Existing Human factors Risks in Eastern Africa Aviation Operation: Focus on skill Risks and Aeromedical factors. A Cross-sectional Study.

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Abstract

Background:

Aviation safety in the Africa region has continued to be a concern for the International Civil Aviation Organization (ICAO) and the industry as a whole. ICAO's 2012 accident statistics show that Africa had an accident rate of 5.3 per one million departures with 3% of the worldwide traffic distribution. A study set out to examine the existing human factors risks in the region's aviation operation with a particular focus on skill and aeromedical risks exist in the Eastern African region.

Methodology:

A cross-sectional study research design was used with quantitative methods of data collection applied; perceptual information was collected by the use of a survey.

Results:

Four categories of variables investigated skills required for the job and had a positive moderately strong correlation with values between 0.4-0.6 and were statistically significant with $p < 0.05$. Another four had a weak positive correlation which is less than 0.4. Eleven out of fifteen categories of the aeromedical variables had a positive moderately strong correlation with values between 0.4-0.6. Four had a weak positive correlation which was less than 0.4. Results did show current skill-related risks in public safety, operations monitoring, quality control, troubleshooting, design and telecommunications, and public safety. Most of the above skills had a direct correlation with each other.

Conclusions:

Aeromedical factors affecting performance included fitness and health, stress, time pressure, and deadlines, sleep-related issues, fatigue, cigarette smoking, alcohol, pain, and nervousness.

Recommendations:

There is a need for redefining human factors risks in Eastern Africa and incorporating them in the curriculum at all levels to ensure that individuals are capable of functioning effectively and safely in a range of situations and environments continuous as well as aeromedical assessment should be designed to fully capture the existing skill related and aeromedical risks in the region and improve the region's safety record.

Keywords: Aeromedical factors, Eastern Africa, Human factors, Human Performance and Limitations, Skills Background, Date Submitted: 2022-09-02 Date Accepted: 2022-09-22

1. Background

Aviation, safety performance has not been evenly distributed across all segments of commercial aviation, nor among all countries and regions

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of the world. (International Civil Aviation Organization [ICAO], 2014) African aviation safety is a continuous concern to ICAO and the aviation industry, with a 3% accident rate at 5,300,000 departures per million (ICAO 2013). (Munene, 2016).

Unfortunately, reliable fatality rates for many aviation operators worldwide are not readily available and this makes safety improvements in these regions quite hard. (ICAO, 2014).

Accidents are occurring for various reasons and human error is cited as the cause of over 70% of these accidents. Understanding human psychology and physiology helps us to put in context how an understanding of human limitations and capabilities contributes to the improvement of flight safety through the reduction of human error (Badshaw, 2001). Martins, *et. al.,* (2014) note that most accident investigations conclude that human is guilty at a rate as high as 80%. Usually, when an accident or incident occurs, the pilot is pinpointed as the guilty party even before the establishment of facts and thorough investigations are done. The readings of the Black Boxes show that 70% to 80% of accidents are due to human error or as a result of failures related to human factors. (FAA, 2010).

Human factors is a popular term in the commercial aviation industry since it is now known that error is the cause of many aviation accidents and incidents and not mechanical failure. Human factors cover the understanding of human limitations and capability, this understanding is later applied in the deployment and design of systems and services It is multidisciplinary and attains information and conclusions by working with the fields of industrial design, operations research, engineering, psychology, statistics, operations research and anthropometry. The various disciplines in human factors include Computer Science, Cognitive Science, Experimental Psychology, Clinical Psychology, Organizational Psychology, Educational Psychology, Anthropometrics, Medical Science, Safety Engineering, and Industrial Engineering. The study of human factors is complex and does not solve errors immediately or cause an instant change in a given situation.

The classic term, “pilot error” or “human error”, is attributed to accidents or incidents over 75% of the time (Phillips, 1994). This needs to be put in context with regards to developing countries that have much poorer safety records as compared to others and so there is a need to determine the existing human factors risks in Eastern Africa region.

