PREVALENCE AND PRACTICES ASSOCIATED WITH HUMAN *TAENIA SOLIUM* INFECTION IN MBOZI DISTRICT, MBEYA REGION

Gloria Mwanjali

Master of Science in Tropical Diseases Control Dissertation

Muhimbili University of Health and Allied Sciences

May, 2010

PREVALENCE AND PRACTICES SSOCIATED WITH HUMAN *TAENIA SOLIUM* INFECTION IN MBOZI DISTRICT, MBEYA REGION

Gloria Mwanjali, BSc. N

Master of Science in Tropical Diseases Control Dissertation
Muhimbili University of Health and Allied Sciences
May, 2010

PREVALENCE AND PRACTICES ASSOCIATED WITH HUMAN *TAENIA SOLIUM* INFECTION IN MBOZI DISTRICT, MBEYA REGION

By

Gloria Mwanjali

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master of Science in Tropical Diseases Control of the Muhimbili University of Health and Allied Sciences (MUHAS)

Muhimbili University of Health and Allied Sciences

May, 2010

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by Muhimbili University of Health and Allied Sciences a dissertation entitled ***Prevalence and practices associated with human Taenia solium infection in Mbozi District, Mbeya region,*** in Fulfilment of the requirements for the degree of Master of Science in Tropical Diseases Control of the Muhimbili University of Health and Allied Sciences (MUHAS).

Prof. Charles M. Kihamia

(Supervisor)

Date: 31/05/2010

Dr. Deodatus C.V. Kakoko

(Supervisor)

Date: 31/05/2010

DECLARATION AND COPYRIGHT

I, **Gloria Mwanjali,** declare that this **dissertation** is my own original work and that it has not been presented and will not be presented to any other University for a similar or any other degree award.

Signature: _____ Date: 31.05.2010

This dissertation is copyright material protected under the Berne Convention, the Copyright Act 1999 and other international and national enactments, in that behalf, on intellectual property. It may not be reproduced by any means, in full or in part, except for short extracts in fair dealing, for research or private study, critical scholarly review or discourse with an acknowledgement, without the written permission of the Directorate of Postgraduate Studies, on behalf of both the author and the Muhimbili University of Health and Allied Sciences.

ACKNOWLEDGEMENT

This study was financed by the Danish International Development Agency (DANIDA) through Cross Disciplinary Risk Assessment of *Taenia solium* Cysticercosis in Eastern and Southern Africa (CESA) project at Sokoine University of Agriculture (SUA).

I wish to express my sincere gratitude to Dr. Arve Lee Willingham III of the Danish Centre for Experimental Parasitology (CEP), Department of Pathobiology, Royal Veterinary and Agriculture University (RVAU) in Denmark and Prof. Faustine P. Lekule, Head, Department of Animal Science and Production (SUA) for their effort to ensure this study received funds.

I am grateful to Prof. Charles M. Kihamia (Supervisor), Department of Parasitology and Medical Entomology (MUHAS); Dr. Deodatus C.V. Kakoko (Supervisor), Department of Behavioral Sciences (MUHAS); and CESA group for devoting their time on various technical issues until the end of this study.

Many thanks are due to the entire staff members of Centre of Disease Control and Prevention (CDC) Atlanta, Department of Parasitic Diseases especially Dr. Patricia Wilkins for inviting me to conduct laboratory analysis of serum samples using Copro-Ag ELISA, Ab-ELISA (rT24h) and Western blot (rES38). Also thanks are due to Dr. Chummy Sikasunge and other staff of Department of Para-clinical Studies, Samora Machel School of Veterinary Medicine at University of Zambia (Lusaka) for giving me all the necessary cooperation during laboratory analysis of samples using Ag-ELISA.

I would like to thank all academic staff members of School of Public Health and Social Sciences (SPHSS) especially Department of the Parasitology and Medical Entomology for their guidance on this study.

Special thanks go to Prof. Karim Hirji, Department of Epidemiology and Biostatistics in SPHSS, MUHAS for his close guidance during analysis of the data.

I would also like to thank the local communities, district and regional authorities of Mbozi district and Mbeya region for their good cooperation that I received as well as for allowing me to carry out the field study in their administrative areas.

DEDICATION

This dissertation is dedicated to my daughter Bryony Vanessa Mwanjali who has always been a source of joy whenever I came home after school and field work.

ABSTRACT

Background: Human cysticercosis/taeniosis is potentially among the zoonotic infections involving humans and swine. In Tanzania, studies on porcine cysticercosis show the disease to be hyperendemic in Northern (17.4%) and Southern (16%) parts of the country. In the Southern part of Tanzania, Mbozi district was leading with a prevalence of 32%.

Objective: To determine the prevalence of, and identify practices associated with, human *Taenia solium* infections in Mbozi district, Mbeya region, Tanzania.

Materials and methods: A community-based descriptive cross-sectional study using cluster random sampling was conducted from April to July 2009 in Mbozi district, Mbeya region. A total of 830 participants between the ages of 15 to 60 years were enrolled in the study. Participants below 15 and above 60 years; people with mental illness; and people who were not willing to participate were excluded from the study.

Accordingly, 830 sera were collected and analyzed using Ag-ELISA (B158/B60) and Ab-ELISA (rT24h) and 820 stool samples were analyzed for *Taenia* species taeniosis using Copro-AgELISA while confirmation of *T. solium* taeniosis was done using Western blot (rES38). Furthermore, Formal-ether Concentration (FEC) technique was used for examining the presence of *Taenia* species eggs and other intestinal parasites. Information on demographic and potential risk factors was obtained using structured questionnaire.

Results: Seroprevalence of human cysticercosis was 16.7% by Ag-ELISA (active cysticercosis) and 45.3% by Ab-ELISA (exposure to human cysticercosis). Multivariate analysis on the risk factors associated with human cysticercosis using logistic regression statistical analysis showed seroprevalence of active cysticercosis to

be significantly associated with increase in age, age group 36-45 years (OR= 2.5; 95% CI =1.2-5.0) and age group between 46-60 years (OR =2.6; 95% C I = 1.3-5.3) ; hand washing practices by dipping (OR= 3.8; 95% CI=2.5-5.9), and being confirmed carrier of *Taenia* species by Copro-AgELISA (OR= 2.6; 95% CI = 1.3-5.2). Furthermore, among participants with active cysticercosis 30 (54.5%) confirmed to have cystic lesion suggestive of neurocysticercosis on CT-scan.

On other hand exposure to human cysticercosis showed to be significantly associated with sex (Male) (OR=1.6; 95% CI=1.1-2.1), hand washing by dipping method (OR=5.10; 95% CI=3.7- 6.9), being confirmed carrier of *Taenia* species by Copro-AgELISA (OR= 2.6; 95% CI=1.3-5.2), and using unsafe water (OR=1.9; 95% CI= 1.4-2.6) Copro-pasitological analysis of stool showed the prevalence of *Taenia* species taeniosis to be 5.2% (by Copro-AgELISA) and *T. solium* taeniosis 4.1% by western blot (rES38). While it showed a prevalence of 1.1% by formal-ether concentration technique. On adjusting for other factors in the logistic regression model, only previous history of passing proglottides was found to be statistically significant (OR = 2.8; 95% CI = 1.4 - 5.8).

Conclusions and recommendations: Findings of the present study show that *Taenia solium* infection (cysticercosis and taeniosis) is hyperendemic in Mbozi district, Mbeya region. Therefore, multidisciplinary control effort should be carried out in that district in order to prevent the spread of the parasite.

TABLE OF CONTENTS

CERTIFICATION ii
DECLARATION AND COPYRIGHT iii
ACKOWLEDGEMENT iv
DEDICATION..... vi
ABSTRACT vii
TABLE OF CONTENTS ix
LIST OF TABLES xiv
LIST OF FIGURES (BAR CHARTS) xv
LIST OF ABBREVIATIONS xvi

CHAPTER ONE 1
1.0 INTRODUCTION 1
1.1 Background to the study 2
1.2 Global situation of *Taenia solium* infections 2
1.2.1 Situation in America (Latin America and Brazil) 2
1.2.2 Situation in Asia 2
1.2.3. Situation in Western and Central Africa 3
1.2.4. Situation in Eastern and Southern Africa 3
1.2.5. Situation in Tanzania 4

CHAPTER TWO 5
2.0 LITERATURE REVIEW 5
2.1 The epidemiology of human *Taenia solium* infection 5
2.2 The burden of disease 8
2.3 The biology of *Taenia solium* 10
2.4 The life cycle of *Taenia solium* 11
2.5 The clinical manifestations of human cysticercosis/taeniosis 12
2.6 Diagnostic methods for human *Taenia solium* infection 13

2.6.1 Parasitological diagnosis for human *Taenia solium* infection 13
2.6.2 Immunodiagnostic methods for human *Taenia solium* infection 14
2.6.3 Immunodiagnosis for taeniosis 14
2.6.4 Immunodiagnosis for human cysticercosis 15
2.6.4.1 Antibody detection for for human cysticercosis 15
2.6.4.2 Antigen detection for for human cysticercosis 16
2.6.4.3 Diagnosis for *Taenia solium* human cysticercosis by neuroimaging 17
2.6.4.4 Molecular diagnosis for human *Taenia solium* infection 18
2.7 Treatments for human cysticercosis/taeniosis 19
2.8 Prevention and control of human cysticercosis/taeniosis 20
2.8.1 Prevention and control of human cysticercosis/taeniosis by abattoir inspection of pork 20
2.8.2 Prevention and control of human cysticercosis/taeniosis by health education campaigns21
2.8.3 Prevention and control of human cysticercosis/taeniosis by human mass treatment 21
2.8.4 Prevention and control of human cysticercosis/taeniosis by treatment of infected pigs. 22
2.8.5 Prevention and control of human cysticercosis/taeniosis by pigs vaccination 23
2.8.6 Prevention and control of human cysticercosis/taeniosis by development 24
2.9 Challenges in prevention and control of human cysticercosis/taeniosis 24

CHAPTER THREE 25
3.0 RESEARCH PROBLEM 25
3.1 Statement of the problem 25
3.2 Rationale of the research study 26
3.3 Research questions 27
3.3.1 General research questions 27
3.3.2 Specific research questions 27
3.4 Conceptual framework for transmission of human *Taenia solium* infection. 28
3.5 Objectives of the research 29
3.5.1 Broad objective 29
3.5.2 Specific objectives 29

CHAPTER FOUR 30
4.0 METHODOLOGY 30
4.1 Study design 30
4.2 Study setting 30
4.3 Study population 30
4.4. Sample size estimation 31
4.5 Definition of terms 32
4.6 Sampling method 32
4.7 Data collection 34
4.8 Research tools 34
4.9 Research assistants 34
4.10 Piloting of research tools 35
4.11 Specimen collection 35
4.11.1 Blood collection for determining the prevalence of human cysticercosis by Antigen ELISA (B158/B60) and Antibody ELISA (rT24h) 35
4.11.1.1 Immunological tests used for detection of *T. solium* human cysticercosis 36
4.11.1.2 Quality assurance 36
4.11.1.3 Procedure for Enzyme-linked-immunosorbent assay (Ag-ELISA) used for the detection of circulating antigens of *T. solium* cysticerci 36
4.11.1.3.1 Radioimaging test for detection of neurocysticercosis (NCC) cases among selected study participants 37
4.11.1.4 Procedure for Enzyme-linked-immunosorbent assay for the detection of circulating antibody of *T. solium* cysticerci Ab-ELISA (rT24h) 38
4.11.2 Stool specimen collection for detection of taeniosis prevalence 39
4.11.2.1 Parasitological examination of stool samples 39
4.11.2.1.1 Procedure for Copro-Antigen ELISA assay used for the detection of taeniosis 39
4.11.2.1.2 Procedure for formal-ether concentration method 40
4. 12 Data entry, cleaning, and analysis 40
4.13 Ethical considerations and research clearance 40

4. 14 Study feedback to the surveyed villages (communities) 41

CHAPTER FIVE 42
5.0 RESULTS 42
5. 1 Quantitative results 42
5.2 Qualitative results 62
5.2.1 Observational results 62

CHAPTER SIX 63
6.0 DISCUSSION, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS ... 63
6.1 Discussion 63
6.2 Conclusion 69
6.3 Recommendations 69
6.4 Limitations of the study 70
6.5 Possible source of bias 70

REFERENCES 71

APPENDICES 84
Appendix 1: STRUCTURED QUESTIONNAIRE (English version) 84
Appendix 2: STRUCTURED QUESTIONAIRE (Swahili version) 89
Appendix 3: INFORMED CONSENT FORM (English version) 94
Appendix 4: INFORMED CONSENT FORM (Swahili version) 96
Appendix 5: ETHICAL CLEARANCE LETTER 98
Appendix 6. PICTURE SHOWING A FREE ROAMING PIG IN ONE OF THE SURVEYED VILLAGES OF MBOZI DISTRICT-TANZANIA (JUNE, 2009) 99

Appendix 7: PICTURE SHOWING PIT LATRINE WITHOUT PERMANENT WALLS OR CLOSING DOOR, EASILY ACCESSIBLE TO ROAMING PIGS IN DISTRICT-TANZANIA (JUNE, 2009) 100

