ITNs could provide evidence-based direction for health educators to promote adequate net care and ensure that ITNs remain effective for as long as possible.

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# TABLES

**Table 1.** Net user characteristics, net use patterns, and net care patterns by presence of holes in ITNs, Senegal, 2012.

| **Variable** | **Total (n=746)** | **No holes (n=249)** | **Holes (n=497)** | **p-value**[a] |
|---|---|---|---|---|
| ***Net user characteristics*** | | | | |
| Ages of people sleeping under the net | | | | |
| # less than 5 years | 0.9 (1.0) | 0.8 (0.9) | 1.0 (1.0) | 0.0024 |
| # 6-14 years | 0.7 (0.9) | 0.6 (0.9) | 0.8 (0.9) | 0.0379 |
| # 15-17 years | 0.1 (0.4) | 0.1 (0.3) | 0.1 (0.4) | 0.4173 |
| # 18 years and over | 0.9 (0.6) | 0.9 (0.6) | 0.9 (0.6) | 0.7629 |
| Number of pregnant women using the net | 0.2 (0.4) | 0.2 (0.4) | 0.2 (0.4) | 0.2623 |
| Enough nets[b] | 453 (61) | 142 (58) | 311 (63) | 0.1586 |
| ***Net use patterns*** | | | | |
| Years using nets | 5.9 (3.9) | 5.3 (3.4) | 6.2 (4.2) | 0.0086 |
| Months per year using nets | 10.0 (3.4) | 10.1 (3.3) | 9.9 (3.4) | 0.4961 |
| Uses net when sleeping outside[b] | 270 (36) | 100 (48) | 170 (52) | 0.3682 |
| Net age (years) | 3.2 (1.7) | 3.0 (1.6) | 3.3 (1.7) | 0.0786 |
| ***Net care patterns*** | | | | |
| Prior repairs[b] | 108 (14) | 11 (5) | 97 (23) | <0.0001 |
| Frequency of washing (times per year) | 3.6 (7.0) | 2.4 (1.9) | 4.2 (8.4) | <0.0001 |
| Last wash (months ago) | 5.6 (4.3) | 5.7 (4.5) | 5.5 (4.3) | 0.5840 |
| Correct soap use[c] | 15 (2) | 2 (20) | 13 (43) | 0.2686 |
| Correct drying practices[c] | 34 (5) | 9 (90) | 25 (83) | 1.0000 |

[a]Mean (SD) and p-value from a two sample t-test unless otherwise noted
[b]Values are number (%) and p-value is from a Chi-square test
[c]Values are number (%) and p-value is from Fisher’s exact test

**Table 2**. Associations of net user characteristics, net use patterns, and net care patterns with the presence of holes in ITNs, Senegal, 2012.

| **Factor** | **Crude OR**[a] | **95% CI** | **Adjusted OR**[b] | **95% CI** |
|---|---|---|---|---|
| ***Net user characteristics*** | | | | |
| Ages of people sleeping under the net | | | | |
| # less than 5 years | 1.27 | (1.08, 1.50) | 2.12 | (1.26, 3.57) |
| # 6-14 years | 1.20 | (1.01, 1.44) | 3.12 | (1.57, 6.22) |
| # 15-17 years | 1.18 | (0.77, 1.82) | 0.71 | (0.14, 4.61) |
| # 18 years and over | 0.96 | (0.75, 1.24) | 1.91 | (0.70, 5.24) |
| Number of pregnant women using the net | 1.51 | (0.74, 3.09) | 1.87 | (0.70, 5.23) |
| Enough nets | 1.25 | (0.92, 1.71) | 0.70 | (0.25, 1.76) |
| ***Net use patterns*** | | | | |
| Years using nets | 1.07 | (1.01, 1.13) | 1.18 | (1.01, 1.36) |
| Months per year using nets | 0.98 | (0.94, 1.03) | 1.03 | (0.88, 1.20) |
| Uses net when sleeping outside | 1.17 | (0.83, 1.66) | 2.45 | (0.83, 7.27) |
| Net age (years) | 1.10 | (0.99, 1.21) | 1.38 | (0.93, 2.03) |
| ***Net care patterns*** | | | | |
| Prior repairs | 5.24 | (2.74, 10.03) | 6.59 | (0.61, 70.87) |
| Frequency of washing (times per year) | 1.10 | (1.02, 1.18) | 1.12 | (0.91, 1.37) |
| Last wash (months ago) | 0.99 | (0.95, 1.03) | 1.00 | (0.89, 1.13) |
| Correct soap use | 3.06 | (0.55, 16.90) | 1.78 | (0.11, 28.85) |
| Correct drying practices | 0.56 | (0.06, 5.42) | 0.31 | (0.04, 2.46) |

