1.0 INTRODUCTION

Human error remains a significant contributor to the global pattern of transportation accidents. Within theglobal aviation sector,it accounts for about 70% of all accidents,often exerbatingfromunsafe acts andassociated preconditions (Munene 2016; Yan and Histon, 2014). Generally, aviation safety management programmes have a common goal to reduce hazards and manage residual risk of air transportation (Oriola and Adekunle 2015). The success of these programs hassustained the ranking of aviation as the highest in terms of safety accreditation among all modes of transportation available today. Global records of flights and passenger movement for the year 2016 indicatethe 37million journeysundertaken within the periodthat moved about 3.7billion passengers recorded 19 fatal accidents that resulted in the death of 325 passengers. In 2017 there were 6 accidents with 19 deaths none attributed to any commercial jet airliner (IATA 2017).

In spite of this outstanding safety accreditation, global flight operations remain fragile and risky. "Human factors involved with visual attention mechanism and fatigue in particular are noted as critical concern in modern aviation accidents contributing between 4-8% of the global aviation disasters" (Candwell 2005). The quest to reduce human error has led tothe increasing attention on the issue of fatigue among aircraft pilots and cabin crew members.The strict work and rest regulation / codes guiding aircraft crewmanagement is designed to eliminate human error and risk associated with fatigue which has continued to feature prominently among the principal causes of global aviation accidents.

Within the African region and Nigeria civil aviation in particular, aviation incident/accident are a commonoccurrenceand is a serious source of concern for the fragile aviationsector. The contribution of human error to the pattern of incidence/accidents in the sector has put it as themost potent risk exposure within Nigeria's civil aviation (Daramola 2014).A Dana Airline local flight that crashed killing 153 passengers in 2013 and a recent loss of the door of another airline while landingare reminders of manydangers that have consistently been attributed to human mistakesin the sector (Pasztor and Hinshaw 2013). An assessment of the physiological and psychological well-being of the flight crew of commercial airlines made up of pilots and cabin crew members maytherefore be critical to mitigating the risk exposure from fatigue. This research therefore investigates the knowledge of fatigue among the flight crews of commercial airlines operating in Nigeria's civil aviation.

Fatigue as conceptualized by ICAO is "a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase or workload that can impair an air crew alertness and ability to safely operate an aircraft or perform safety-related duties" . Fatigued pilots and creware thought to likely exhibit any one or more of the followingunsafe duty attributes. These include; indifference or carelessness to operational performance, attitude and mood deterioration, impaired logic, slow movement and thinking, lower accuracy and timing, frequent mistakes, lower perception to risk, memory difficulties,poor coordination and concentration " (Caldwell and Caldwell 2003; Caldwell 2008;Caldwell et al 2009; Caldwell 2012; Locke 2014). Any one of these attributes remains a potent risk that has accounted for one or more incident/accident in the global civil aviation (Rudari 2016).

Scholarlyworks onfatigue among flight crewdocumented in literature such as that ofXuet. el. (2015) has suggested that"pilots across the globe may be working beyond the regulated duty hours stipulated by ICAO.Such extended workinghours are a result of increasing flight demand by passengers as well as opening of new airports.A LSC survey reported in The Economist

Magazine of2016 observed close to 60% of the 7000pilots working within the EuropeanUnionhad reported their colleagues were often tired at work. Gregory et al (2010) also notedthat about 84% of pilots interviewed ina United States surveyhad also acknowledged that fatigue affected their performance while another 28% outrightlyacknowledged nodding off during flight. Locke(2014) reported 57% of Brazil's local commercial airline pilots had nodded off during national flights; this observation was noted to have increased to nearly 70% among pilots oninternational duty.