Appendix 8: ETHICAL PICTURE SHOWING ACTIVE CYSTS ON CT-SCAN OF ONE PARTICIPANTS (FEBRUARY , 2009) 101

Appendix 9: PICTURE SHOWING CALCIFICATION OF CYSTS ON CT-SCAN OF ONE PARTICIPANTS (FEBRUARY , 2009) LETTER 102

LIST OF TABLES

Table 1. Basic characteristics of study participants (n=830) 44

Table 2. Population and sampling data 46

Table 3. Frequency of seropositive for *T. solium* cysticercosis (Ag-ELISA and AbELISA) according to village 47

Table 4. Table showing results of revalence of *Taenia solium* infection in surveyed villages of Mbozidistrict,Mbeyaregion 48

Table 5. Table showing CT-scan results for neurocysticercosis 49

Table 6. Univariate analysis on risk factors associated with human cysticercosis (Ag and Ab ELISA) in Mbozi district 50

Table 7. Univariate analysis on symptoms suggestive to be associated with human cysticercosis (Ag and Ab ELISA) in Mbozi district 52

Table 8. Multivariate analysis on factors for human cysticercosis that were considered in the logistic regression analysis 54

Table 9. Table showing the results of taeniosis by villages in surveyed villages of Mbozi district, Mbeya region 56

Table 10. Univariate analysis on risk factors associated with taeniosis 57

Table 11. Multivariate analysis on factors for taeniosis that were considered in the logistic regression analysis 59

Table 12. Results of Coproparasitologic examinations of 820 persons sampled in villages of Mbozi district 60

Table 13. Polyparasitic intestinal infection seen upon microscopic examination of stool samples in surveyed villages of Mbozi district 61

LIST OF FIGURES (BAR CHARTS)

Fig 1: The Life cycle of *Taenia solium* 12

Fig 2: Figure showing sampling distribution of study participants 42

Fig 3: Bar chart showing age distribution of participants. 45

LIST OF ABBREVIATIONS

$1NH_2SO_4$	1 mole ammonium sulphate.
CNS	Central nervous system.
Copro-Ag ELISA	Coproantigen ELISA test.
CSF	Cerebral Spinal Fluid.
CT-Scan	Computed Tomography Scan.
DAS	District Administrative Secretary.
DED	District Executive Secretary.
DMO	District Medical Officer.
DNA	Deoxy- ribo Nucleic Acid.
EITB	Enzyme-linked Immuno Electro Transfer Blot.
ELISA	Enzyme Linked Immuno Sorbent Assay.
FGD	Focus Group Discussions.
INFOSAN	International Food Safety Authorities Network.
M DA	Mass drug administration.
MRI	Magnetic Resonance Imaging.
NBCS	Newborn cough syrup.
NCC	Neurocysticercosis.
nm	Nano meter.
OD	Optical density.
PBS	Phosphate Buffer Solution.
PCR	Polymerase Chain Reaction.
rT24h	Recombinant protein GP 24 ant human antibody.
SCC	Subcutaneous cysticercosis.
T. solium	*Taenia solium.*
Tw	Tween twenty.
µl	Microliter

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Human cysticercosis and taeniosis are disease conditions caused by a cestode known as *Taenia solium*. The parasite belongs to family Taeniidae, genus *Taenia* and is commonly known as pork tapeworm due to its strong relationship with pigs. When a person develops adult tapeworm of *T. solium* in the intestine, the condition is termed as taeniosis. The condition is acquired by ingestion of raw or undercooked pork containing viable cysticercus of *Taenia solium* (Sarti et al., 1992; Garcia et al., 2003).

Human cysticercosis is infection with the larval stage of the parasite (cysticercus cellulosae) acquired through faecal-oral contamination with *T. solium* fertilized eggs from the faeces of human tapeworm carriers (Schanz et al., 1992). If fertilized eggs from faeces of humans infected with the intestinal parasites (taeniosis) are ingested by a person via contaminated food, water, or hands, the oncospheres penetrate the gut and the larval cysts (cysticerci) lodge selectively in certain organs of the body such as the subcutaneous tissues, eyes, muscles and the brain (Rajshekhar, 2010; Rahalkar et al., 2000).

However, the parasite shows to have a strong tropism to the central nervous system (CNS) causing a condition known as neurocysticercosis (NCC) resulting in severe headache, epileptic seizures, blindness, mental disturbance, and even death (Sinha and Sharma, 2009; Murrel et al., 2005). Only neurocysticercosis (NCC) and Ophalmic cysticercosis (OCC) are significant public health problem associated with costs in health care, psychosocial impact and lost productivity (Garcia et al., 2004; Abba et al., 2010). The lodgment of cysts in the subcutaneous tissues and muscles is only a cosmetic issue.

1.2 Global situation of *Taenia solium* infections

1.2.1 Situation in America (Latin America and Brazil)

T. solium is endemic in most countries of Latin America including Mexico, Guatemala, Honduras, Ecuador, Bolivia, and Brazil. The average human cysticercosis seroprevalence in Latin America is 10%. In South America neurocysticercosis is a major cause of morbidity creating the loss of huge amounts of resources every year (Flisser et al., 1988).

Among Latin American countries, human cysticercosis is hyperendemic in Peru and is associated with a large number of seizure cases. Hyperendemicity in Peru supported by presence of high human seroprevalence ranged from 7.1-26.9% (mean, 13.9%). The estimate of human neurocysticercosis in Brazil is 3 - 5.6% (Garcia et al., 2003) while in Ecuador the prevalence of taeniosis and human cysticercosis is estimated to be 1.46% by the formalin-ether technique and 2.25% by Ag-ELISA respectively (Rodriguez-hidalgo et al., 2006). The risk factors for persistence of *T. solium* infection in Latin America are pork consumption and pig husbandry practice, hence human cysticercosis/ taeniosis may be significant, but largely unrecognized as a public health problem.

1.2.2 Situation in Asia

Taenia solium infections in human beings have been reported in many countries in Asia such as India, China, Indonesia, Thailand, and Korea. Seroprevalence studies indicate high rates of exposure to the parasite in several countries such as Vietnam, China, Korea and Indonesia with rates ranging from 0.02 to 12.6%. Rates of taeniosis, as determined by stool examination for ova, have also been reported to range between 0.1 and 6% in the community in India, Vietnam, Bali (Indonesia), and China. Despite the fact that *T. solium* infection is present for a long time in Asia, the epidemiological data on the prevalence of taeniosis and *T. solium* human cysticercosis in most countries of Asia are poorly worked out and not easily available (Rajshekhar et al., 2003).

1.2.3. Situation in Western and Central Africa

In West Africa, human cysticercosis and taeniosis have been reported in Benin, Ghana, Ivory Coast, Senegal, Bukina-faso, and Togo. In some regions of Nigeria, the prevalence of human taeniosis is quite high 8.6%. Despite the presence of *T. solium* infection in the regions, surprisingly no cases of human cysticercosis have been reported, although epilepsy is very common (Zoli et al., 2003).

In Central Africa, human cysticercosis is hyperendemic in Rwanda, Burundi, the Democratic Republic of Congo, and Cameroon. In Cameroon, one of the few countries where the cysticercosis-taeniosis complex has been examined in more detail; human cysticercosis especially neurocysticercosis has been shown to be one of the major causes of epilepsy with figures as high as 44.6% (Nsengiyumva et al., 2003). In the Western province of Cameroon large scale surveys have shown that active human cysticercosis is present in 0.4% - 3 % of the local population (Nguekam et al., 2003).

1.2.4. Situation in Eastern and Southern Africa

T. solium infection is endemic in Eastern and Southern of Africa. In these areas, most studies have been conducted to determine the prevalence of porcine cysticercosis but little has been done to determine the prevalence of human cysticercosis/taeniosis. The prevalence of porcine cysticercosis found in Eastern and Southern Africa countries rank among the highest in the world. High prevalence in the region suggests the widespread presence of human tapeworm carriers, in turn posing a high risk of human cysticercosis in rural areas and urban centers of the region. Hence, the disease is emerging as an important constraint for the nutritional and economic well being of resource-poor smallholder farming communities (Phiri et al., 2003).

1.2.5. Situation in Tanzania

Taenia solium infection has been reported in pigs in Northern and Southern parts of the country. However, data on the human aspect of the parasite is lacking in many endemic areas because most studies have only examined the livestock aspect of the parasite (Ngowi et al., 2007). Community-based studies on porcine cysticercosis done in Tanzania estimated the prevalence of porcine cysticercosis to be 17.4% in the northern highlands district of Mbulu while in southern highlands it ranged between 5.1% -16.9% (Phiri et al., 2003).

Recently, the first study to rule out human neurocysticercosis done by Winkler et al. (2008) in Mbulu district (northern part), reported the prevalence of 14% in epileptics. However, lack of data on human *T. solium* infections in the country could underestimate the magnitude of the problem. There is a need for conducting the epidemiologic studies to characterize the prevalence of the disease in endemic areas so that control activities can be initiated earlier.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The epidemiology of human *Taenia solium* infection

Human cysticercosis/taeniosis is potentially among the important zoonotic infections involving humans and pigs. The disease is emerging as a serious problem in public health and veterinary medicine in many developing countries of Latin America, Africa, and Asia where people eat pork and traditional pig husbandry is practiced and expanding (Engels et al., 2003). In most cases disease conditions in human caused by *Taenia solium* especially, cysticercosis is largely under-recognized in developing countries (Tsang and Wilson., 1995; Garcia et al., 1999).

The infection is related to underdevelopment and is found in countries that lack adequate sanitary infrastructure and health education. Nonetheless, due to the recent increase of migration and tourism, industrial countries are also reporting cases of human cysticercosis (Flisser et al., 2006). Despite its impact on humans, the disease is among the most serious neglected helminthic zoonoses threatening humans worldwide especially the poorest segments of the human population (INFOSAN report, 2006). The human populations considered to be at highest risk of infection with this zoonotic helminth are people living in rural areas, where most of them earn their livelihood wholly or partly through livestock rearing mainly pigs (Phiri et al., 2003). In endemic countries, the disease is also widely prevalent even in urban and semi-urban areas due to increase in pork consumption.

The occurrence and prevalence of *T. solium* in endemic areas is associated with several factors such as cultural practices (eating raw or poorly cooked), poor social economic condition, human behavior (outdoor defection, poor personal hygiene), high levels of taeniosis and porcine cysticercosis, and poor sanitary conditions (Sarti et al., 1992). Garcia et al. (1999) suggested that determining the percentage of

the porcine population that is infected is a better epidemiological indicator of *T. solium* infection in humans.

The human *T. solium* carrier is the sole source of cysticercosis infections in pigs and cysticercosis (neurocysticercosis) in humans. In general, pigs are the source of human taeniosis; an intestinal tapeworm infection acquired by eating raw or undercooked pork contaminated with *Cysticercus cellulosae* (cysticerci), the larval stage of the cestode. The pig is infected by ingestion of *T. solium* eggs or proglottides in human faeces and acquires cysticercosis (Sikasunge et al., 2008). Normally, the cyst can be killed by adequate cooking of pork at 80°C or above (Murrel et al., 2005). However, the risk for taeniosis increases when infected pork containing viable cysts in the infected tissue is eaten raw or inadequately cooked like in barbecue. Thus, the consumption of boiled or fried pork decreases the risk for taeniosis than traditional barbecue (Rodriguez-Canul et al., 2002).

The risk factor for human cysticercosis is presence of human tapeworm carrier in a household. For this reason, domestic workers from endemic areas may import the disease into even non-pork consuming households and non-endemic areas through environmental contamination (Flisser et al., 2003). The risk for contamination of water sources increases in places where outdoor defecation practices are common. There is no information on temperature inactivation of *T. solium* eggs in contaminated food products such as drinking water and other food (Smith, 1994). Thus, preventing contamination of water sources from eggs passed by the tapeworm carrier through treatment is very important for disease control.

Transmission of human cysticercosis seems to be due to direct contact (for example, living in the same household) with a tapeworm carrier. There is very little evidence for indirect dissemination through air, water, flies, or vegetables. Thus, tapeworm carriers are continuously exposed to infection themselves via external autoinfection (Garcia et al., 2006). Although the disease is associated with pigs,

even vegetarians and other people who do not eat pork (like Jews and Muslims) can acquire cysticercosis like any other faecal orally transmitted disease (Schanz et al., 1992). Furthermore, concentration of cases of taeniosis in communities increases the risk for human-to-human infections through faecal-oral route especially in areas with poor personal hygiene and sanitation (WHO, 2002). Thus, early identification of *T. solium* taeniosis cases is of great importance due to its epidemiological implications (Mayta et al., 2008).

In most cases, transmission of human cysticercosis depends on the extent of environmental pollution with parasite eggs from human *T. solium* carrier in a community. Under favorable condition such as high humidity and low temperature, eggs passed by a human tapeworm carrier have the ability to survive for months to years in the environment. Ability of parasite eggs to survive for a long time in the environment is responsible for maintenance of the disease in both humans and pigs (Smith, 1994). Hence, presence of a large number of tapeworm carriers increases the risk for disease transmission especially in places where personal hygiene and sanitary conditions are poor (Sarti et al., 2003).

Cysticercosis infection in human (not necessarily leading to disease) seems to occur early in life with age specific seroprevalence values peaking between 5 and 15 years of age and most infected humans appear to be asymptomatic. However, disease (symptomatic neurocysticercosis) presents mostly between 15 and 40 years of age, and without any particular association with sex or race (Allan et al., 1996; Garcia et al., 2003). Sarti et al. (1992) reported that seropositivity increased with age and reached a maximum in subjects aged 46-55 years. Furthermore, findings from other studies show sex to be one of the risk factors for human cysticercosis with more males affected than females (Houinato et al., 1998). In addition, Sarti et al. (2003) reported seropositivity with human cysticercosis to be associated with previous history of passing tapeworm proglottides, frequent consumption of pork,

poor personal and household hygiene, and previous history of seizures (Sarti et al., 2003).