The Eastern African region is a substandard performer in aviation safety. In the region existing human factors risks are not elaborately investigated and documented partly because common aeromedical conditions are not detectable at autopsy (hypoxia, spatial disorientation, fatigue, stress), complicating the ability to indict medical causation. There are relatively poor records about the safety implications of aeromedical variables such as distress, fatigue, spatial disorientation, or mild hypoxia. No dynamic assessment processes have been done to assess the effects of hazards such as distress, hypoxia, fatigue, workload, and spatial disorientation on performance. Dynamic processes are important in accident chains but are generally not detectable post-flight or post-crash. Furthermore, aerospace medicine assessment tools are very necessary for aviation but they are not evolving with the aerospace environment. Shortcomings with these tools are at the pre-flight selection and retention level and inflight retention, selection, performance, and enhancement level. Hence the need for a study of the existing human factors risks in the region’s aviation operations including existing skills-based human factors risks and aeromedical risks in the region.

Much as there are different reasons why aircraft accidents occur, studies reveal that most of these causes are related to human factors and not technical failures. Enormous resources and efforts are needed when undertaking accident and incident investigations. This is not a total loss because the information gained from such investigation work is greatly improving aviation safety by reducing causes of similar accidents and incidents in the future. Safety is improved through investigating each accident independently, then learning from it and ensuring that similar accidents do not occur. Looking at the causes of accidents in a broad sense and comparing them across regions and countries over time gives great gain to the aviation industry (Oster, 2013). The purpose of this study was to identify existing human factors risks in the East African region, characterizing these risks through modeling exposure and consequences, prioritizing the risks, and making recommendations about necessary improvements and what factors contributed to the accident is very important. (GAO, 2012, Oster, 2013). Information from such studies is used to inform the designing of aircraft, structuring of aviation training, and the making of policies and procedures which help humans perform better, perform with better capabilities while lowering the natural limitations, in turn, it will help in making key decisions that will improve safety in the study region. Understanding when accidents are most likely to occur helps target approaches to improve safety, but to reduce accidents it is also necessary to try to determine why they occur.

2. Methodology

Study design:

A cross-sectional study research design was used where quantitative methods of data collection were applied; perceptual information was collected by the use of a survey.

Setting:

The study countries: Kenya and Uganda were selected based on their central location in the Eastern Africa region.

Sample:

The first step involved a purposive selection of 43, operators with valid licenses, trainers, and employers from Kenya and Uganda for the period between 2018 and 2020. A purposive sampling procedure was used to draw a representative sample of aviation stakeholders. The target sample included Aviation Managers, Employers, Pilots, Student Pilots, Flight Instructors, Air Traffic Controllers (ATC), Ground Operators, Engineers, Safety officers, and Security.

Methods and tools:

Questionnaires; structured self-administered questionnaires with an informed consent form were administered to different members in each study group, who were key informants, supervisors, and employers. The questionnaire tool contained open-ended and closed-ended categories of questions intended to collect qualitative and quantitative data when filled in by respondents. The questionnaires used in this research were generated based on research objectives and the dimensions of the independent and dependent variables and structured into sections for ease of capture of data. The questions asked reflected on the different aspects of human physiology in Human Performance and Limitations related to daily operations, aviation incidents, and accidents.

Variables:

Knowledge, skills, and aeromedical factors of trained aviation personnel in the region were established using questionnaires and guiding question tools.

Bias:

Some of the ethical considerations in this research were; written consent of respondents was sought from each respondent before engagement; confidentiality was ensured when interacting with the respondents and disseminating information, and all information given by respondents was handled with confidentiality. Respondent anonymity – all addresses and contacts as well as names of respondents remained anonymous during and after the study.

Data analysis:

Involved coding the data and subjecting it to the statistical package SigmaPlot. Analysis of binary variables was done with correlation to investigate associations between different factors.

3. Results:

The above figure showed that both female participants from Kenya and Uganda were less than the males.

Uganda had most of its participants between the ages of 26- 35 while Kenya had most of its participants between 36- 45 years of age. It is