[a]Odds ratio and 95% confidence interval from a univariate logistic regression

[b]Odds ratio and 95% confidence interval from a multivariate logistic regression, adjusted for net owner's sex and all other net user characteristics, net use patterns, and net care patterns listed

**Table 3.** Net user characteristics, net use patterns, and net care patterns by quality of ITNs[a], Senegal, 2012.

| Variable | Good (n=635) | Poor (n=111) | p-value[b] |
|---|---|---|---|
| ***Net user characteristics*** | | | |
| Ages of people sleeping under the net | | | |
| # less than 5 years | 0.9 (1.0) | 1.2 (1.0) | 0.0039 |
| # 6-14 years | 0.7 (0.9) | 0.9 (1.0) | 0.0101 |
| # 15-17 years | 0.1 (0.4) | 0.1 (0.4) | 0.6495 |
| # 18 years and over | 0.9 (0.6) | 0.8 (0.6) | 0.0214 |
| Number of pregnant women using the net | 0.2 (0.4) | 0.3 (0.5) | 0.0675 |
| Enough nets[c] | 387 (62) | 66 (59) | 0.6660 |
| ***Net use patterns*** | | | |
| Years using nets | 5.8 (4.0) | 6.3 (3.7) | 0.4150 |
| Months per year using nets | 9.9 (3.4) | 10.3 (3.2) | 0.2943 |
| Uses net when sleeping outside[c] | 237 (51) | 33 (47) | 0.4917 |
| Net age (years) | 3.1 (1.6) | 3.8 (2.0) | 0.0014 |
| ***Net care patterns*** | | | |
| Prior repairs[c] | 69 (13) | 39 (39) | <0.0001 |
| Frequency of washing (times per year) | 3.6 (7.2) | 3.2 (5.5) | 0.4746 |
| Last wash (months ago) | 5.5 (4.3) | 6.3 (4.5) | 0.0810 |
| Correct soap use[d] | 12 (34) | 3 (60) | 0.3446 |
| Correct drying practices[d] | 31 (89) | 3 (60) | 0.1542 |

[a]Nets with less than or equal to 500cm$^2$ of holes were considered good quality, while nets with more than 500cm$^2$ of holes were considered poor quality
[b]Mean (SD) and p-value from a two sample t-test unless otherwise noted
[c]Values are number (%) and p-value is from a Chi-square test
[d]Values are number (%) and p-value is from Fisher's exact test

**Table 4.** Associations of net user characteristics, net use patterns, and net care patterns with ITN quality[a], Senegal, 2012.