Human cysticercosis may also occur in humans if eggs are conveyed to the mouth by unclean fingers after defecation (Flisser, 1994). Normally, poor hand washing practice is influenced by traditions and poor accessibility of clean safe water for domestic purposes. Like other fecal oral diseases, poor personal hygiene such as poor hand washing practices or lack of hand washing before eating or after defecation could be a risk factor for acquisition of human cysticercosis. Thus, presence of tapeworm carrier food handlers with poor hand washing in a household or community poses the greatest risk for acquiring the disease.

2.2 The burden of disease

Human cysticercosis/taeniosis imposes substantial global burden on human beings but the exact extent of burden is still not known or is even underestimated. The under estimation is due to lack of reliable tools for confirmation, identification of patients or infected animals and lack of epidemiological data at local, national, and global level (Ito et al., 1998). The burden (mortality and morbidity) of disease is counted mainly in terms of neurocysticercosis that is related to epilepsy, ocular cysticercosis, other neurological manifestations, and economic losses (Engels et al., 2003; Garcia et al., 1999). In *T. solium* endemic areas of developing countries, neurocysticercosis and ocular cysticercosis are the major public health problems, affecting the quality of life mainly in older children and adults. Hence, the estimated economic consequences due to chronic disability caused by *T. solium* infection are heavy (Flisser et al., 1993).

The financial loss due to human cysticercosis is very difficult to estimate; but the impact is certainly exceeded by the social impact of the disease, especially because of the negative perception of epilepsy in many African communities. The studies done in Senegal and Tanzania showed that most people believe that epilepsy is a

contagious, caused by witchcraft, and is a shameful disease. Therefore, the patients with epilepsy are treated and managed locally and often isolated to prevent the spread of the ailment. The stigmatization and discrimination of epileptics may be barriers to providing adequate medical management. Apart from the medical impact, the disease prohibits their rights to other social events (Ndoye et al., 2005; Rwiza et al., 1993; Zoli et al., 2003).

According to the survey of Preux et al. (2000) in West Cameroon, only 27% of epileptics get married and 39% fail to enter into any professional activity. Furthermore, certain practices of traditional healers might be quite harmful to the patients. Majority of healers explained epilepsy as the presence of excess foam in the abdomen. Some patients reported that they were asked to inhale smoke from burnt cola nut leaves as a form of treatment. Others had to restrict certain foodstuffs such as meat, eggs, sweet potatoes, and sugar cane, which are practically highly nutritious foods. Hence, the overall social burden of human cysticercosis could be huge.

The diagnosis and management of human cysticercosis especially neurocysticercosis is costly due to greater demand of economic resources for laboratory and hospital services. The study done in Peru estimated health related cost and productivity loss due to neurocysticercosis to be about US$ 966 (Rajkotia et al., 2007). While the recent study done by Carabin et al. (2006) in South Africa reported the overall estimated cost for neurocysticercosis to be US$ 18-24 in 2004, which is far beyond the reach of the affected resource-poor population. This preliminary estimate in Africa suggests that *T. solium* cysticercosis results in a considerable monetary cost in a region that is already economically constrained.

2.3 The biology of *Taenia solium*

Taenia solium exists as adult tapeworm in intestine of human host and larva form known as cysticerci mostly in muscles of pigs, human, and dogs. The larval form (cysticercus) has size of 8-15 millimeters (mm), fluid contents <0.5 milliliters (ml) and hooks in scolex is found in human and pig. The metacestodes do not have a strobila, it has only scolex with hooklets and bladder surface is wart like. The adult *Taenia solium* appears flattened ribbon-like, cream in color, and its length measures between 2 to 4 meters (m). The body of adult worm is divided into three parts namely scolex, neck and strobila, or chain of proglottides (Murrer et al., 2005).

The head (scolex) appears global with about 1 millimeters (mm) diameter equipped with 4 suckers of diameter 0.4-0.5 millimeters (mm) and a rostellum with 22-32 hooklets arranged in a double crown. The scolex is used as an organ for attachment in the intestine of the human host. The short and slender neck region form budding zone (zone of proliferation) containing germinative cells from which new segments grow up to form a long and segmented strobila. The strobila contains about 700-1000 proglottides with length of 1.5-8.0 millimeters (mm) and maximum breadth of 7-10 millimeters (mm). During proliferation, as proglottides are formed behind the neck region and pushed posteriorly, they form a zone of proliferation; zone of immature proglottides; zone of mature ploglottides and zone of gravid proglottides (Pawlowski and Murrel, 2001).

Immature proglottides appear like transverse rectangles, located in the anterior part of the body where inner organs develop. Mature proglottides are square in shape, located in the mid part of the body having 375-575 testes, a centrally straight uterus, 3 lobes of ovary, and a vitelline gland. Mature proglottides containing pregnant proglottides are located in the posterior part of the body. The pregnant proglottides are longitudinal rectangular and contain a branched uterus filled with eggs (30-40 thousand eggs), vaginal sphincter is absent but have a large cirrus pouch for excretion. The number of main branches on each side of the uterine stem

range between 7-16 uterine branches and this is a distinguishing feature for *Taenia solium* (Pawlowski and Murrel, 2001)

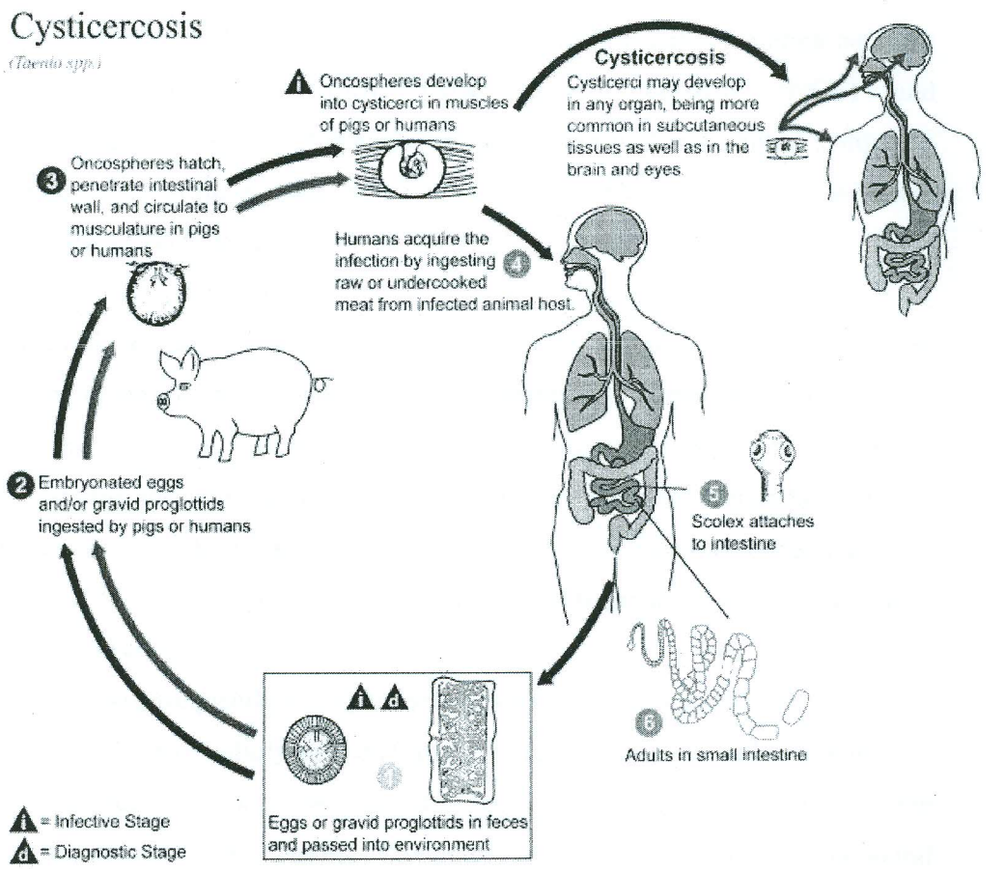
2.4 The life cycle of *Taenia solium*

Under natural conditions, the life cycle of *Taenia solium* is maintained between human as the only definitive host harboring adult worm in the small intestine and pigs harboring the larval form as intermediate host.

Naturally, humans become infected by ingesting raw or undercooked pork containing viable larvae (*Cysticercus cellulosae).* In the small intestine the larva evaginates and head (scolex) attaches strongly to the mucosa of the upper small intestine by means of its suckers and hooks, and then begins forming segments (proglottides). The scolex of *T. solium* has four suckers and a double crown of hooks, a narrow neck, and a large strobila measuring 2–4 meters (m) and consisting of several hundred proglottides. About 2 months after infection, gravid proglottides begin to detach from the distal end and are excreted in the faeces to the immediate environment; each segment contains 50–60 × 10^2fertile eggs (Garcia et al., 2003; Garcia et al., 2006).

Accidental infection can occur in human by ingestion of the parasite egg whereby instead of being definitive host, they become intermediate hosts like pigs (Garcia et al., 2005). After viable eggs of *T. solium* have been ingested via contaminated food, water, or hands; infective embryos (hatched from the eggs) actively cross the intestinal mucosa, reach the blood circulation and are transported anywhere in the body to lodge in capillaries where they develop into immature cysts and later into viable larval cysts with thin walled vesicles measuring 10-20 millimeters (mm) in diameter, with a clear liquid content. Although any organ or tissue may harbor cysts, the brain, muscles, and subcutaneous tissue are the most commonly affected tissues (Engels et al., 2003: Garcia et al., 2006; Nash, 2003).

Fig 1: The Life cycle of *Taenia solium*



Source from U.S. Centers for Disease Control and Prevention (CDC)

2.5 The clinical manifestations of human cysticercosis/taeniosis

Taeniosis is characterized by mild symptoms or none at all. However, abdominal pain, distension, diarrhea, and nausea have been attributed to tapeworm infection, but there are no data from controlled experiments that demonstrate any association, and most patients seem to be free of symptoms (Flisser, 1994; Schanz et al., 1998).

Clinical manifestations of *T. solium* human cysticercosis depend on the affected organ, outside the central nervous system (CNS) cysticercosis causes no major symptoms. Subcutaneous cysticercosis (SCC) presents as small, movable, painless

nodules that are most commonly noticed in the arms or chest. After a few months or even years, the nodules become swollen, tender & inflamed, and then they gradually disappear. Subcutaneous cysticercosis is rare in Latin America but very common in Asia and Africa. Only Neurocysticercosis (NCC) and Ophthalmic/Ocular (OCC) cysticercosis are associated with substantial symptoms in endemic areas. In most cases, neurocysticercosis (NCC) is associated with late onset of epilepsy (Garcia et al., 2003 & 2006).

In neurocysticercosis, most clinical manifestations become evident when the parasite is damaged and dying due to inflammatory responses. There is no pathognomonic clinical feature or typical neurocysticercosis syndrome (Ito et al., 2006). Usually the clinical manifestations become evident depending on the number, location, stage of the parasites, viability of cysts, stage of degeneration of cysts, size of the parasite as well as the degree of inflammation secondary to host immune response.

Because there are frequently multiple cysts at various locations and stages, clinical symptoms can be particularly varied (Garcia et al., 2005). Signs and symptoms for human cysticercosis include late onset of seizures, focal neurological signs, severe chronic headache, intra-cerebral hypertension, and cognitive behavioural dysfunctions (Garcia et al., 2003; Da Costa et al., 2005). In most cases, epileptic seizures is the key symptom in intraparenchymal cysticercosis (Garcia et al., 2006).

2.6 Diagnostic methods for human *Taenia solium* infection

2.6.1 Parasitological diagnosis for human *Taenia solium* infection

The parasitological diagnosis of taeniosis can be done by direct microscopic examination of stool sample for *T. solium* eggs, scolex, or proglottides. Although the method is cheap and easy to perform, direct microscopic technique is known to have low sensitivity and specifity (Mayta et al., 2000; Allan et al., 2003).

2.6.2 Immunodiagnostic methods for human *Taenia solium* infection

Development of improved immunodiagnostic tools has been contributed to our knowledge on the importance of human cysticercosis/taeniosis by enabling sero-epidemiological surveys and community-based studies to be carried out (Deckers and Dorny, 2010). Immunodiagnostic techniques include the method of detecting specific antibodies and circulating parasite antigen in serum or cerebrospinal fluid. Despite the presence of improved immunodiagnostic tools for human cysticercosis, the potential use of immunodiagnostic tools to identify cases of *T. solium* infections such as neurocysticercosis (NCC) is difficult to obtain. In endemic developing countries, the use of immunodiagnostic methods such as Enzyme-linked Immuno Electro Transfer Blot (EITB) and other special assays may only be restricted to research studies (Dorny et al., 2003).

2.6.3 Immunodiagnosis for taeniosis

As the major problem with direct microscopy for diagnosis of taeniosis is low sensitivity of the technique, the problem was minimized by introduction of immunological method such Copro-AgELISA test (Allan et al., 2003: Mayta et al., 2007). Generally, Coproantigens are parasite specific metabolic products present in faeces of a person with taeniosis independent of eggs or proglottides. Immunological tests such as Copro-AgELISA can detect this product in an infected person (Flisser and Gyorkos, 2007).