The study by Goode (2003) associatedhigher hours of duty time of commercial aircraft pilots in the United States with increasing probability of accident.Similarly, Caldwell (2008) observedthat longer flight have greater propensity for spontaneous micro-sleeps among pilots. The study further suggested"micro-sleep is 9 times more likely to occur among pilots during night flights than day flights". Caldwell(2012)further associated fatigue with the waking periods of pilots.Fatigue will likely occur when the wake period is longer than 16 hours and pre-duty sleep less than 6 hours or when the work period occurs during the pilot's usual sleep hours. Torregroza et al (2014) further emphasized the importance of rest periods by associating the amount of time spent resting before a trip with the oddsof a crash among Colombian truck drivers. Vejvoda et al (2014) suggested pilots as being significantly more fatigued at their duty end,the study in addition notes pilots with four consecutive night shifts are 36% more likely to have an accident than when working one night shift. Lee and Kim (2018) observed that"fatigue is affected by seven independent variables; flight direction, crew scheduling, partnership, aircraft environment, job assignment, ethnic difference, and hotel environment.

In spite of the number of literature on the subject,"fatigue-related performance problems in aviation isstill thought to be underestimated, underappreciated and underreported" (Candwell

2005; Caldwell 2012)."Failures in the effort to acquire new areas of knowledge in spite ofthe advancement in scientific understanding of issues around fatigue, sleep, shift work, and circadian physiologyin the past decades" have been noted byCadwell et al (2009).Jackson (2006) furtherobserved research on pilots/crewfatigue is skewed towardsthose on long hull flights whileLiterature onshort hull flight is scarce.

Literatures so far reviewed suggesta dearth of studies emanating from Africa's civil aviation on the subject of fatigue.This is in spite of Africa's aviationbeing ranked as having the highest regional accident rate while accounting for only3% of global scheduled commercial flights (ICAO, 2011). This study therefore investigatesthe knowledge of fatigue among short hull flight crew members operating within Nigeria's civil aviation. The choice of Nigeria is justified because of itsgrowing civil aviation market and accident. Its aviation industry is one of the busiest in Africawith an annual average of 40,000 flights and an accident fatality ratio that ranks far above the global average (Daramola2014).Investigating the knowledge of fatigue is therefore precursor to other studies that must emanate in the sector as part of effort to mitigate flight risk in the country.

The following research questions are outlined to guide this research. Do flight crews operating commercial flights in Nigeria have knowledge of fatigued pilots?What is association between the sleep pattern of airline crewmembers and symptoms of fatigue? What is the association between crew workload/duty circle and common symptoms of fatigue? In line with observation ofTorregroza et al (2014) on the influence of socio-economic characteristics on odds of accidentsoccurrence, what is the influence ofcrew's socio-economic characteristicson the knowledge offatigue among pilots?

The theoretical framework adopted in guiding this study is theDomino Theory of Accident Causation developed by W. H. Heinrich.The theory stipulates accidents as a culmination of events in sequence occurring in a fixed and logical order. Five crucial steps in this sequence include; Ancestry and social environment, Worker fault; Unsafe act together with mechanical and physical hazard; Accident, Damage or injury. Sabet et al (2013) suggests in order improve safety;the removal of the factor preceding the accident is expedient.Fatigue which therefore isthe factor preceding the "unsafe act" inthe aviation accident domino is the subject of ourinvestigation. The knowledge thus gained from this study willhelp contribute significantly in enhancing existingsafety policies within Nigeria andthe global civil aviation.

2.0 METHODS

This study is designed as a research survey on flight crews currently workingwithin Nigeria's Civil Aviation. The aim of the survey is to gauge the knowledge of fatigue among theircolleagues. As a way of encouraging true response from the target audience, the term "micro-sleep" was used in place of the word "fatigue" as respondents will likely be averseto the term "fatigue" dueto the sensitivity of the subject in safety regulation.

Data used for the study emanated froma structured questionnaire survey distributed among pilots and cabin crew members of commercial airlinesoperating within Nigeria. The survey took place over a 2month period in the city ofLagos, the hub for local commercial flights in Nigeria. In order to estimate the target population for the study, flight crew recordswas sourced from the Nigeria Civil Aviation Authority (NCAA)the national aviation safety regulatory agency. Information indicates there are about 7,478 pilots and 4,644 cabin crewso far licensed by the authority. However, a good percentage among thesearenoted tobe outside the target audience as they either held no valid license, retired or operate other class of aircraft that are not on commercial schedule. These in the opinion of the researchers make it difficult to use the NCAA information as a sample frame list.