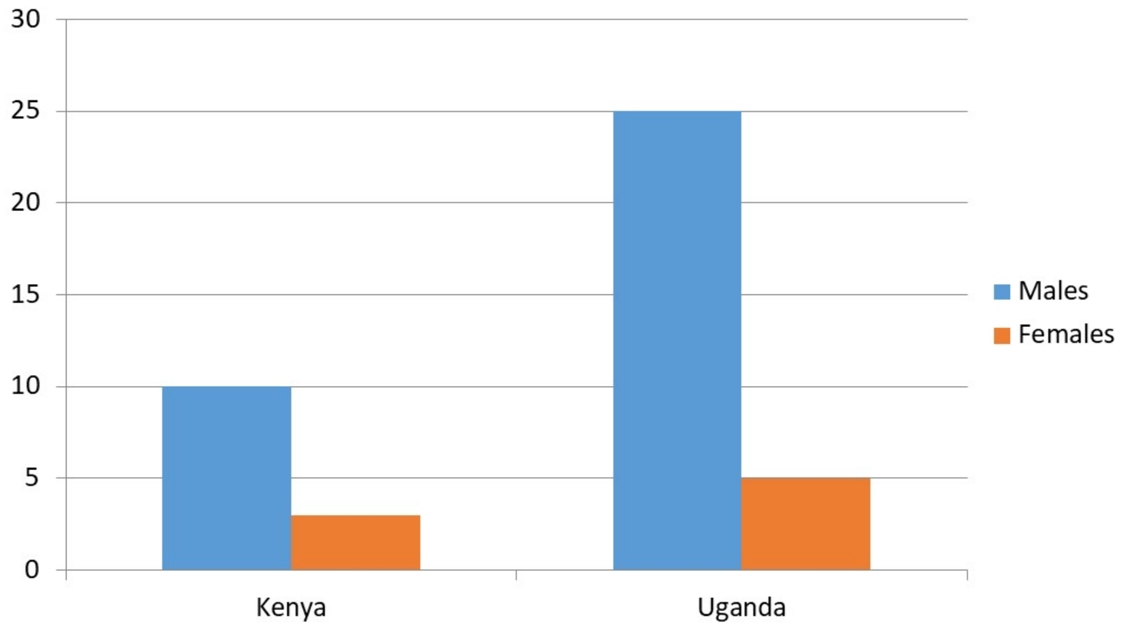

Figure 1: Gender comparison of participants from Kenya and Uganda

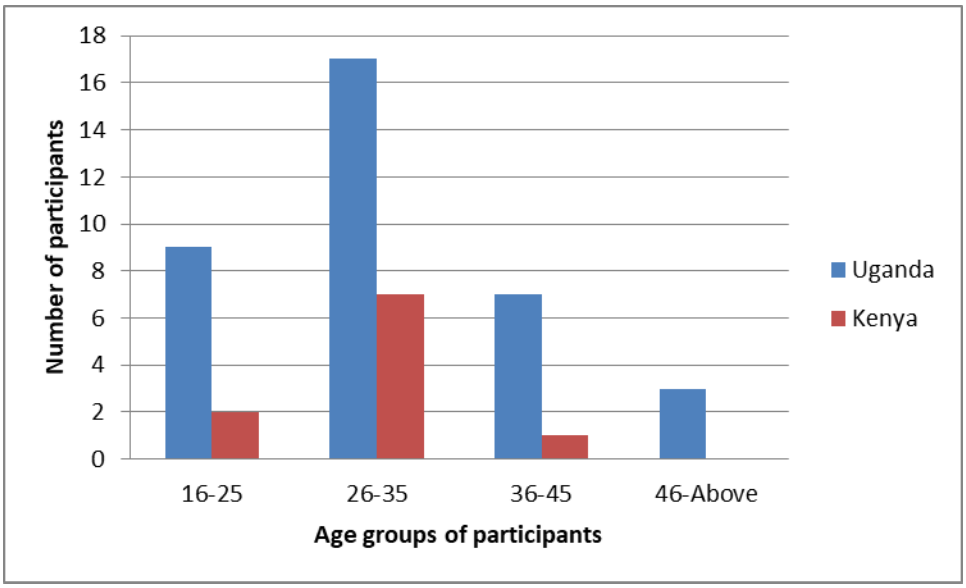

Figure 2: Comparison of age groups between participants from Kenya and Uganda

worth noting that Uganda had some participants above the age of 46.

Figure 3 showed that the largest number of participants from Kenya were pilots and engineers followed by ATC, flight operators, and management. In Uganda, a big percentage of participants were engineers, followed by pilots, managers, and lastly flight operators.

The highest level of education for participants from Kenya and Uganda was mainly at the license level. This was followed by diploma holders and lastly those with other qualifications like seminars and certificates.

Skill based risks

The highest level of human performance training for participants from Kenya and Uganda was mainly at a basic level. This was followed by certificate holders, diplomas, elementary, and lastly those with no qualifications.

The table 1 closely analyzed the correlation among different skills required for the job among the participants from both countries. Four categories of the variables had a positive moderately strong correlation with values between 0.4-0.6 and were significant with $p < 0.05$. Another four had a weak positive correlation which is less than 0.4 and was significant with $p < 0.05$.