The antibodies used are obtained from hyper immune rabbit sera raised against *T. solium* adult worm somatic antigens. The use of this test increases the detection of parasitologically proven intestinal *T. solium* cases by a factor of at least 2.6 times in comparison with microscopy. Furthermore, the test does not have cross-reactions with other intestinal helminth infections such as *Ascaris, Trichuris* and *Hymenolepis* species (Allan et al., 1990 & 1993).

Coproantigens are stable for weeks in unfixed fecal samples kept at room temperature and for years in frozen samples or in chemically fixed samples (e.g.

formalin) kept at room temperature. In addition, Coproantigens can be detected prior to patency and they are no longer detectable within a week of treatment. With that characteristic, it could be a good tool for monitoring of disease after treatment.

However, a major disadvantage of this test is that it is only genus-specific, making it impossible to differentiate between *T. solium* and *T. saginata* infections (Allan et al., 1996). The test is used to detect *Taenia* species-specific antigen in human host fecal samples. The test has high sensitivity (95%) and specificity (>99%), hence it is an effective tool for epidemiological studies in taeniosis (Allan et al., 1990; Garcia et al., 1999). Coproantigen test has the capacity of detecting 60-70% of cases that can be missed by microscopy (Garcia et al., 1998: Mayta et al., 2000).

2.6.4 Immunodiagnosis for human cysticercosis

Immunodiagnostic techniques for detection of human cysticercosis include detection methods for specific antibodies and for circulating parasite antigen in serum or cerebral spinal fluid (CSF) (Murrel et al., 2005). While Ag-ELISA measures only active cysticercosis (presence of viable cysticerci), detection of circulating antibodies indicates exposure as well as active infection (Dorny et al., 2004a). Thus, a positive antibody test would indicate a transient antibody response, active or past infection (Garcia et al., 2001; Gonzalez et al., 2006; Ferrera et al., 2005).

2.6.4.1 Antibody detection methods for human cysticercosis

Infection with *T. solium* results in a specific antibody response, mainly of the IgG class (Carpio et al., 1998). In surveys on cysticercosis, antibody detection systems have been useful in identifying the risk factors associated with transmission of *Taenia solium*; whereby a high seroprevalence in a community indicates a "hot spot", hence preventive and control measures should be applied (Dorny et al., 2003).

The most common immunodiagnostic techniques used to detect circulating cysticercus antibody includes Enzyme Linked Immunosorbent Assay (ELISA) and

Enzyme Linked Immuno Electrotransfer Blot (EITB). When compared to enzyme linked immunosorbent assay (ELISA), enzyme-linked immunoelectrotransfer blot (EITB) has higher specificity (100%) and sensitivity varying from 70% to 90% (Tsang et al., 1989). Inspite of EITB having higher sensitivity, immunodiagnostic kits are unfortunately difficult to obtain in endemic countries, so the use of the EITB and other special assays may only be restricted to research studies (Deb et al., 2000).

Although the EITB was recognized as the 'immunological method of choice for confirmation of the diagnosis of cysticercosis by WHO and the Pan American Health Organization, for practical reasons assays such as the *T. solium* cyst-fluid-based ELISA are still commonly used in many laboratories in the developing world (Ferreira et al., 1997).

Despite this, the antibody detection tests such as ELISA and EITB are the most appropriate tools for measuring exposure to *T. solium* in sero-epidemiological surveys. The methods can overestimate the prevalence of cysticercosis in endemic areas due false positive serology. The false positive can result due to immune tolerance, inactive disease, localized antibody production in the CSF, past infection with *T. solium* in cured patients or cross reactivity with other helminths species (Deb et al., 2000: Dorny et al., 2003).

2.6.4.2 Antigen detection methods for human cysticercosis

Detection of antigens secreted by viable parasites may be useful for diagnosis and serological monitoring of the efficacy of antiparasitic therapy in cysticercosis thereby reducing the number of imaging studies required (Dorny et al., 2003). Several assays have been developed to detect parasite antigens, but only the monoclonal antibody-based tests directed at defined parasite antigens may ensure reproducibility and specificity (Erhart et al., 2002). Detection of *T. solium* Antigen may be done using serum as well as on cerebral spinal fluids (Choromanski et al., 1990; Garcia et al., 2000).

Dorny et al. (2003) reported that in the case of cysticercosis (neurocysticercosis) antigen detection using CSF sample may be more appropriate for diagnosis than serum; however, sampling of CSF is more cumbersome than blood sampling. Among antigen detection methods, Ag-ELISA has proved to be highly sensitive (85%) and specific for identifying infected individuals. Also Ag-ELISA has a higher sensitivity (65%) in patients with a single viable cyst or only enhancing lesions compared to antibody test (Erhart, et al., 2002; Garcia et al., 2000).

In addition, antigen test has more advantages compared to antibody test, the findings from the study done by Erhart et al. (2002) found a very high agreement between an ELISA for detecting circulating antigen, CT-scanning and biopsy examination of subcutaneous cysticerci. Remarkably low levels of cross-reactions were observed in serum samples from a wide range of helminth and protozoan infections. Hence, application of Ag-ELISA for the detection of circulating parasite antigens may present some diagnostic advantages as it demonstrates not only exposure but also active infection (Dorny et al., 2003).

2.6.4.3 Diagnosis for *Taenia solium* human cysticercosis by neuroimaging

The diagnosis of human cysticercosis especially neurocysticercosis was greatly improved by the introduction of Computed Tomography scan (CT-scan) and Magnetic Resonance Imaging scan (MRI). These techniques demonstrate the number and topography of lesions, their stage of involution and the degree of host inflammatory reaction against the parasites. In general, compared to CT-scan, MRI provides better image detection and definition (Garcia et al., 2003).

Both CT-scan and MRI can show the invaginated scolex of *Taenia solium*. During the degenerative phase, the cyst shows a ring-like or a nodular contrast enhancement with or without perilesional edema. The final stage is observed when the cyst dies and a process of mineralization and resorption takes place, resulting in calcified nodules. Within the CSF, cyst membrane appears thin the fluid is isodense

and non-inflamed extraparenchymal (ventricular or sub-arachnoid) cysticerci are usually not visible on CT-scan and may be only revealed by MRI scan. Study has shown that for diagnosis of neurocysticercosis, MRI is more sensitive than CT-scan, since MRI improves recognition of perilesional edema and degenerative changes of the parasite as well as small cysts or those located inside the ventricles, brain stem, cerebellum and the racemose vesicles at the level of the posterior fossae and basal cisterns. However, for detection of calcification in neurocysticercosis, CT-scan is more sensitive (Ito et al., 2006).

Despite the advantages shown by neuroimaging technique in diagnosis of human neurocysticercosis, the major problem of neuroimaging technique is its high cost for testing and the equipments is scarcely available in many poor endemic countries especially in the rural population at risk. Under these conditions, serology may provide the only tool for diagnosis of infection. Moreover, for accurate diagnosis of neurocysticercosis, both serological tests and neuroimaging tests should be used together in order to increase diagnostic sensitivity (Dorny et al., 2003).

2.6.4.4 Molecular diagnosis for human *Taenia solium* infection

Molecular diagnosis of *Taenia solium* infections can be done on the basis of sequence data of the full-length mitochondrial DNA from *T. solium* using multiplex PCR (Yamasaki et al., 2004; Nakao et al., 2002). Specimens used for DNA analysis includes egg(s), metacestodes, adult tapeworms (proglottides) from taeniosis or cysticercosis confirmed cases, nodules resected from suspected cysticercosis cases, and faeces of taeniosis confirmed cases either by parasitological observation of expelled ploglottides or Copro-AgELISA positive (Wandra et al., 2006).

The method enables differentiation of human *Taenia* species and two genotypes of *T. solium* i.e. The Asian type and the American/African type (Okamoto et al., 2001; Ito et al., 2002; Nakao et al., 2002). Hence, Micro satellite DNA studies may be

more useful for detection of such polymorphism of *T. solium* in the world and for tracing cases in more detail (Campbell et al., 2006).

2.7 Treatments for human cysticercosis/taeniosis

In endemic countries, *T. solium* infections can be treated by using Niclosamide, Albendazole, or Praziquantel. However, in endemic countries, both drugs have very limited market making it difficult to find (Garcia et al., 2003). For treatment of taeniosis, Niclosamide, or Praziquantel are the drugs of choice, however Praziquantel has disadvantage of causing neurological symptoms such as headache, seizures in person with asymptomatic viable brain cysts. Apart from that, Praziquantel can increase the risk for autoinfection as it disintegrates the proglottides. The usual dose for taeniosis is 2 g orally in a single dose for Niclosamide while for Praziquantel a dosage of 5-10 mg/kg orally is required (Sarti et al., 2000).

For human cysticercosis, treatment is needed only in neurocysticercosis while subcutaneous cysticercosis is a cosmetic problem. There are five modalities that can be offered to patients with neurocysticercosis: larvicidal/cesticidal agents, corticosteroids, anti-seizure, surgery, and general supportive measures in impaired individuals or symptomatic treatment (Nash, 2003). Currently, cesticidal agents used for treatment of neurocysticercosis include Praziquantel and Albendazole. However, Albendazole has largely supplanted Praziquantel because of its slightly greater cure rates, low cost, and increased availability (Nash, 2003; WHO, 2005).

Despite the success shown by cesticidal drugs, the drug can increase the risk of hydrocephalus and seizures during treatment. To reduce the possibility of inflammatory response and exacerbation of symptoms caused by cesticidal drug actions, some authors have advocated simultaneous administration of steroids such as Dexamethasone and Prednisolone with cesticidal drugs. The currently accepted schemes for treatment of neurocysticercosis include 8 days of Albendazole

treatment (15 mg/kg daily) simultaneously with administration of steroids, or 15 days of Praziquantel 50 mg/kg daily (Deb et al., 2000; Nash, 2003).

2.8 Prevention and control of human cysticercosis/taeniosis

Control of human cysticercosis/taeniosis requires effective collaboration between community, agriculture and health sectors. The control of disease caused by *T. solium* is cost-effective if we target the animal reservoir by periodic deworming of pigs, pork inspection, and proper pig rearing practices. Eradication of human cysticercosis/taeniosis can be possible by removing the parasite from pigs, human hosts or both (INFOSAN report, 2006). Although diseases caused by *T. solium* is theoretically easy to control and declared eradicable, the infection remains neglected in most endemic countries due to lack of information, awareness on the extent of the problem, suitable diagnostic tools and management capacity, appropriate prevention and control strategies (Willingham et al., 2006).

2.8.1 Prevention and control of human cysticercosis/taeniosis by abattoir inspection of pork

Preventing selling and consumption of *T. solium* infected pork is one of the strategies that can be used for prevention and control of human cysticercosis/taeniosis in endemic areas. In endemic areas of developing countries, most of pigs are kept in rural areas where most pigs are slaughtered illegally and pork is consumed without inspection. This is due to lack of diagnostic materials for pork inspection and lack of meat inspection personnel.

Policy pertaining to meat inspection targeting slaughter houses in most endemic areas is a challenge, since pork inspection is based on visual examination of key sites of the carcasses, the method is not 100 percent sensitive. Hence relying on visual examination will seriously underestimate the real prevalence of porcine cysticercosis, causing infected pork to enter into the food chain, in turn the risk for transmission of human cysticercosis/taeniosis (Murrel et al., 2005).

more useful for detection of such polymorphism of *T. solium* in the world and for tracing cases in more detail (Campbell et al., 2006).

2.7 Treatments for human cysticercosis/taeniosis

In endemic countries, *T. solium* infections can be treated by using Niclosamide, Albendazole, or Praziquantel. However, in endemic countries, both drugs have very limited market making it difficult to find (Garcia et al., 2003). For treatment of taeniosis, Niclosamide, or Praziquantel are the drugs of choice, however Praziquantel has disadvantage of causing neurological symptoms such as headache, seizures in person with asymptomatic viable brain cysts. Apart from that, Praziquantel can increase the risk for autoinfection as it disintegrates the proglottides. The usual dose for taeniosis is 2 g orally in a single dose for Niclosamide while for Praziquantel a dosage of 5-10 mg/kg orally is required (Sarti et al., 2000).

For human cysticercosis, treatment is needed only in neurocysticercosis while subcutaneous cysticercosis is a cosmetic problem. There are five modalities that can be offered to patients with neurocysticercosis: larvicidal/cesticidal agents, corticosteroids, anti-seizure, surgery, and general supportive measures in impaired individuals or symptomatic treatment (Nash, 2003). Currently, cesticidal agents used for treatment of neurocysticercosis include Praziquantel and Albendazole. However, Albendazole has largely supplanted Praziquantel because of its slightly greater cure rates, low cost, and increased availability (Nash, 2003; WHO, 2005).

Despite the success shown by cesticidal drugs, the drug can increase the risk of hydrocephalus and seizures during treatment. To reduce the possibility of inflammatory response and exacerbation of symptoms caused by cesticidal drug actions, some authors have advocated simultaneous administration of steroids such as Dexamethasone and Prednisolone with cesticidal drugs. The currently accepted schemes for treatment of neurocysticercosis include 8 days of Albendazole

and non-inflamed extraparenchymal (ventricular or sub-arachnoid) cysticerci are usually not visible on CT-scan and may be only revealed by MRI scan. Study has shown that for diagnosis of neurocysticercosis, MRI is more sensitive than CT-scan, since MRI improves recognition of perilesional edema and degenerative changes of the parasite as well as small cysts or those located inside the ventricles, brain stem, cerebellum and the racemose vesicles at the level of the posterior fossae and basal cisterns. However, for detection of calcification in neurocysticercosis, CT-scan is more sensitive (Ito et al., 2006).