An alternate method was used to estimate the target population through information from the NCAA. This indicated that there are currently 6 commercial airlines that operating on schedulewithin Nigeria. On the average these airlines use 3 aircraft for their operations. Using the average number of planes, the number of crew members required to man each plane and averagenumber of crew set needed to operate safely each week we can then estimate the sample population. This translates to 6 (number of airliners)* 7 (averagenumber of crew members in each plane)* 3(number of planes operated by each airline) = 126 (sample population).

The sample size for the study can thus be determined using the Taro Yemani formula formulae:

$$n = \frac{N}{1+N(e)^2}$$

Where n = Sample size

N = Population of the study (126)

e = margin of error [which stands for 0.05 in this study].

1= a constant

$$\frac{126}{1+126(0.05)^2} = n = 95$$

Analytical tools employed includethe paired sampleT-test used to establish theassociation between hours of night sleep by air crew and theircommon symptoms offatigue. Themodel was also used to gauge the association between perceivedworkload by airlines against the common symptoms of fatigueexhibited by respondents.Lastly, a multivariate binary logistic regression model was used inassessingthe influence of respondent'ssocio-economic attributes on the odds of knowledge of micro-sleep occurrence among pilots.

The model specification for the logistic regression is expressed as;

$$P(R) = \frac{1}{1 + e^{-(b_0 + b_1x_1 + b_2x_2 ......b_nx_n + e)}} \quad \text{(eq. 1)}$$

Where;

P = dependent variable (odd of micro-sleep)

a = is the constant of the equation

b= is the criterion of the independent variable X_1........................ X_n

The independent variablesused in the referenced category for the binary logitare highlighted below, these include:

X_1 = Gender (Male = 0; Female = 1)

X_2 = Age (< 25yrs= 0; Others = 1)

X_3 = Distance of residence from airport(< 5km= 0; Others = 1)

X_4 = Years of flying experience (< 5= 0; Others = 1)

X_5 = Class of flight crew(pilot = 0; Others = 1)

3.0 RESULT

The result of the response to the knowledge of micro-sleep among pilots operating commercial flights is presented in table 1 below. There are 41 respondents who make up 43.2% of the total responses that acknowledged having knowledge pilots having micro-sleep during flight. This opinion was expressed by 11 captains, 12 co-pilots and 18 cabin crew members. On the contrary, there 54 respondents whodeclined ever having knowledge of micro-sleep incidence among pilots during flight in Nigeria. These are made up of 4 captains, 11 co-pilots and 39 cabin crew members. From the above result a good number of the respondents have affirmed at some point having heard of pilots having micro-sleep which in turn indicates fatigue.

Table 1: Knowledge of micro-sleep among pilots flying in Nigeria

Class of crew	knowledge of pilot fatigue		Total
	Yes	No	
Captain	11	4	**15**
Ist officer	12	11	**23**
Cabin crew	18	39	**57**
Total (%)	**41 (43.2%)**	**54 (56.8%)**	**95 (100%)**

Source: Authors' field work, 2018

The study by way of objective sought to establish the association between hours of sleep and the symptom of fatigue by respondents. The most important symptoms that have been identified in literature includestress, lack of concentration, micro-sleep, poor memory and anxiety. Table 2 below shows a cross tabulation of the fatigue symptoms associated witheach respondent and the average of hours of night sleep. The result of the chi-square for the association returned a value of 7.333and a probability value of 0.835 which is not significant at 95% confidence level. This suggest there is no convincing evidence that any relationship exist between the respondents' dailysleep pattern andsymptoms of fatigueexpressed in this study.