Aeromedical risks

The table 2 closely analyzed the correlation between different aeromedical factors among the participants from both countries. Eleven out of fifteen categories of the above variables had a positive moderately strong correlation with values between 0.4-0.6 and were significant with $p < 0.05$. Another four had a weak positive correlation which was less than 0.4 and was significant with $p < 0.05$.

This shows that 38 out of the 43 participants had issues with their weight, 30 out of 43 consumed alcohol 27 of the participants were cigarette smokers and only 3 had shortness of breath.

4. Discussion:

The results in table 1 showed that there was a direct correlation between public safety, operations monitoring, quality control, troubleshooting, design and telecommunications, and public safety with design and telecommunication. Keeping in mind that Shappell *et. al.,* 2007 realised that much as situational and demographic variables are physical and easier to study, it is not the case with the human error where it is not easy to ascertain methods of investigation that are acceptable and easy to understand.

Martin, *et. al.,* 2014 argues that the human component varies in aviation and this is a possible reason for human error. A system failure due to human variability has been observed as a source of error causing accidents and incidents (Reason, 1990). The high level of misunderstanding in aviation operations arises as a result of a lack of control when performing a task: due to poor motivation, stress and fatigue, failure to control the situation, inadequate training, and poor instructions (Martin, *et. al.,* 2014).

Reason in 1990 wrote that accidents are not a one-day event but do occur days, weeks, or even years before the actual event. However, neglect and/or poor attention leading to a crash should reflect that there is a particular level of user and system interactions that created favourable conditions for the accident to occur.

CENIPA (Central Research and Prevention of Accidents, Brazil) and NTSB (National Transportation Safety Bureau, USA) suggests a list of difficulties in operation, the type of training aircraft, and its maintenance, as important to note in the training of crew worldwide. They further note that these affect the safety of the flight but unfortunately they are not emphasized during training. It is also worth noting that aviation trainers and professionals in aviation are not aware of the circumstances leading to accidents and incidents, sometimes as a result of a lack of experience (Martins, *et. al.,* 2014).

Optimum performance in all these areas is directly related to training/ skill and level of experience. Levels of training, evaluation of training, and experience directly affect the skill.

An understanding of components that lead to errors can be reached by gagging performance errors, evaluating crew qualifications and train-