Despite the advantages shown by neuroimaging technique in diagnosis of human neurocysticercosis, the major problem of neuroimaging technique is its high cost for testing and the equipments is scarcely available in many poor endemic countries especially in the rural population at risk. Under these conditions, serology may provide the only tool for diagnosis of infection. Moreover, for accurate diagnosis of neurocysticercosis, both serological tests and neuroimaging tests should be used together in order to increase diagnostic sensitivity (Dorny et al., 2003).

2.6.4.4 Molecular diagnosis for human *Taenia solium* infection

Molecular diagnosis of *Taenia solium* infections can be done on the basis of sequence data of the full-length mitochondrial DNA from *T. solium* using multiplex PCR (Yamasaki et al., 2004; Nakao et al., 2002). Specimens used for DNA analysis includes egg(s), metacestodes, adult tapeworms (proglottides) from taeniosis or cysticercosis confirmed cases, nodules resected from suspected cysticercosis cases, and faeces of taeniosis confirmed cases either by parasitological observation of expelled ploglottides or Copro-AgELISA positive (Wandra et al., 2006).

The method enables differentiation of human *Taenia* species and two genotypes of *T. solium* i.e. The Asian type and the American/African type (Okamoto et al., 2001; Ito et al., 2002; Nakao et al., 2002). Hence, Micro satellite DNA studies may be

more useful for detection of such polymorphism of *T. solium* in the world and for tracing cases in more detail (Campbell et al., 2006).

2.7 Treatments for human cysticercosis/taeniosis

In endemic countries, *T. solium* infections can be treated by using Niclosamide, Albendazole, or Praziquantel. However, in endemic countries, both drugs have very limited market making it difficult to find (Garcia et al., 2003). For treatment of taeniosis, Niclosamide, or Praziquantel are the drugs of choice, however Praziquantel has disadvantage of causing neurological symptoms such as headache, seizures in person with asymptomatic viable brain cysts. Apart from that, Praziquantel can increase the risk for autoinfection as it disintegrates the proglottides. The usual dose for taeniosis is 2 g orally in a single dose for Niclosamide while for Praziquantel a dosage of 5-10 mg/kg orally is required (Sarti et al., 2000).

For human cysticercosis, treatment is needed only in neurocysticercosis while subcutaneous cysticercosis is a cosmetic problem. There are five modalities that can be offered to patients with neurocysticercosis: larvicidal/cesticidal agents, corticosteroids, anti-seizure, surgery, and general supportive measures in impaired individuals or symptomatic treatment (Nash, 2003). Currently, cesticidal agents used for treatment of neurocysticercosis include Praziquantel and Albendazole. However, Albendazole has largely supplanted Praziquantel because of its slightly greater cure rates, low cost, and increased availability (Nash, 2003; WHO, 2005).

Despite the success shown by cesticidal drugs, the drug can increase the risk of hydrocephalus and seizures during treatment. To reduce the possibility of inflammatory response and exacerbation of symptoms caused by cesticidal drug actions, some authors have advocated simultaneous administration of steroids such as Dexamethasone and Prednisolone with cesticidal drugs. The currently accepted schemes for treatment of neurocysticercosis include 8 days of Albendazole

treatment (15 mg/kg daily) simultaneously with administration of steroids, or 15 days of Praziquantel 50 mg/kg daily (Deb et al., 2000; Nash, 2003).

2.8 Prevention and control of human cysticercosis/taeniosis

Control of human cysticercosis/taeniosis requires effective collaboration between community, agriculture and health sectors. The control of disease caused by *T. solium* is cost-effective if we target the animal reservoir by periodic deworming of pigs, pork inspection, and proper pig rearing practices. Eradication of human cysticercosis/taeniosis can be possible by removing the parasite from pigs, human hosts or both (INFOSAN report, 2006). Although diseases caused by *T. solium* is theoretically easy to control and declared eradicable, the infection remains neglected in most endemic countries due to lack of information, awareness on the extent of the problem, suitable diagnostic tools and management capacity, appropriate prevention and control strategies (Willingham et al., 2006).

2.8.1 Prevention and control of human cysticercosis/taeniosis by abattoir inspection of pork

Preventing selling and consumption of *T. solium* infected pork is one of the strategies that can be used for prevention and control of human cysticercosis/taeniosis in endemic areas. In endemic areas of developing countries, most of pigs are kept in rural areas where most pigs are slaughtered illegally and pork is consumed without inspection. This is due to lack of diagnostic materials for pork inspection and lack of meat inspection personnel.

Policy pertaining to meat inspection targeting slaughter houses in most endemic areas is a challenge, since pork inspection is based on visual examination of key sites of the carcasses, the method is not 100 percent sensitive. Hence relying on visual examination will seriously underestimate the real prevalence of porcine cysticercosis, causing infected pork to enter into the food chain, in turn the risk for transmission of human cysticercosis/taeniosis (Murrel et al., 2005).

2.8.2 Prevention and control of human cysticercosis/taeniosis by health education campaigns

Health education can be regarded as the key factor in obtaining the commitment for, development of, and continuing involvement in a prevention and control program (Murrer et al., 2005). In Mexico, for example, a long-term reduction in the porcine cysticercosis rate was achieved through a multidisciplinary community education effort that focused on changing attitudes and practices (Sarti et al., 1997).

Despite health education being effective control strategy, for it to cause permanent effect on disease prevention, multidisciplinary input, active community participation, committed and enthusiastic community leaders are required. However, the strategy can be expensive since it requires a number of personnel, improvement in infrastructure such as the construction of latrines, pigpens, and slaughterhouses to facilitate changes in the people's practices (Sarti and Rajshekhar, 2003).

2.8.3 Prevention and control of human cysticercosis/taeniosis by human mass treatment

Anthelminthic treatment of human taeniosis reduces the incidence of cysticercosis both in humans and in pigs, and thus lowers the potential risk for epilepsy. Since a tapeworm carrier is the direct source of infection for him or herself and surrounding people, treatment of taeniosis is extremely important to avoid future neurocysticercosis cases. With the introduction of safe and efficient drugs such as Praziquantel and Niclosamide for treatment of taeniosis, mass chemotherapy of humans has become a feasible strategy for the control of this zoonosis (Sarti and Rajshekhar, 2003; Murrel et al., 2005; Garcia et al., 2006).

Presently there are two well-known synthetic, safe and highly effective drugs against tapeworms in humans, i.e. Niclosamide and Praziquantel. The choice of drug for individual treatment and mass intervention depends mainly on availability

and cost, although sporadic contraindications have to be respected as well (Murrel et al., 2005).

Mass chemotherapy of porcine cysticercosis with Oxfendazole and human taeniosis with Niclosamide or Praziquantel, selective detection and treatment of human taeniosis, and community health education has been tried in several countries, with limited success. Most of these trials applied the selected measure in a single village, limiting the generalisability of the results, and did not provide long term sustainability data (Garcia et al., 2006). When using Praziquantel for treatment of *T. solium* infections, one needs to use doses higher than 10 mg/kg in order to increase efficacy, but higher doses of Praziquantel pose a risk of inducing seizures in asymptomatic individuals harboring live cysticerci.

To avoid complication of Praziquantel, a single dose of 2 g Niclosamide orally should be the drug of choice for mass chemotherapy. However, to ensure high compliance and impact of mass human chemotherapy, the intervention should be combined with other mass health campaigns such as children preventable immunizable diseases. The effect of mass human chemotherapy intervention on disease can be checked by monitoring the rate of porcine cysticercosis in the target community. Furthermore, when designing such intervention, the cost and the logistics of drug distribution must be considered. For positive impact of mass human chemotherapy intervention in a short time, mass communication and education campaign towards safe disposal of human feces has to be implemented simultaneously (Sarti and Rajshekhar, 2003).

2.8.4 Prevention and control of human cysticercosis/taeniosis by treatment of infected pigs

Another approach for prevention and control of these parasitic diseases in human is periodic treatment of porcine cysticercosis with antiparasitic drugs such as Oxfendazole. This alternative has some advantages over a vaccine because Oxfendazole is cheap and it acts both as a treatment and a prophylaxis. Treatment

of pigs together with mass human chemotherapy campaigns will interrupt the cycle at the two potential points of *T. solium* transmission, pig and human (Sarti and Rajshekhar, 2003). Gonzalez et al. (1998) reported that a single dose Oxfendazole treatment of pigs should be included in mass cysticercosis control programs as a simple but effective method of decreasing porcine cysticercosis in endemic countries.

Despite the control of human cysticercosis/taeniosis by treatment of infected pig being a cost effective way of controlling a disease, the method has several challenges in its implementation. First, it may be difficult to convince communities to buy drugs while they know cyst can be killed by boiling or freezing. Second, the method is costly, as it requires health education campaigns before administration. Third, the method anchors cost for close supervision and monitoring of treated pigs for at least 3 months after treatment (Sarti and Rajshekhar, 2003).

2.8.5 Prevention and control of human cysticercosis/taeniosis by pigs vaccination

An alternative approach to interrupting the transmission cycle of *T. solium* cysticercosis is the vaccination of pigs (WHO, 2005). Since pigs are the only intermediate host in human cysticercosis/taeniosis zoonosis, vaccination could be an effective preventive measure. Probably the combination targeted on treatment of tapeworm carriers and vaccination of pigs, mainly in rural habitats, will enable communities to eradicate *T. solium* infection especially human neurocysticercosis (Flisser and Lightowlers, 2001).

In implementing control of human cysticercosis/taeniosis by vaccination, logistics for distribution of vaccine, cost of purchasing a vaccine, and availability of trained personnel needed to run a mass intervention campaign are essential components required to be considered. In so doing one must decide if such an intervention should be implemented over the entire country or only in places and communities where transmission of the disease has been demonstrated as 'hot spots' (Sarti and Rajshekhar, 2003). Thus, if governments will take up the challenges, then

theoretically this intervention strategy could be one of the best to prevent the transmission of this zoonosis.

2.8.6 Prevention and control of human cysticercosis/taeniosis by development

Taenia solium (cysticercosis in pigs and human) as well as taeniosis in human infections is potentially an eradicable infectious disease (PAHO/WHO, 1995). The disappearance of *T. solium* in most European countries is important evidence of the potential eradication of the parasite in the long term (Sarti and Rajshekhar, 2003). The eradication of this zoonosis in those countries is attributed to their economic development such as development in the spheres of environmental sanitation, pig husbandry and strict meat inspection (PAHO/WHO, 1995). Unfortunately, these measures are not yet feasible in all developing countries. Although the overall economic development is the best strategy for control of the *T. solium* infection, this is likely to require several decades in some developing countries. Therefore, other control approaches discussed must be relied upon for effective control of disease (Sarti and Rajshekhar, 2003).

2.9 Challenges in prevention and control of human cysticercosis/taeniosis

Control of human cysticercosis/taeniosis faces several practical obstacles in spite of being theoretically feasible. The obstacles include poor public awareness, lack of diagnostic facilities for diagnosing *Taenia solium* carriers, poor availability of taenicides in endemic areas, and low priority offered to the control of human cysticercosis/taeniosis (Pawlowski et al., 2005). These obstacles cause the disease to lose attraction for funding research and control activities compared to other diseases. To overcome these obstacles, effective health education, wider use of newly developed tests for *T. solium* infection detection, strengthening of health services infrastructure, essential drugs distribution, and increasing priority given in prevention of human cysticercosis/taeniosis is needed (INFOSAN report, 2006).

CHAPTER THREE

3.0 RESEARCH PROBLEM

3.1 Statement of the problem

Taenia solium infections, especially human cysticercosis, impose a substantial burden on humans globally. However, in endemic countries of the world, the burden of the disease is usually underestimated (Ito et al., 1998). In these areas, only the tapeworm carriers and the infected pigs are important in terms of transmission of the human cysticercosis.

The burden of *T. solium* disease is counted mainly in terms of neurocysticercosis presenting itself with seizures or epilepsy (Garcia et al., 2006). Although there are many causes of epilepsy such as trauma to the skull, brain tumor, encephalitis, blood clots (infarcts) and hemorrhages in the brain; neurocysticercosis is also a major cause of epilepsy in endemic areas. The findings from Rwanda revealed human cysticercosis (neurocysticercosis) as one of the major causes of epilepsy with figures as high as 44.6% (Zoli et al., 2003).

Neurocysticercosis causes psychosocial, medical, and economic impact on humans affected by the disease. Stigma and discrimination as psychosocial impact of the disease can be barrier to provision of adequate medical management (Rwiza et al., 1993; Zoli et al., 2003). Neurocysticercosis causes high economic loss in affected communities that in turn reduce the effective labor required in crop and livestock production in rural areas, thus perpetuating the vicious cycle of rural poverty and disease.

The burden of the disease can be reduced by management of disease using cysticidal drugs or surgical intervention, in turn reducing the psychosocial impact of the disease. Usually neurocysticercosis is diagnosed by immunological and radiological tests. However, high cost for the diagnosis of the disease is constraining factors for effective management of the disease in most developing

countries. For example, the cost of radiological tests in Tanzania is USD 200 for CT-scan and USD 450 for MRI, which are too high for ordinary people. In addition, immunological tests are not available in the country.