Table 2: Common symptoms fatigue exhibited*Hours sleep

	Hours of Night Sleep				
Symptoms of fatigue	**3-5**	**5-7**	**7-9**	**9-11**	**Total**
Stress	2	11	10	4	**27**
Lack of concentration	0	20	17	4	**41**
Micro sleep	0	8	4	2	**14**
Poor memory	2	4	2	0	**8**
Anxiety	0	3	2	0	**5**
Total	**4**	**46**	**35**	**10**	**95**
Pearson Chi-Square	Value: 7.333, D.F: 12, Asymp. Sig. (2-sided): 0.835				

Source: Authors' field work, 2018

The degree to which respondents work load is inducing fatigue on air crew in Nigeria civil aviation was also assessed.From the result, about 28.3% of these respondents either strongly agreed or agreed to fact they are being overworked by airlines. Those who either disagreed or strongly disagree make-upabout 41.3% of the entire respondents while those that are indifferent make up the remaining 28.3%.The study further sought toestablish an associationbetween the workload and the common symptoms of fatigue earlier outlined by respondents. The Chi-Square analysis in table 3 below returned a value of 28.209 with a probability value of 0.030, an outcome that is significant at 95% confidence level. From this result we can confidentlyinfer that an association exists between the perception of workloadand symptoms of fatigue expressed in this study.

Table 3: Cross tabulation of workload opinion and symptoms fatigue exhibited

	Symptoms fatigue exhibited					
Workload opinion	**Stress**	**Lack of concentration**	**Micro sleep**	**Poor memory**	**Anxiety**	**Total**
Strongly Agreed	2	7	0	0	0	**9**
Agree	2	6	7	4	0	**19**
Indifferent	13	8	5	1	0	**27**
Disagree	6	15	2	5	0	**28**
Strongly Disagree	3	5	0	0	4	**12**
Total	**26**	**41**	**14**	**10**	**4**	**95**
Pearson Chi-Square	Value: 28.209, D.F: 16, Asymp. Sig. (2-sided): 0.030					

Source: Authors' field work, 2018

Thestudy also assessed the influence ofrespondents' socio-economic characteristics on knowledge of fatigue among colleagues.The followingsocio-economic attributes of crew members were entered into the logit regression;Gender, Age Marital status, Distance of residence to the airport, Years of flying experience and Category of aircrew of respondents. The result of the logistic regression is presented in table 4 below.

From the result, the Nagelkerke R Squarewhich indicates the joint contribution of all socio-economic independent variables entered into the model to changes in the dependent variable. Their joint contributionaccounts forabout 58.3% of the variation in the dependent variable.The Hosmer and LemeshowTest suggeststhe entiremodel as being adequate in predicting the knowledge of micro-sleep episode among the target population with a significance valueof 0.258 (must be greater than 0.05).The classificationtable suggests the model was able tocorrectly predict 80.4% of the response to the knowledge of micro-sleep among pilots by these respondents'.

The binarylogit regressionmodel indicates forevery unit increase in the knowledge of micro-sleep episodeamong respondents', the male gender increasedby3.912 units. Theexponential value of the modelfurther suggest the odds male respondents having such knowledge is 50 times more than their female counterparts. This result is highly significant at 95% confidence level with a probability value of 0.014.

Every unit increase in the awareness of micro-sleep among pilotscan also be associated with a concomitant increase in the age of respondents by 1.8 units. The knowledge of pilot micro sleep among aircrew is 6 times more likelyto occur among thereferenced age categoryof 25 and below than any other age category used in this survey.This result is nearly significant at 95% confidence level with a probability value of 0.052.

The influence of distance of flight crews'residence from the Airportonawareness of micro-sleep episodes among pilotsalso shows that every unit increase insuch knowledge can be associated with a-1.860 unit change in the distance of respondents'residence to the airport. The odds of knowledge of micro-sleep isthuslow among those who live closest to the airport among respondents as the odds is 0.156 times likely to occur. This relationshipis highly significantat 95% confidence level with a probability value of 0.012.