| Factor | Crude OR[b] | 95% CI | Adjusted OR[c] | 95% CI |
|---|---|---|---|---|
| ***Net user characteristics*** | | | | |
| Ages of people sleeping under the net | | | | |
| # less than 5 years | 1.33 | (1.09, 1.61) | 1.44 | (0.79, 2.61) |
| # 6-14 years | 1.36 | (1.10, 1.67) | 1.89 | (1.00, 3.56) |
| # 15-17 years | 1.13 | (0.68, 1.88) | 0.50 | (0.05, 5.55) |
| # 18 years and over | 0.67 | (0.48, 0.94) | 0.87 | (0.30, 2.55) |
| Number of pregnant women using the net | 1.93 | (0.94, 3.94) | 1.72 | (0.65, 4.56) |
| Enough nets | 0.91 | (0.61, 1.38) | 0.84 | (0.30, 2.36) |
| ***Net use patterns*** | | | | |
| Years using nets | 1.03 | (0.96, 1.09) | 1.04 | (0.89, 1.23) |
| Months per year using nets | 1.03 | (0.97, 1.10) | 1.02 | (0.85, 1.21) |
| Uses net when sleeping outside | 0.84 | (0.51, 1.38) | 0.77 | (0.26, 2.31) |
| Net age (years) | 1.22 | (1.10, 1.36) | 0.90 | (0.59, 1.37) |
| ***Net care patterns*** | | | | |
| Prior repairs | 4.29 | (2.66, 6.90) | 4.71 | (1.17, 18.95) |
| Frequency of washing (times per year) | 0.99 | (0.95, 1.03) | 0.98 | (0.84, 1.14) |
| Last wash (months ago) | 1.05 | (0.99, 1.10) | 1.00 | (0.87, 1.13) |
| Correct soap use | 2.88 | (0.42, 19.62) | 1.52 | (0.10, 22.42) |
| Correct drying practices | 0.19 | (0.02, 1.53) | 0.25 | (0.03, 2.53) |

[a]Nets with less than or equal to 500cm$^2$ of holes were considered good quality, while nets with more than 500cm$^2$ of holes were considered poor quality
[b]Odds ratio and 95% confidence interval from a univariate logistic regression
[c]Odds ratio and 95% confidence interval from a multivariate logistic regression, adjusted for net owner's sex and all other net user characteristics, net use patterns, and net care patterns listed

**Table 5.** Net user characteristics, net use patterns, and net care patterns by quality of ITNs[a], Senegal, 2012.

| Variable | Good (n=691) | Poor (n=55) | p-value[b] |
|---|---|---|---|
| ***Net user characteristics*** | | | |
| Ages of people sleeping under the net | | | |
| # less than 5 years | 0.9 (1.0) | 1.4 (1.0) | 0.0005 |
| # 6-14 years | 0.7 (0.9) | 1.0 (1.1) | 0.0342 |
| # 15-17 years | 0.1 (0.4) | 0.1 (0.3) | 0.9643 |
| # 18 years and over | 0.9 (0.6) | 0.8 (0.5) | 0.0708 |
| Number of pregnant women using the net | 0.2 (0.4) | 0.4 (0.5) | 0.0595 |
| Enough nets[c] | 426 (62) | 27 (49) | 0.0533 |
| ***Net use patterns*** | | | |
| Years using nets | 5.9 (4.0) | 6.2 (3.2) | 0.6903 |
| Months per year using nets | 9.9 (3.4) | 10.6 (3.0) | 0.1215 |
| Uses net when sleeping outside[c] | 252 (50) | 18 (53) | 0.7484 |
| Net age (years) | 3.2 (1.6) | 3.6 (2.1) | 0.1646 |
| ***Net care patterns*** | | | |
| Prior repairs[c] | 83 (15) | 35 (49) | <0.0001 |
| Frequency of washing (times per year) | 3.6 (6.9) | 3.8 (7.6) | 0.8308 |
| Last wash (months ago) | 5.6 (4.3) | 6.0 (4.3) | 0.5642 |
| Correct soap use[d] | 15 (39) | 0 (0) | 0.5192 |
| Correct drying practices[d] | 33 (87) | 1 (50) | 0.2908 |

[a]Nets with less than or equal to 1,000cm$^2$ of holes were considered good quality, while nets with more than 1,000cm$^2$ of holes were considered poor quality
[b]Mean (SD) and p-value from a two sample t-test unless otherwise noted
[c]Values are number (%) and p-value is from a Chi-square test
[d]Values are number (%) and p-value is from Fisher's exact test