3.2 Rationale of the research study

Taenia solium infection is among the important neglected zoonotic diseases in endemic areas of developing countries of Africa, America and Asia. In order to control *T. solium* infection, collaboration between community, veterinary and medical professionals as a team is important.

In Tanzania, studies on *T. solium* infection have been carried out only on pigs (porcine cysticercosis). The findings from these studies showed *T. solium* infection to be hyperendemic in Mbeya region in the districts of Mbozi, Mbeya-Rural, and Chunya with the prevalence of 32%, 30.7% and 7.6% using Ag-ELISA respectively (Boa, 2005; Komba, 2008).

Despite the hyperendemicity of *T. solium* infection in Mbeya region, no surveys on the human aspect of infection (human cysticercosis/taeniosis) have been undertaken in the area (Boa, 2002). This study will focus on determining the prevalence and practices associated with human *T. solium* infections in Mbozi district, Mbeya region. The information obtained from this study will help in understanding the extent of *T. solium* infections in humans in Mbozi district and formulation of appropriate health intervention for control and management of *T. solium* infections in the country.

3.3 Research questions

3.3.1 General research questions

1. What is the extent of human *Taenia solium* infections in the study area?
2. What practices are associated with these infections in the human population?

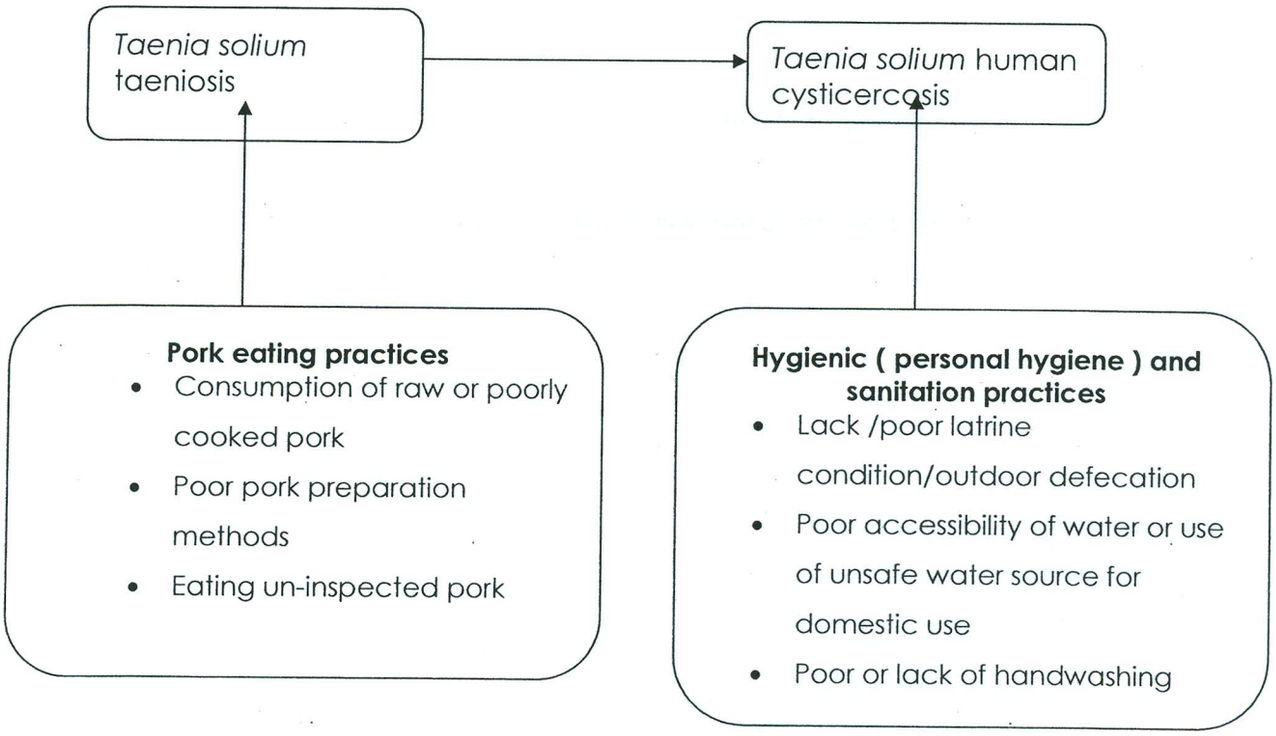
3.3.2 Specific research questions

1. What is the prevalence of human cysticercosis in the study area?
2. What is the prevalence of taeniosis in the study area?
3. Is there an association between pork consumption and taeniosis in the study area?
4. Is there an association between pork preparation and taeniosis in the study area?
5. Is there an association between sanitation practices and human cysticercosis in the study area?
6. Is there an association between handwashing practices before eating and human cysticercosis in the study area?

3.4 Conceptual framework for transmission of human *Taenia solium* infection.

For effective prevention and control of *T. solium* infections understanding practices associated with the disease is very crucial. In most endemic areas practices such as eating raw pork, eating poorly cooked pork, and eating un-inspected pork increases the risk for taeniosis while poor personal hygiene and sanitation conditions together with the use of untreated human excreta as fertilizers increases the risk for *T. solium* human cysticercosis.

Diagram 2: Diagrammatic presentation of conceptual frame work



3.5 Objectives

3.5.1 Broad objective

To determine the prevalence of, and identify practices associated with, human *Taenia solium* infections in Mbozi district, Mbeya region.

3.5.2 Specific objectives

The specific objectives of this study include:-

1) To determine the prevalence of human cysticercosis in the study area.
2) To determine the prevalence of taeniosis in the study area.
3) To examine the association between pork consumption and taeniosis in the study area.
4) To examine the association between pork preparation and taeniosis in the study area.
5) To find out the association between sanitation practices and human cysticercosis in the study area.
6) To find out the association between handwashing practices before eating and human cysticercosis in the study area.

CHAPTER FOUR

4.0 METHODOLOGY

4.1 Study design

A community-based descriptive cross-sectional study. Data collection took place from April to July 2009.

4.2 Study setting

The study was done in thirteen villages of Mbozi district, Mbeya region; Chipumpu, Chitete, Itaka, Itepula, Iyula, Mbozi, Mkutano, Mpela, Nambala, Namole, Nandanga, Nkangamo and Sakamwela. The study villages were selected following a preliminary survey that was conducted by Komba (2008), which indicated the presence of high prevalence of porcine cysticercosis.

The District is located in Southern highlands of Tanzania, Southwest of Mbeya region between Latitudes 7° and 9° 12' South of the equator, Longitudes 32° 7' 30" and 33° 2' 0" East of Greenwich Meridian, with an altitude with an altitude 900 – 2750 meters above the sea level. It is one among 8 districts of Mbeya region, Tanzania; the district is divided into 26 wards. To the north, the district is bordered by Chunya district, to the east by Mbeya Urban and Ileje districts, to the south, by Zambia and to the west by the Rukwa Region.

The estimated human population in Mbozi district is about 513,600. The district has 152 villages and 119,308 households (National Census report, 2002). The inhabitants grow mainly coffee, beans, rice, and maize. Some of the households also keep goats, chickens, and ducks. Pig rearing is very common in Mbozi district and pork consumption rate is very high.

4.3 Study population

The study population consisted of household members between the ages of 15 to 60 years who were living in sampled households in the selected villages. Usually the

disease or symptoms of human cysticercosis (symptomatic neurocysticercosis) presents mostly between 15-40 years of age (Garcia et al., 2006).

4.4. Sample size estimation

Marginal error(m)	Estimated prevalence(p)	Design effect(d)	Adjusted confidence coefficient(t)	Minimum sample size required(n)	Non compliance rate(r)	objective
6%	* 20%	1.5	2.24	420	25%	1
4%	** 9%	1.5	2.24	440	25 %	2

Sample size projection table that was used to calculate the sample size

* Prado-jean et al., 2007

** Zoli et al., 2003

Sample size estimation was calculated using the formula:-

$$n = \frac{t^2 \times p (1 - p) \times d}{m^2}$$

Where n is the required number of individuals to be examined, t^2 is adjusted confidence coefficient for objectives 1 and 2, p is a known or estimated prevalence, and m is the allowable error of estimation while d is the design effect. The study used 95% confidence level with an allowable error of estimation of 0.05. Since we have two different disease conditions with different prevalence, the study used the highest minimum sample size obtained using estimated prevalence (p) of 9% reported by Prado-Jean et al., (2007).

Thus $n = \frac{(2.24)^2 \times 0.09 \times 0.91}{(0.04)^2} = 385$

In order to take into account the nonresponse rate, the minimum sample size obtained was multiplied by 25% of sample size (i.e. 25/100 x 385) = 480. The sample size was then adjusted by 60% to permit adequate power for each

comparative analysis for 4 comparisons i.e. n + (60%n) = 480 + (60/100 x 480) = 480+288=768 ≈ 800=900. Therefore, the minimum of 900 participants was sampled.

4.5 Definition of terms

Terms used in the present study refers to the following:

Neurocysticercosis:

Neurocysticercosis (NCC) is defined as infection of the brain and its coverings by the larval stage of the *Cysticercus cellulosae* (Garcia et al., 2003).

Epileptic seizure:

Occurrence of more than two seizures at least in the last one/ two years on separate days.

Taeniosis:

Intestinal infection caused by *Taenia solium.*

Human cysticercosis:

Development of cysticerci of *Cysticercus cellulosae* in tissues of humans.

Active human cysticercosis:

People who had antigens of viable *Cysticercus cellulosae* in the body.

Exposure to human cysticercosis:

People who had antibody against viable, dying, or calcified *Cysticercus cellulosae* in the body.

Prevalence:

The total number of cases of the disease in the population at a given time.

4.6 Sampling method

A cluster-random sampling with probability proportion to size technique was used for selection of households. The sampling of household in the selected villages was done using a list available at Village Executive Officers (VEO) office in each selected village. About 10% of total households in each selected village participated in the study except in Mkutano and Nandanga villages where less than 10% of sampled households participated in the study.

In each selected village, one day was used by the principal investigator to introduce herself and the research team to VEO. Permission to conduct the study in the respective village was sought in the same visit. On the followed visits, the principal investigator (GM) called a village meeting and explained the purpose of the study to the villagers. After the village meeting she had a meeting with local authorities and then requested a list of available households from VEO in the respective village. Simple random sampling using lottery method was used to select households from available list. The selected households were visited by the research team on the following days to explain the purpose of the study to household members.

After finishing home visit in a village, household members ranging between the age of 15- 60 years within the sampled household who consented to participate in the study, were invited to VEO office for interview and sample collection on a planned day with assistance from local authorities. Among consented participants in each sampled household who came at VEO office, only one household member was selected to participate in the study at random by tossing a coin or lottery. The aim of the study and procedures to be involved was explained to the sampled participants and then individual written informed consent was obtained prior to the whole procedure of data collection.

Participants were included into the study if; they were living in the sampled household, had age between 15 years and 60 years and gave consent for participation. However, participants were excluded from the study if; they had age below 15 years and above 60 years; had mental disability, in absence of relative to consent/to respond to questions asked on behalf and did not give consent to participate.

4.7 Data collection

Data collection was conducted for three months (120 days) after training and recruitment of research assistants, pre-testing of research tools and obtaining informed consent from study participants. During interviews, both Swahili and local language were used to collect information from participants.

4.8 Research tools

A structured questionnaire designed for the purpose of the study was used as study tool. Information collected included:-

- Demographic information (age, sex, religion, marital status, and educational level).
- Pork consumption habit and preparation practices.
- Personal hygiene practices (hand washing before eating and boiling of drinking water).
- Sanitation practices (presence of latrine, type of latrine present, source of drinking water).
- Previous histories of passing proglottides in stool and suggestive symptoms for neurocysticercosis such as chronic severe headaches, partial seizures and epileptic seizures.

4.9 Research assistants

Five research assistants were recruited including two laboratory technicians, a social scientist, and two medical doctors. Administration of questionnaire was conducted by the researcher with assistance of the social scientist and medical doctors, while laboratory technicians collected and processed the blood samples to get sera. Training of research assistants was done for one week in Mbozi district before data collection. Training focused on conduction of structured interview, storage, and handling of specimens. Both theory and practical teaching methods were used to make sure research assistants understood the research tools being used.

4.10 Piloting of research tools

The piloting of research tools was conducted at Mlowo village, within the Mlowo ward after training of research assistants. The piloting enabled the principal investigator to identify areas in the research tools that needed modification before embarking onto the real study.

4.11 Specimen collection

During the field work both stool and blood specimens were collected from the same participant enrolled in the study. A total number of 830 sera were obtained from enrolled participants, among them only 820 returned stool specimens while 10 participants did not provide stool specimen.

4.11.1 Blood collection for determining the prevalence of human cysticercosis by Antigen ELISA (B158/B60) and Antibody ELISA (rT24h)

Collection of blood from sampled participants took place in the community, at the office of Village Executive Officer (VEO) as suggested by participants. A total number of 830 blood samples from participants were collected.

During blood taking, 10 mls of venous blood was collected from each consented participant using vacutainer system in a labelled plain vacutainer tube. After collection of blood samples in a day, blood specimens were transported to Mbozi mission hospital or Vwawa district hospital within 4-5 hours after collection. In Vwawa or Mbozi mission hospital, all blood samples were centrifuged at a speed of 3500 rpm, then serum extracted, aliquoted, and kept frozen. In villages that were far from the storage facility, centrifugation was done at the site, then sera were transported to the nearby proposed storage facility (Vwawa district hospital or Mbozi mission hospital) using cool box packed with ice packs in order to ensure that the specimens were frozen.