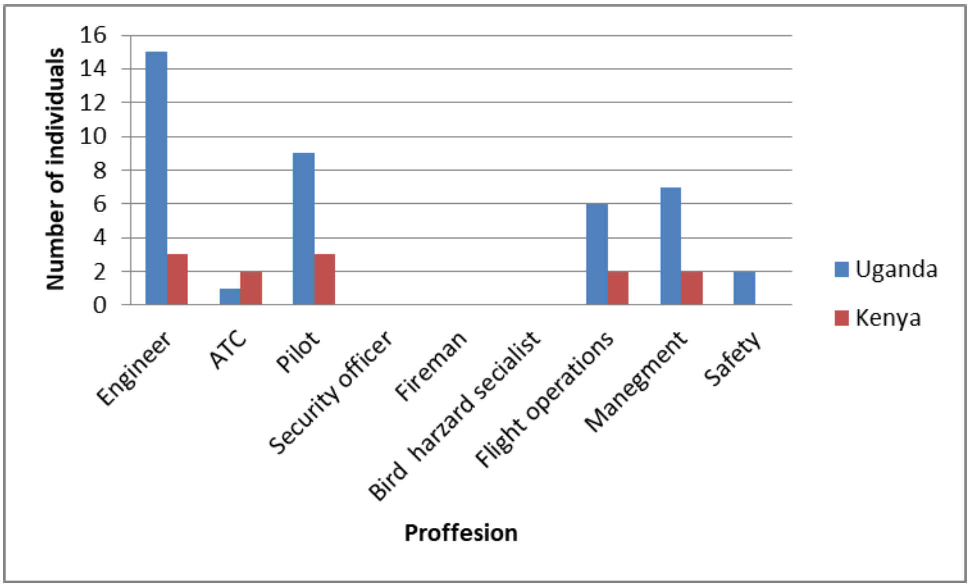

Figure 3: Different professions of participants from Kenya and Uganda

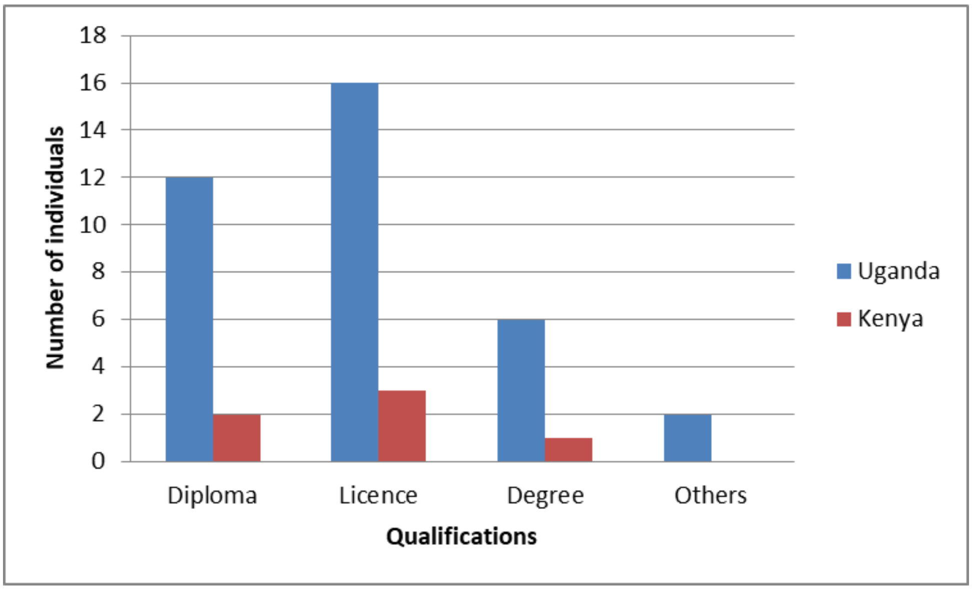

Figure 4: Level of education of participants from Kenyaand Uganda

Table 1: **Correlation of data on skills required for the job between Kenyan and Ugandan participants**

	Value	p- value
Operations Monitoring x Public Safety	0.562	0.00003
Operations Monitoring x Design	0.317	0.025
Quality Control x Public safety	0.312	0.03
Quality Control x Trouble shooting	0.550	0.0000596
Trouble shooting x Public safety	0.394	0.00582
Trouble shooting x Telecommunication	0.609	0.000000
Public safety x Design	0.454	0.00127
Public safety x Telecommunication	0.313	0.0344

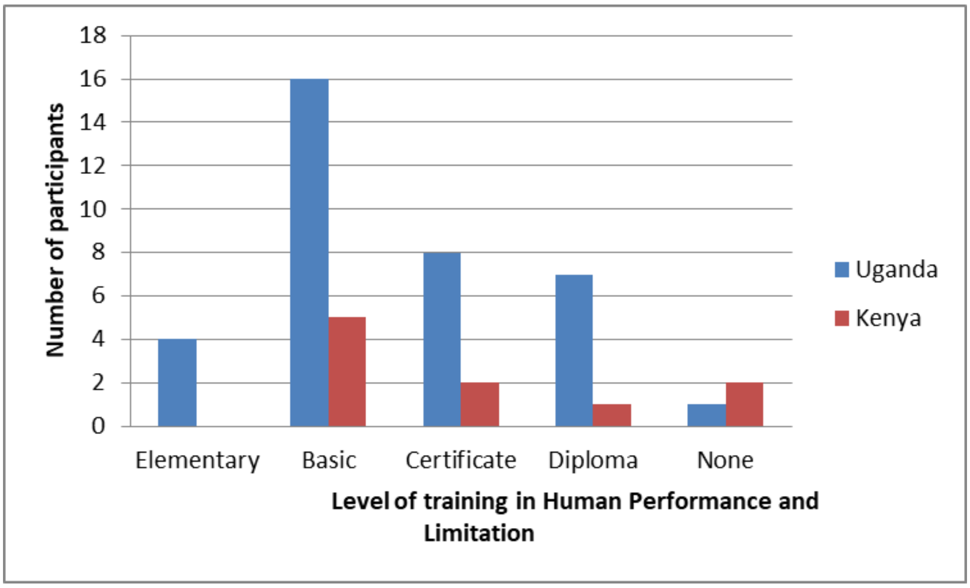

Figure 5: Level of Human performance and limitation training of participants from Kenya and Uganda

Table 2: **Correlation of data on Aeromedical factors for Kenyan and Ugandan participants**