The influenceof flying experience also shows that every unit increase inthe knowledge of micro-sleep episode among pilots theflying experience of respondents also reduces by -2.844.Knowledge of micro-sleep also shows a very low odd of occurrenceamong those with least experience as it is 0.058 times likely to occur among those with the lowestnumber of flight hours compared to those with higher flight hours. This relationshipis alsosignificant at 95% confidence level with a probability value of 0.033.

Lastly, every unit increase inthe knowledge of micro-sleep among pilots reduced such association amongcaptains by-0.348 among captains with odds of occurrence with a0.0706 likelihood of occurrence compared to any other category of flight crew used in this survey. This relationship is however not significant at 95% confidence level. Among first officers however, every unit increase in the knowledge of micro-sleep among respondents causesa 0.452 change in the number of 1st officers. However, the odds of such knowledge is1.571 times more likely occur among 1st officers than any other category of flight crew members used in this survey. This result againis not significant at 95% confidence level with a probability value of 0.654.

Table 4: Showing influence of socio-economic characteristics of flight crew on fatigue.

-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
36.767	0.434	0.583
Hosmer and Lemeshow Test		
Chi-square: 8.921	DF: 7	Sig : 0.258
Classification Table: **Overall Percentage**	80.40%	
Variables entered in Logiteq.		

	B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Gender	3.912	1.593	6.030	1	.014	50.003	2.202	1135.313
Age	1.819	.937	3.768	1	.052	6.164	.983	38.669
MaritalStatus(single)	-1.425	1.228	1.347	1	.246	.241	.022	2.668
Dist.Residence	-1.860	.745	6.242	1	.012	.156	.036	.670
Fly.Experience	-2.844	1.334	4.543	1	.033	.058	.004	.796
Q7			.253	2	.881			
(Captain)	-.348	1.779	.038	1	.845	.706	.022	23.069
(1st Officer)	.452	1.010	.200	1	.654	1.571	.217	11.376
Constant	1.324	3.296	.161	1	.688	3.758		

Source: Authors' field work, 2018

4.0 DISCUSSION

There is a good reason to suspect there is a prevalenceof fatigue among commercial pilots flying within Nigeria's airspace.Close to half of the respondents about 43.2%of those interviewedin this surveyacknowledged havingknowledge of micro sleep among pilots operating within Nigeria’s' air space. Based on this figure, the likelihood of pilots suffering from fatigue is thus high. Interestingly, this observation is similar to the pattern of report noted in the works of Gregory et al (2010);Locke(2014) and The Economist article of 2016 on fatigue among pilots operating in Brazil, America and European countries. With the growth projections and likely increasing patronage of Nigeria's local civil aviation, pilots in the country may be at the risk of increasing level of work fatigue withhigher risk of safety breaches and accidents owing to the negative effect of fatigue.

From theanalysis, attempts to associatefatigue symptoms with the pattern of night sleepof respondent to this survey did not yield any reliable outcome. Generally, circadian disruptions are some of the most critical and reputable source of fatigue identified in literature and are often exhibited asmicro-sleep.Caldwell (2012) noted "when the waking period of a pilot is longer than 16 hours and their pre-duty sleep less than 6 hours,fatigue will likely set in".Asimilar publication in 2012by the British Office of Rail Regulation also noted themounting evidence that "working long weekly hours over long periods increases the risk of accidents and incidents".Being fatigue is noted as “producing impairments on awide range of tasks thatis equivalent to having a blood alcohol concentration above the drink driving limit in most of Europe".This study found no convincing evidence to suggest any influencefrom the pattern of night sleepof respondents and incidence of fatigue. It could therefore be indicativethe suspectedfatigue acknowledged earlier in this study could be from other sources.