At the end of data collection, serum samples were transported to Dar es Salaam using cool box packed with dry ice and stored in a freezer at -20°C until transported to CDC-Atlanta (USA) and University of Zambia (UNZA)-LUSAKA

for serological analysis using Ab-ELISA (rT24h), western blot (rES38), and Ag-ELISA (B158/B60) techniques respectively by the principal investigator. During transportation, serum samples were kept frozen by packing samples in a cool box with dry ice. The samples reached laboratory in the required temperature proposed by the test developer.

4.11.1.1 Immunological tests used for detection of *T. solium* human cysticercosis

For detecting human cysticercosis, both Ag-ELISA (B158/B60) and Ab-ELISA (rT24h) were used by the researcher. The (B158/B60) Ag-ELISA was used in order to detect participants with active human cysticercosis (i.e. people with viable, degerating, well established cysts), while Ab-ELISA was used in order to detect exposure to human cysticercosis (i.e. people with dying, degenerating, or calcified cysts).

4.11.1.2 Quality assurance

For quality assurance, samples were kept in duplicate in each ELISA plate, any plate with positive and negative readings in a duplicate were treated as contamination, thus the specimen was repeated.

4.11.1.3 Procedure for Enzyme-linked-immunosorbent assay (Ag-ELISA) used for the detection of circulating antigens of *T. solium* cysticerci

A monoclonal antibody (MoAb) based ELISA to detect circulating antigens of *T. solium* cysticerci in serum was used as described by Dorny et al. (2000). Briefly, the sera were pre-treated using trichloroacetic acid (TCA) and used in ELISA at a final dilution of 1/4. Two MoAbs (MoAb B158C11A10 and MoAb B60H8A4) were used in a sandwich ELISA. The first monoclonal antibody (MoAb B158C11A10) was diluted at 5 µg/ml in carbonate buffer (0.06 m/pH 9.6) for coating while the second monoclonal antibody (a biotinylated MoAb B60H8A4) was diluted at 2.4 µg/ml in phosphate-buffered saline containing (PBS) 0.05%

Tween 20 and 1% new-born calf serum as detector antibody. The incubation was carried out at 37 ^{0}C on a shaker for 30 minutes for the coating of the first MoAb and for 15 minutes for all subsequent steps.

Before addition of O-phenylene diamine (OPD), 100 µl of streptavidine diluted at 1/10,000 in blocking buffer was added in all wells except for the substrate control. Then a chromogen/substrate solution consisting of OPD (Dako, Glostrup, Denmark, #S2045) and H_2O_2 was added and incubated without shaking at room temperature for 15 minutes. To stop the reaction, 50 µl of (4 N) H_2SO_4 was added to each well. The plates were read using an ELISA reader (Thermo labsystems Multiskan) at 492 nanometer. The ELISA ratio was calculated by dividing the OD of the sample by the calculated cut-off value of the eight negative controls at 95% confidence interval (Dorny et al., 2000). After analysis of serum samples using Ag-ELISA, few selected cases went for CT-scan at Muhimbili National Hospital, Dar es Salaam to rule out neurocysticercosis.

4.11.1.3.1 Radioimaging test for detection of neurocysticercosis (NCC) cases among selected study participants

CT-scan test was used for detection of neurocysticercosis cases among the few selected Ag-ELISA positive participants. Of all Ag-ELISA positive participants, only 55 participants were CT- scanned at Muhimbili National Hospital (MNH), Dar es Salaam. The participants scanned included all Ag-ELISA positive epileptics (28 patients) and 25% of randomly selected Ag-ELISA positive non-epileptic participants (i.e 27 participants). The CT- scan of the head was done from base to vertex before and after I.V contrast in all selected participants. All scans were performed by the same radiographer and read by the same radiologist.

4.11.1.4 Procedure for Enzyme-linked-immunosorbent assay for the detection of circulating antibody of *T. solium* cysticerci Ab-ELISA (rT24h)

The test is based on recombinant proteins derived from LLGP diagnostic antigens. The assay used rT24h in ELISA assay for detection of anti-cysticercal antibodies. The test has high specificity of 94.2% and sensitivity 96.1%. The Ab-ELISA (rT24h) was performed as follows: polystyrene ELISA plate was coated with 100 micro liter (µl) diluted Antigen (1.5 microgram (µg)/ milliliter (ml) solution into each well and then incubated for 2 hours (hrs) at room temperature on a minutes (min) orbital shaker at speed 5. Unbound antigen (Ag) was decanted and wells washed five times with phosphate-buffered saline with plus 3% Tween 20 (PBS/Tw). After washing the plates, 98 microliter (µl) of PBS/Tw + 5% Milk was added in each well. Thereafter, 2 microliter (µl) of either standard control or test samples were added in appropriate wells except in a blank well in which 100 µl of PBS/Tw were added.

The test sera were assayed in duplicate for quality control. The plates were then incubated at room temperature for 30 min on a shaker at speed 5 before washing. Thereafter, plates were incubated with 100 µl of diluted conjugate (peroxidase conjugated Goat anti-Human IgG-whole molecule) for 30 min on a shaker at room temperature. Then unbound conjugate was decanted and plates washed five times following which 100 micro liter (µl) of TMB substrate-1component (Kirkegaard and Perry.cat#52-00-00) were added per well and then incubated for 10 minutes at room temperature on a min orbital shaker at speed 5. The reaction was stopped by addition of 100 micro liter of stop solution ($1NH_2SO_4$) per well and plates were read at 450 nanometer (nm) on THERMOmax microplate reader using SoftmaxPRO Software. The cut off optical density (OD) was calculated using a standard curve and an optical density (OD) value ≥2.55 was considered positive.

4.11.2 Stool specimen collection for detection of taeniosis prevalence

Stool samples were collected from the same person from whom blood sample was taken. The participants were given a stool container and information on how to collect stool after they had been interviewed and given a blood sample. Majority of participants managed to bring stool on the same day and only a few returned on the followed day. After returning the stool sample, immediately the stool sample was fixed with 3mls of 10% formalin in a 30ml stool container, then aliquoted in 2mls cryovials for transportation to CDC-Atlanta (USA) to be analyzed using Copro-Antigen ELISA (Copro-AgELISA) test. The remaining portion was examined using formal-ether concentration method in order to detect *Taenia* species eggs and other intestinal parasite eggs, larvae, or cysts. All laboratory tests were performed blinded.

4.11.2.1 Parasitological examination of stool samples

The faecal samples were examined microscopically using formal-ether concentration method and using Co-AgELISA test. Faecal samples were also examined for other intestinal parasite eggs, larvae, or cysts. A total number of 820 participant's stool was examined using formal-ether concentration method and Copro-AgELISA test.

4.11.2.1.1 Procedure for Copro-Antigen ELISA assay used for the detection of taeniosis

During analysis of stool samples by Copro-AgELISA, the ELISA plates were coated with RbATSIgG antibody and incubated in a robotic machine (Trituris) containing all required reagents for each step and test sera (samples). The robotic machine analyzed all samples, and results were read by Vmax plate reader using SOFTmax software. All reactions with concentrations greater than 0.02 µg/ml were considered positive. Similarly, in the robotic machine, the samples were kept in a duplicate. Any duplicate with positive and negative test results were treated as contamination and repeated. Confirmation of *Taenia solium* taeniosis was done using sera of Copro-AgELISA positive participants by western blot (rES38) test.

4.11.2.1.2 Procedure for formal-ether concentration method

A stool sample in a stool container was stirred using an applicator stick, and then poured on top of centrifuge tube containing two layers surgical gauze. Diluted 10% formalin was added to reach 10ml, then 3mls of ether added into a centrifuge tube containing specimen. The solution in a centrifuge tube was shaken vigorously and centrifuged at a speed of 3000 rotations per minute (rpm) for 1-2 minutes. The contents of the centrifuge tube were discarded by inverting it, the remaining portion of sediment was then put on a glass slide, covered with cover slip and examined microscopically at 10 X or 40 X objectives for presence of *Taenia* species eggs and other intestinal parasites eggs, larvae or cysts. At the end of the laboratory work, all participants with taeniosis and other intestinal parasites were treated at the nearby health facilities under supervision of the principal investigator and a medical doctor from Mbeya referral hospital.

4. 12 Data entry, cleaning, and analysis

All questionnaires were checked daily for completeness and consistency. Data entry was done using EPI info software version 6. Cleaning of data and analysis was done using Statistical Package for Social Scientist (SPSS) version 13. During data analysis, Univariate analysis on categorical variables was done using chi-squared test whereby p-values of equal or less than 0.05 was considered statistically significant. On the other hand, Multivariate analysis on statistically significant factors obtained upon Univariate analysis was done using logistic regression statistical analysis method in order to adjust for other factors.

4.13 Ethical considerations and research clearance

The study protocol and the manner in which informed consent obtained was approved by the ethical committee at Muhimbili University of Health and Allied Sciences (MUHAS) (see appendix 5). The research permit was granted by the Regional Medical Officer (RMO) of Mbeya region. Permission to conduct the study in the villages was granted by District Administrative Secretary (DAS) and District Executive Director (DED) of Mbozi district. The director of Mbeya referral hospital

and District Medical Officer (DMO) at Vwawa district hospital were also informed about the study.

Consent to participate in this study was obtained from individual participants sampled in a particular household by signing the consent form attached on the questionnaire. The consent form contained information on risk and benefit for participation. Participants who tested positive with Ag-ELISA (Participants with active human cysticercosis) were referred to Mbeya referral hospital by the principal investigator for further management while participants with other intestinal parasites were treated during the feedback.

4. 14 Study feedback to the surveyed villages (communities)

The principal investigator revisited the surveyed villages for feedback in December 2009 to February 2010. During feedback, participants received their results individually and treatment was done accordingly. During treatment, Niclosamide 2g was given to participants with taeniosis (1g start followed by 1g after 2hours) while for those with *Hymenolepis nana,* 6g of Niclosamide was given in 3 divided dose (i.e. 2g daily for three days). Albendazole 400mg single dose was given to participants with hookworm infection, enterobiasis, and ascariasis. For those with strongyloidiasis 400mg of Albendazole was given for three consecutive days. In case of giardiasis, Metronidazole 2g daily for three days was given while 40mg/kg of Praziquantel was given in those with schistosomiasis. No adverse effects occurred during treatment.

In addition, during feedback phase, participatory health education was done simultaneously with CT-scanning of selected participants at Muhimbili National Hospital. Health education focused on the ways of acquiring the disease, the impact of the disease on human and pigs and how to prevent the disease in order to create community awareness. At the end of health education, members from each village were able to suggest the best way of controlling the disease according to their capability.

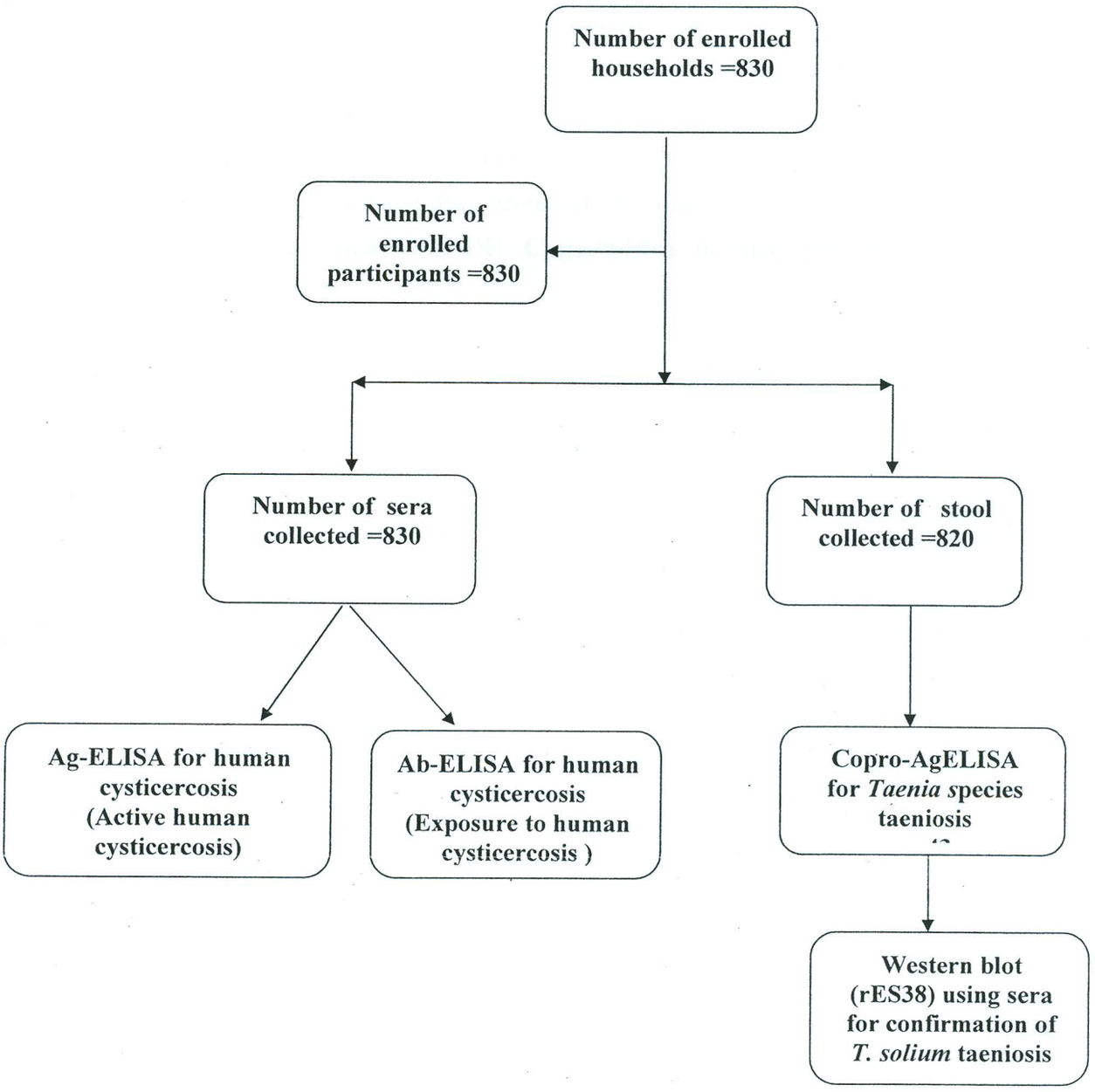
CHAPTER FIVE

5.0 RESULTS

This chapter presents the findings of the study. Analysis was conducted according to the objectives of the study and similarly findings are presented according to the objectives.