	Value	p- value
Problem solving x Stress	0.537	0.0000946
Problem solving x General Health	0.276	0.0574
Problem solving x Concentration	0.517	0.000264
Copping with stress x General Health	0.376	0.00086
Copping with stress x Sleep disorders	0.320	0.0306
Copping with stress x Concentration	0.509	0.0003
Concerns about illness x General Health	0.414	0.00298
General Health x Sleep disorders	0.513	0.0003
General Health x Concentration	0.589	0.0000184
General Health x Appetite for food	0.447	0.00195
Sleep disorders x Concentration	0.459	0.00143
Sleep disorders x Appetite for food	0.318	0.031
Concentration x Appetite for food	0.435	0.00270
Appetite for food x well being	0.467	0.00115
Anxiety x weight gain	0.487	0.000659

ing, and examining standard operating procedures and regulations. Over and over again it has been observed that errors can be identified and predicted by crew members. Errors have multiple causal factors which relate to the level of training, operating procedures, regulatory policies, or the type of job. After all this, the difficult task is with identifying the corrective measures before a much more dangerous situation occurs. Different teams deal with human factors worldwide, these included The FAA team in the USA, (Dekker, 2003), they believe that by improving error detection and eliminating certain features on the aircraft, manufacturers can easily improve operation when they detect future causes of errors. Unfortunately aviation operations approvals and regulations today do not go through the tedious process of evaluating the project details from a flight deck to reduce the occurrence of pilot errors and other problems in performance problems

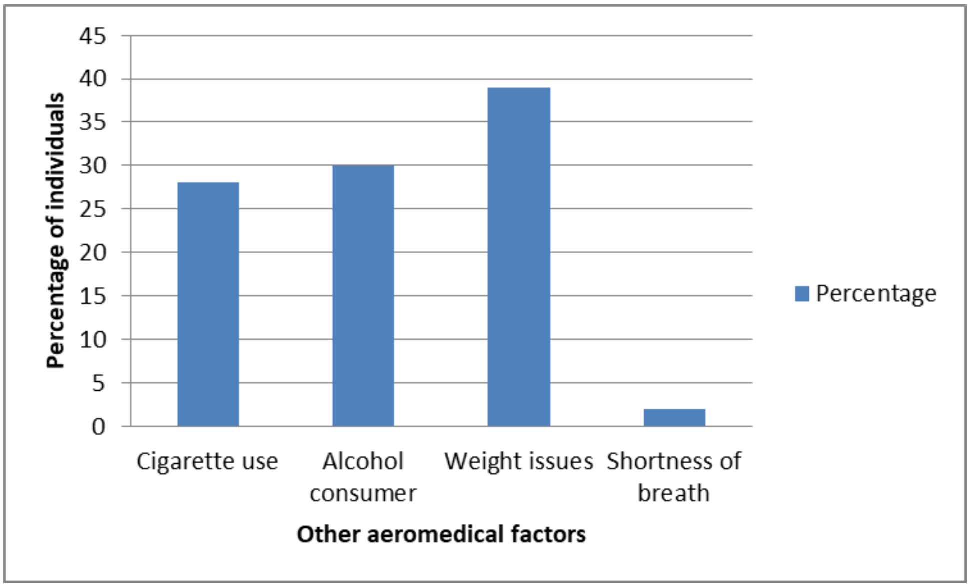

Figure 6: Other significant aeromedical factors forparticipants from both Kenya and Uganda

that lead to accidents (Martins *et. al.,* 2014).

Haslinda and Mahyuddin (2009) training can be made more effective by developing systems that align training effectiveness with organization activities. They further suggest training evaluation should check effectiveness in behaviour, learning, reaction, and results in level (Hamid Khan, 2002). Effectiveness goes to the heart of what training and development are all about in an organization: giving employees the knowledge and skills they need to perform their jobs effectively (Noe and Schmitt, 2006) Cheng and Ho (2001). One of the cited reasons for considering training and development as an unnecessary and expensive expenditure is that most organizations are unsure of the contributions of training and development toward the organization's overall performance due to a lack of evaluation. (Bramley and Kitson, 1994) (WCES, 2012).