**Table 6.** Associations of net user characteristics, net use patterns, and net care patterns with ITN quality[a], Senegal, 2012.

| Factor | Crude OR[b] | 95% CI | Adjusted OR[c] | 95% CI |
|---|---|---|---|---|
| ***Net user characteristics*** | | | | |
| Ages of people sleeping under the net | | | | |
| # less than 5 years | 1.54 | (1.20, 1.99) | 0.98 | (0.46, 2.11) |
| # 6-14 years | 1.43 | (1.08, 1.88) | 1.34 | (0.55, 3.27) |
| # 15-17 years | 0.98 | (0.47, 2.07) | 1.56 | (0.16, 15.1) |
| # 18 years and over | 0.65 | (0.41, 1.04) | 0.80 | (0.19, 3.42) |
| Number of pregnant women using the net | 2.27 | (0.95, 5.46) | 2.31 | (0.63, 8.44) |
| Enough nets | 0.58 | (0.34, 1.01) | 0.65 | (0.15, 2.74) |
| ***Net use patterns*** | | | | |
| Years using nets | 1.02 | (0.93, 1.12) | 1.05 | (0.83, 1.34) |
| Months per year using nets | 1.08 | (0.98, 1.18) | 0.98 | (0.77, 1.25) |
| Uses net when sleeping outside | 1.12 | (0.56, 2.25) | 0.41 | (0.08, 2.08) |
| Net age (years) | 1.13 | (0.98, 1.30) | 1.04 | (0.55, 1.99) |
| ***Net care patterns*** | | | | |
| Prior repairs | 5.67 | (3.12, 10.28) | 13.45 | (2.14, 84.42) |
| Frequency of washing (times per year) | 1.00 | (0.97, 1.05) | 1.04 | (0.92, 1.18) |
| Last wash (months ago) | 1.02 | (0.95, 1.09) | 1.06 | (0.88, 1.28) |
| Correct soap use | Uncalculable | | Uncalculable | |
| Correct drying practices | 0.15 | (0.01, 2.83) | 1.37 | (0.07, 28.63) |

[a]Nets with less than or equal to 1,000cm$^2$ of holes were considered good quality, while nets with more than 1,000cm$^2$ of holes were considered poor quality
[b]Odds ratio and 95% confidence interval from a univariate logistic regression
[c]Odds ratio and 95% confidence interval from a multivariate logistic regression, adjusted for net owner's sex and all other net user characteristics, net use patterns, and net care patterns listed

**Table 7.** Net user characteristics, net use patterns, and net care patterns by total number of holes in ITNs, Senegal, 2012.

| Variable | Correlation | p-value[a] |
|---|---|---|
| ***Net user characteristics*** | | |
| Ages of people sleeping under the net | | |
| # less than 5 years | 0.08 | 0.0921 |
| # 6-14 years | 0.09 | 0.0545 |
| # 15-17 years | -0.26 | 0.5588 |
| # 18 years and over | -0.02 | 0.6226 |
| Number of pregnant women using the net | 0.04 | 0.6049 |
| Enough nets[b] | 1.4 (0.9) | 0.3004 |
| ***Net use patterns*** | | |
| Years using nets | 0.00 | 0.9993 |
| Months per year using nets | 0.06 | 0.1752 |
| Uses net when sleeping outside[b] | 1.3 (0.8) | 0.3746 |
| Net age (years) | 0.07 | 0.1235 |
| ***Net care patterns*** | | |
| Prior repairs[b] | 1.7 (0.9) | 0.0007 |
| Frequency of washing (times per year) | -0.01 | 0.7886 |
| Last wash (months ago) | 0.07 | 0.1762 |
| Correct soap use[b] | 0.9 (0.9) | 0.0361 |
| Correct drying practices[b] | 1.3 (0.9) | 0.6600 |

[a]Pearson's correlation coefficient between variable and ln(number of holes) and test of significance unless otherwise noted
[b]Mean (SD) of ln(number of holes) in the category, p-value from two sample t-test