This study however found significant association froman extrinsic factor,that is, the level of workloadexpressed by the respondents fromtheir employers and their most importantsymptoms of fatigue. This finding supports in part the findings of Lee and Kim (2018) who noted job assignment and crew scheduling as part of the sources of fatigue among pilots.From our study thereisconvincing evidence to suggest airline operators may be overworking their flight crews particularly pilots which poses a flight risk. Studies by Caldwell(2012)and Locke (2014) have .noted such risk could come in form of negligence of flight crew. One of such negligencewas exhibited in early months of 2018 when theemergencydoor of alocal commercial airlinersuddenly opened during landing. The observation of a passenger close to the emergencydoor was said to have been ignoredby a cabin crew memberbefore take-off. Such indifferenceby the cabin crew staff could emanate from fatigue. Studies such as Caldwell and Caldwell (2003);Novacek(2003);Caldwell et al (2009); Caldwell(2012); Locke (2014); ICAO (2013) all noted an attitude ofindifference; carelessness and impaired logic as part of the classic symptoms associated with fatigue. The flight was at risk of an explosive decompression during flight with a likelihood ofa fatal crash.

The study also established thatsocio-economic attributes of respondents could be associated with the knowledge of micro-sleep episode among pilots. A study by Torregroza-vargas et al (2014) had associated the occurrence of fatigue and accident on the socio-economic characteristics of respondents in a study of truck drivers in Colombia. From the result of this study, knowledge of micro-sleepappears to rest more with male aircrew than their female counterpart. The reason for this more likely to be as a result of the industry being male dominated. This study also found that knowledge of micro sleep isalso 6 times more likely to occur among those withlower ageor young flight crew. Those that are younger are also keen observers of events around them especially within a highly regulated work environment such as the aviation sector. They are likely more expressive of the ideals of the industry rather than older and more mature air crew who may want to cover their tracks.

Although those living closer to the airportappear tohabour more knowledge of fatigue or micro-sleep among pilots, the oddsof this likelihood is however low. This suggeststhe distance of residence maynot bean important source of the knowledge of fatigue among respondents particularly those that live within a 3km radius of the airport. Most local airlines have their headquarters located within the vicinity of the Lagos airport which can be easily accessed by these crew.There was anticipation that such knowledge would increase as distance of residency increases, the reverse was however observed in the result.

The years of flying experience and knowledge of micro-sleep are negatively related suggesting knowledge of fatigue reduces with higher experience among respondents'. This however suggeststhe lower ranking members of the flight crews are more susceptible to the knowledge of fatigue among the crew than the more experienced hands. From the result so far, any attempt to investigate fatigue should focus on junior ranking officers who may be more expressive than the older and more experienced crews. For some reasons captains are less likely to have knowledge of micro-sleepdespite experience. Although both results appear to be achance events, first officers appear to be in better position with information of fatigue or micro-sleep among colleagues. Those socio-economic attributes that do not make meaningful contribution to the knowledge of micro-sleep are marital status of the respondents and the class of aircrew of respondents.

Based on the findings of this study, the following recommendations are proposed to mitigate and manage the risk from pilot fatigue.Foremost, airlines and the local air transport authority (NCAA) must pay careful attention to flight crew work schedules in order to ensure the work rules as recommended by International Civil Aviation Organization is not violated. Furthermore, periodic assessment should be made on aircrew in the country as a way to ensure compliance.

The study shows information on the knowledge of pilot fatigue is common among lower ranking flight crew members; the regulatory agency should explore such area of knowledge to fish out information on fatigue. Finally the regulatory authority in Nigeria should enforce international best practices for crew work schedule by airlines operating in Nigeria.The sleep schedule of flight crew should be monitored, good night sleep will likely avoid incidence of micro-sleep.

5.0 CONCLUSSION

In conclusion, thisstudy established that fatigue exist among pilots operating in Nigeria civil aviation particularly among less experienced crew members. The likely source of the fatigue as a risk is from work load induced by airline operators or management. The effort to lower the risk of fatigue in the industry must focus on lower ranking crew by regulatory authorities.Other area of research may be necessary to be investigated, this study examined fatigue among flight crews alone, it may be necessary to extend the study to other stake holders in flight operations such as ground crew, maintenance engineers and air traffic controllers who all jointly contribute to the human error phenomenon in the aviation sector.

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