Giving the student or crew, the opportunity of self-knowledge, identifying possible "psychological breakdowns" that biological features can present and can endanger the safety of flight. It should be given, thus, more humane and scientific support to the crew and everyone else involved with the aerial activity, reducing factors that can cause incidents and accidents (Martins, *et. al.*, 2014). The authors go on to write that and define human cognition as the mental processes that are involved in thinking and their use. Due to its multidisciplinary nature, it focuses on anthropology, psychobiology, cognitive psychology, philosophy, artificial intelligence, and linguistics. These fields are being employed in a better understanding of human perception, memory, and thinking, which leads to a much broader understanding of human behavior. Cognition is then considered a broad field, composed of mental imagery, attention, language, problem-solving, creativity, decision making, consciousness, cognitive changes during development throughout life, human intelligence perception, memory, reasoning, and artificial intelligence among others. Humane support during aerial activity and self-knowledge of the crew or the aviation trainee is very very important but allowing individuals to identify their own "psychological breakdowns" during flight is very dangerous (Martins, *et. al.,* 2014).

Molloy and O'Boyle, (2005) further note that individual human factors are wide and shift from time to time based on training and competency which is relevant to the current situation. The authors support that defined areas of competence are necessary for developing a study curriculum for aviation efficiency and safety improvement. For example; complex automation changes the procedures for implementing certain activities in certain types of aircraft even if they are different models or series under the same manufacturer. Any loopholes in training or inadequate training will make it difficult for the crew to understand procedures. Accident investigations suggested that pilot training should include an evaluation of the biological machine, a psychological stage, which allows the trainee or crew to check their self-knowledge and identify "psychological breakdowns". This would give more humane support to the crew and trainee during aerial activity, and reduce accidents and incidents. Accident investigators recommend a psychological phase in the crew's training. (Dekker 2003). Another example of an area of competence that needs to be incorporated into the study region's aviation curriculum is automation, as it has a visible impact on human performance. The myth that there is less need for investing in human skill as automation increases stands to be investigated". Various experiments show that in humans there is a demand for new knowledge and greater skills created in response to better handling automation. FAA 2010 investigations, during automated flight platforms, showed that aviation companies are reporting problems in nature and the complexity of the flights. This is because automated systems require additional knowledge and training of the crew on how to work subsystems and automated methods differently. Studies also show mental models have to be created in response to modified system operations in the industry. This means that there is a shift from manual to automatic operations and it does affect the logical flow of information too. The normal training process does not teach the crew how to manage new situations in an automated environment but does teach them how to do so in normal situations only. This kind of situation is very serious and manifests in aviation investigation reports as the crew fails to know what to do in emergencies after computer decisions are taken. (NTSB, 2011).

showed that data obtained on outstanding aeromedical factors included stress, sleep, appetite, weight, concentration, alcohol, smoking, anxiety, and age. The findings by Reason's (1977 to 2001) on Human Factors proved that stress was both domestic and work-related. Since it is hard to separate our work and home life, the two will inevitably affect each other. Overloadingcan lead to stress. If someone appears to be suffering from stress, it is wise not to give them a complex or critical task as this will add to stress and increase the likelihood of error.

Stress affects performance among other human factors as in Table 2 stress has a weak positive correlation with sleep at a value of 0.320 and a p-value of 0.0306, stress and problem solving had a moderate positive correlation with problem-solving at a value of 0.537 and a p-value 0.0000946. In this context stress is the psycophysical problem leading to tension (Congeton *et. al.,* 1997) whether it is actual or perceived, it creates a situational imbalance between demands and resources available (Desaulnires, 1997: Mathews 2002). Teamwork may relieve and eliminate stress. However, Glasser *et. al.*, 1999 argue that the relationship between teamwork and stress is relatively weak. Serfaty *et. al.,* 1993 research results showed that efficient teams were able to maintain the same level of performance with one-third of the time available to make decisions.

Sleep; people working long hours, (particularly unsociable hours) have an increased likelihood that they will error. Adults require 8 hours of sleep to function properly and as the good rule of thumb states; every hour of high-quality sleep is good for two hours of activity Reason's work (1977 to 2001). Wickens, *et. al.,* (2004) describes sleep disruption as a night sleep of less than 7 hours. Another author also notes that cognitive abilities are affected by sleep disturbance. (Baranski, *et. al.,* 2011), this is in agreement with findings in table 2 where sleep had a moderate correlation with concentration at a correlation value of 0.459 at a p-value of 0.00143. Sleep issues arise after people have been working long hours, (particularly unsociable hours) and have an increased likelihood that they will error due to interruption of the circadian rhythm.