**Table 8.** Associations of net user characteristics, net use patterns, and net care patterns with total number of holes[a], Senegal, 2012.

| **Factor** | **Crude parameter estimate[b]** | **95% CI** | **Adjusted parameter estimate[c]** | **95% CI** |
|---|---|---|---|---|
| ***Net user characteristics*** | | | | |
| Ages of people sleeping under the net | | | | |
| # less than 5 years | 0.07 | (-0.01, 0.15) | -0.02 | (-0.27, 0.24) |
| # 6-14 years | 0.09 | (0.00, 0.18) | -0.07 | (-0.36, 0.22) |
| # 15-17 years | -0.06 | (-0.27, 0.14) | -0.40 | (-1.20, 0.40) |
| # 18 years and over | -0.03 | (-0.17, 0.10) | -0.02 | (-0.50, 0.47) |
| Number of pregnant women using the net | 0.08 | (-0.24, 0.41) | 0.16 | (-0.30, 0.61) |
| Enough nets | -0.09 | (-0.26, 0.08) | 0.07 | (-0.40, 0.54) |
| ***Net use patterns*** | | | | |
| Years using nets | 0.00 | (-0.02, 0.03) | 0.00 | (-0.07, 0.07) |
| Months per year using nets | 0.02 | (-0.01, 0.04) | -0.01 | (-0.08, 0.07) |
| Uses net when sleeping outside | -0.09 | (-0.28, 0.11) | -0.25 | (-0.72, 0.22) |
| Net age (years) | 0.04 | (-0.01, 0.09) | -0.02 | (-0.17, 0.14) |
| ***Net care patterns*** | | | | |
| Prior repairs | 0.36 | (0.15, 0.57) | 0.34 | (-0.32, 1.00) |
| Frequency of washing (times per year) | 0.00 | (-0.01, 0.01) | -0.02 | (-0.06, 0.02) |
| Last wash (months ago) | 0.01 | (-0.01, 0.04) | 0.00 | (-0.06, 0.06) |
| Correct soap use | -0.68 | (-1.31, -0.05) | -0.45 | (-1.49, 0.59) |
| Correct drying practices | -0.2 | (-1.10, 0.71) | -0.08 | (-0.95, 0.80) |

[a]A 1 unit increase in predictor will have an expected effect equal to the parameter estimate on ln(number of holes)
[b]Parameter estimate and 95% confidence interval from a univariate linear regression
[c]Parameter estimate and 95% confidence interval from a multivariable linear regression, adjusted for all other net user characteristics, net use patterns, and net care patterns listed

**Table 9.** Net user characteristics, net use patterns, and net care patterns by total hole area($cm^2$) in ITNs, Senegal, 2012.

| Variable | Correlation | p-value[a] |
|---|---|---|
| ***Net user characteristics*** | | |
| Ages of people sleeping under the net | | |
| # less than 5 years | 0.15 | 0.0008 |
| # 6-14 years | 0.12 | 0.0098 |
| # 15-17 years | -0.06 | 0.2005 |
| # 18 years and over | -0.06 | 0.1760 |
| Number of pregnant women using the net | 0.01 | 0.8598 |
| Enough nets[b] | 4.4 (2.2) | 0.2234 |
| ***Net use patterns*** | | |
| Years using nets | 0.04 | 0.4911 |
| Months per year using nets | 0.11 | 0.0166 |
| Uses net when sleeping outside[b] | 4.4 (2.1) | 0.1243 |
| Net age (years) | 0.15 | 0.0011 |
| ***Net care patterns*** | | |
| Prior repairs[b] | 5.2 (2.1) | 0.0003 |
| Frequency of washing (times per year) | -0.03 | 0.5037 |
| Last wash (months ago) | 0.18 | 0.0001 |
| Correct soap use[b] | 5.0 (1.8) | 0.6376 |
| Correct drying practices[b] | 4.9 (1.5) | 0.5912 |