Fatigue (results from the distress thermometer are not shown); if someone appears visually tired, it is advised that they do not undertake any form of a critical task to minimize the chances of error. One of the key informants from the operator's management noted that; "All flying involves some level of stress and fatigue".

The time spent on task can also be a cause of fatigue (Van Dongen, Belenky, and Krueger, 2011: Isaac and Ruitenberg, 1999). Gilbertova and Gilvicky, (1967) noted that the level of attention decreased when performing monotonous tasks, but increased when performing a new or demanding. During many incidents and accidents, fatigue has been pinpointed (Dorrian *et. al.,* 2007). Some authors note that there is a complex relationship between fatigue and performance. As the two may not directly influence each other but may have other intervening influences such as demand in performing a task and motivation. Martins *et. al.*, 2014 note that emotional fatigue and stress among crew members can increase as a result of reducing cockpit crew members to only two individuals. An example is in large four-engine aircrafts carrying hundreds of passengers with only 2 cock pit crew members. All sensitive operations including emergency procedures, monitoring, and sensitive checks are carried out by the two individuals.

Stern, *et. al.,* (1994) also noted that fatigue also affects attention. Prof Reason's work (1977 to 2001) still notes that fatigue arises if someone appears visually tired, it is advised that they do not undertake any form of a critical task to minimize the chances of error. Furthermore, he also noted that low levels of physical fitness can lead to tasks not being carried out correctly especially if it requires physical exertion. Given a human "black-box" and associated systemic changes, potential positive outcomes include fatigue management using dynamic cognitive/physiologic monitoring protocols, automated G-tolerance or hypoxia algorithms, and post-event analysis. We are data poor relative to the safety implications of variables such as fatigue, spatial disorientation, or mild hypoxia. These may be important in accident chains, but are generally not detectable post-flight or post-crash (Steinkraus, *et. al.,* 2012).

Martins, *et. al.,* 2014 pinpoint the amount of rest and body rhythms, the number of sleep hours, and related sleep disorders, acceleration due to gravity and G forces, high altitude, night take-off illusions, and disorientation among others notes as predictable and very important reduction of human error but few studies have been carried out on them. arising from causes so predictable, yet so little studied. He further suggests that scenario-based studies should be done at individual workplaces and on specific aircraft.

Figure 6 shows that a high number of the participants smoked cigarettes. Tobacco smoking has harmful effects in just about every respect. In particular, on the respiratory system and cardiovascular systems, it reduces the ability to withstand G- forces and the effects of hypoxia and degrades night vision as well. Cigarette smoke contains carbon monoxide, a poisonous gas that renders haemoglobin unable to bind to oxygen. Figure 6 still shows that a high number of the participants consumed alcohol. Alcohol potentially damages the body directly, and immediately, and negatively affects human performance. It degrades the ability to perform tasks properly. It disrupts sleep patterns and loss of REM sleep, leading to fatigue, decreasing hypoxia threshold, creating a greater inability to cope with lack of oxygen at altitude, reduction in quality of vision, and diminishing balance among others (CAE ATPL 2020).

5. Conclusion

Analysis of existing human factors risks in the region's aviation operations showed that the current risks are in public safety, operations monitoring, quality control, troubleshooting, design and telecommunications, and public safety. Most of the above skills had a direct correlation with each other. Aeromedical factors affecting performance included fitness and health, stress, time pressure and deadlines, sleep, fatigue, cigarette smoking, alcohol, pain, and nervousness.

Recommendations:

Include a need for redefining human factors areas of competence in Eastern Africa and modifying the training curriculum with evidence-based changes to improve regional aviation performance and safety as recommended by Molloy, and O'Boyle, (2005). Secondly, an evaluation of regional aviation training and the need for aeromedical assessment tools that can fully capture the existing aeromedical risks in the region is necessary.

6. List of Abbreviations.

ASMs: Aeromedical specialists
AME: Aviation Medical Examiners
ATPL: Airline Transport Pilot License
CRM: Crew Resource Management
EASA: European Aviation Safety Agency
FAA: Federal Aviation Administration
HFACS: Human Factors Analysis and Classification System
HRD: Human Resource Development
ICAO: International Civil Aviation Organization
PPL: Private Pilot License
NTSB: National Transportation Safety Bureau
SMS: Safety Management System
CAA: Civil Aviation Authority
IATA: International Air Transport Association
SACAA: South African Civil Aviation Authority
KCAA: Kenya Civil Aviation Authority

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