[a]Pearson's correlation coefficient between variable and ln(total hole area) and test of significance unless otherwise noted
[b]Mean (SD) of ln(total hole area) in the category, p-value from two sample t-test

**Table 10.** Associations of net user characteristics, net use patterns, and net care patterns with total hole area[a] ($cm^2$), Senegal, 2012.

| **Factor** | **Crude parameter estimate[b]** | **95% CI** | **Adjusted parameter estimate[c]** | **95% CI** |
|---|---|---|---|---|
| ***Net user characteristics*** | | | | |
| Ages of people sleeping under the net | | | | |
| # less than 5 years | 0.32 | (0.13, 0.50) | -0.05 | (-0.53, 0.43) |
| # 6-14 years | 0.28 | (0.07, 0.49) | 0.04 | (-0.52, 0.59) |
| # 15-17 years | -0.31 | (-0.80, 0.17) | -1.26 | (-2.78, 0.26) |
| # 18 years and over | -0.22 | (-0.54, 0.10) | -0.25 | (-1.17, 0.68) |
| Number of pregnant women using the net | 0.06 | (-0.65, 0.77) | 0.28 | (-0.58, 1.15) |
| Enough nets | -0.25 | (-0.64, 0.15) | 0.36 | (-0.54, 1.26) |
| ***Net use patterns*** | | | | |
| Years using nets | 0.02 | (-0.04, 0.08) | -0.04 | (-0.17, 0.09) |
| Months per year using nets | 0.07 | (0.01, 0.12) | 0.08 | (-0.06, 0.22) |
| Uses net when sleeping outside | -0.35 | (-0.81, 0.10) | -1.23 | (-2.12, 0.34) |
| Net age (years) | 0.19 | (0.08, 0.30) | 0.04 | (-0.25, 0.33) |
| ***Net care patterns*** | | | | |
| Prior repairs | 0.93 | (0.43, 1.42) | 1.31 | (0.05, 2.57) |
| Frequency of washing (times per year) | -0.01 | (-0.03, 0.02) | -0.03 | (-0.11, 0.05) |
| Last wash (months ago) | 0.09 | (0.05,0.14) | 0.07 | (-0.04, 0.18) |
| Correct soap use | 0.31 | (-1.03, 1.65) | 0.55 | (-1.43, 2.53) |
| Correct drying practices | 0.76 | (-1.00, 2.53) | 1.02 | (-0.64, 2.68) |

[a]A 1 unit increase in predictor will have an expected effect equal to the parameter estimate on ln(hole area)
[b]Parameter estimate and 95% confidence interval from a univariate linear regression
[c]Parameter estimate and 95% confidence interval from a multivariable linear regression, adjusted for all other net user characteristics, net use patterns, and net care patterns listed

**Table 11.** Significant associations in adjusted models.

| **Factor** | **Model 1: Presence of at least one hole** | **Model 2: ITN quality (500cm$^2$ cutoff)** | **Model 3: ITN quality (1,000cm$^2$ cutoff)** | **Model 4: Number of holes** | **Model 5: Total hole area (cm$^2$)** |
|---|---|---|---|---|---|
| ***Net user characteristics*** | | | | | |
| Ages of people sleeping under the net | | | | | |
| # less than 5 years | X | | | | |
| # 6-14 years | X | | | | |
| # 15-17 years | | | | | |
| # 18 years and over | | | | | |
| Number of pregnant women using the net | | | | | |
| Enough nets | | | | | |
| ***Net use patterns*** | | | | | |
| Years using nets | X | | | | |
| Months per year using nets | | | | | |
| Uses net when sleeping outside | | | | | |
| Net age (years) | | | | | |
| ***Net care patterns*** | | | | | |
| Prior repairs | | X | X | | X |
| Frequency of washing (times per year) | | | | | |
| Last wash (months ago) | | | | | |
| Correct soap use | | | | | |
| Correct drying practices | | | | | |

FIGURES

Figure 1. Distribution of total hole area in ITNs.