5. 1 Quantitative results

Fig 2: Figure showing sampling distribution of study participants.



5.1 Demographic characteristics of the study participants

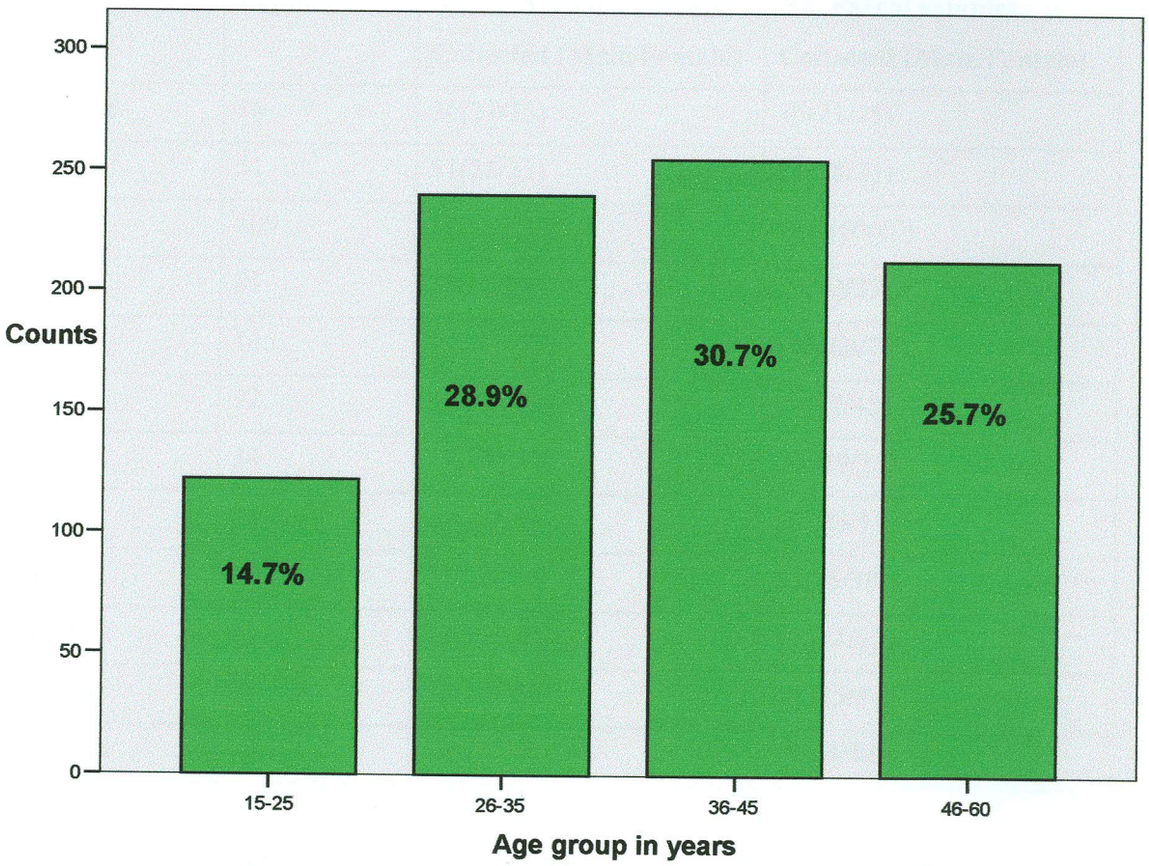
During the 3 months of data collection, there were a total of 900 sampled households within the study villages. Out of the sampled households, only 830 (92.2%) households agreed to participate in the study and in each household one person was enrolled.

There were more male 476 (57.4%) participants than females 354 (42.6%). The age range of study participants was 15-60 years with mean age of 37.86 ± 11.3 years. Majority of them 255 (30.7%) were between 36-45 years. A large proportion of participants had finished primary education (77.1%) and the least had College or University education (0.5%). In addition, most of participants (80.2%) were married. Regarding participants' religions, Christians were the majority (82.4%) and the least were Muslims (1.7%). Moreover, inhabitants enrolled in the study consisted mostly of farmers (85.4%). Characteristics of study population are presented in Table 1.

Table 1. Basic characteristics of study participants (n=830)

Variable	N	(%)
Sex		
Male	476	(57.4)
Female	354	(42.6)
Marital status		
Married	666	(80.2)
Unmarried	90	(10.8)
Widow/Divorced/Separated	74	(8.9)
Religion		
Christian	684	(82.4)
Moslem	14	(1.7)
No religion (pagans)	132	(15.9)
Education		
Never gone to school	137	(16.5)
Primary education	640	(77.1)
Secondary education	49	(5.4)
College/University	4	(0.5)
Occupation		
Farmers	709	(85.4)
Business/self employment	72	(8.7)
Employed	12	(1.4)
Others (students)	37	(4.5)

Fig 3. Bar chart showing age distribution of participants.



Regarding the age, majority 255 (30.7%) fell into age 36-45 years, followed by 40 (28.9%) age group 26-35 years, 213 (25.7%) age group 46-60years and 122 (14.7%) age group 15-25 years.

Table 2. Population and sampling data

Village	Population	No. Serum samples Collected (Male/Female)	No. Faecal samples Collected (Male/Female)
Chipumpu	36	36(21/15)	36(21/15)
Chitete	51	51(28/23)	51(28/23)
Itaka	109	109(60/49)	109 (60/49)
Itepula	81	81(52/29)	79(52/27)
Iyula	145	145(66/79)	145(66/77)
Mbozi	92	92 (47/45)	92(47/45)
Mkutano	34	34(19/15)	34 (19/15)
Mpela	34	34(23/11)	34 (23/11)
Nambala	55	55 (25/30)	55(25/30)
Namole	33	33(21/12)	33 (21/12)
Nandanga	38	38(25/13)	38 (25/13)
Nkangamo	59	59(45/14)	58(44/14)
Sakamwela	61	61(43/18)	58 (42/16)
Total	**830**	**830(476/354)**	**820(473/347)**

In this study, 830 blood samples were collected from consented participants of the sampled households. However, only 820 participants collected the stool samples. Most of participants who collected the samples were from Iyula, Itaka, Mbozi and Itepula and others were from the remaining villages.

Table 3. **Frequency of seropositive for *T. solium* cysticercosis (Ag-ELISA and Ab-ELISA) according to villages of Mbozi district, Mbeya region**

Village	Number tested	Ab-ELISA Positive cases		Ag-ELISA Positive cases	
		N	(%)	N	(%)
Itaka	109	49	(45)	35	(32.1)
Iyula	145	50	(34.5)	19	(13.1)
Itepula	81	30	(37)	15	(18.5)
Chitete	51	39	(76.5)	11	(21.6)
Chipumpu	36	24	(66.7)	0	(0)
Mbozi	92	28	(30.4)	8	(8.7)
Nambala	55	20	(36.4)	9	(16.4)
Mpela	34	23	(67.6)	13	(38.2)
Sakamwela	61	20	(32.8)	7	(11.5)
Namole	33	26	(78.8)	9	(27.3)
Nandanga	38	29	(76.3)	4	(10.5)
Nkangamo	59	18	(30.5)	6	(10.2)
Mkutano	34	20	(58.8)	2	(5.9)
Total	**830**	**376**	**(45.3)**	**139**	**(16.7)**

Human cysticercosis cases were detected in all studied villages using Ab-ELISA (rT24h) and Ag-ELISA (B158/B60) tests. In using Ab-ELISA test a large proportion of participants with circulating antibodies of *T. solium* cysticercus (exposed to human cysticercosis) were found in Namole 26 (78.8%); Nandanga 29 (76.3%); Mkutano 20 (58.8%); Mpela 23 (67.6%); Chitete 39 (76.5%); and Chipumpu 24 (66.7%). Majority of participants with circulating antigens of *T. solium* cysticercus (active human cysticercosis) were also found in the villages of

Mpela 13 (38.2%); Itaka 35 (32.1%); Namole 9 (27.3%); and Chitete 11 (21.6%). Despite the high rate of exposure to human cysticercosis in chipumpu village, surprisingly no one had circulating *T. solium* cysticercus antigens (i.e. no single case of active cysticercosis was found).

Table 4. The prevalence of *Taenia solium* infection in surveyed villages of Mbozi district, Mbeya region

Disease condition	No tested positive		95% Confidence Interval
	N	(%)	
Taenia species taeniosis (Copro-AgELISA)	43/820	(5.2)	(3.7 - 6.7)
T. solium taeniosis (rES38)	34/820	(4.1)	(2.8 - 5.5)
Active human cysticercosis (Ag-ELISA)	139/830	(16.7)	(14.2 - 19.2)
Exposure to human cysticercosis (Ab-ELISA)	376/830	(45.3)	(41.9 - 44.7)

The overall prevalence of active human cysticercosis in all surveyed villages (by Ag-ELISA) was 16.7% with 95% CI (14.2% -19.2%) while exposure to human cysticercosis 45.3% (by Ab-ELISA) with 95% CI (41.9% - 48.7%). For taeniosis, the overall prevalence of *Taenia* species taeniosis in all surveyed villages was 5.2% (by Copro-AgELISA) with 95% CI (3.7% - 6.7%) while the prevalence of *T. solium* taeniosis was 4.1 % with 95% CI (2.8% - 5.5%) using western blot (rES38).

Table 5. **Table showing results of CT-scan on cystic lesion suggestive of neurocysticercosis among 55 selected participants scanned**

		CT-scan results		
		Positive	**Negative**	**Total**
Ag-ELISA	**Epileptics**	18 (64.3%)	10 (35.7%)	28
	Non-epileptics	12 (44.4%)	15 (55.6%)	27
Total		30	25	55

A total of 30 (54.6%) Ag-ELISA positive participants CT-scanned, confirmed to havecystic lesion suggestive of neurocysticercosis. Among confirmed cases, 18 (64.3%) were epileptics and 12 (44.4%) non-epileptics.

Table 6. Univariate analysis on risk factors associated with human cysticercosis (Ag and Ab ELISA) in Mbozi district, Mbeya region

Risk factor	Total	Ag-ELISA +VE		p-value	Ab-ELISA +VE		p-value
		n	(%)		N	(%)	
Age group							
15-25	122	11	(9.0)	0.025	54	(44.3)	0.979
26-35	240	35	(14.6)		109	(45.4)	
36-45	255	50	(19.6)		118	(46.3)	
46-60	213	43	(20.2)		95	(44.6)	
Sex							
Female	354	48	13.1	0.034	134	(37.9)	0.001
Male	476	91	19.1		242	(50.8)	
Presence of latrine							
Present	817	137	(16.8)		370	(45.3)	
Absent	13	2	(15.4)	0.895	6	(46.2)	0.950
Source of water							
Safe water source	449	76	(16.9)	0.880	230	(51.2)	0.001
unsafe water source	381	63	(16.5)		146	(38.3)	
Handwashing practice							
Dipping	451	110	(24.5)	0.001	280	(62.4)	0.001
Running	379	29	(7.6)		96	(25.2)	
Confirmed carrier by Copro-AgELISA							
Positive	43	15	(34.9)		30	(69.8)	
Negative	777	122	(15.7)	0.004	342	(44.0)	0.004
Missing	10	2	(20)		4	(40.0)	

The prevalence of active human cysticercosis increased statistically significantly with age. A large proportion of seropositive participants by Ag-ELISA were in the age group 46-60 years and lowest were in age group were in age group 15-25 years

$p<0.05$. In addition, males had a statistically significantly higher prevalence of active human cysticercosis (19.1%) as compared to females (13.6%) $p<0.05$. Exposure to human cysticercosis showed no big difference across different age groups. Furthermore, the prevalence of exposure to human cysticercosis was statistically significantly associated with sex, with more males affected than females ($p<0.05$).

Most of the households surveyed had a pit latrine (98.4%) while only 1.6% lived in a household without a latrine. Among 13 households, without a latrine (1.3 %) said they used neighbors latrine and (0.2%) defecated outside the house in the bush around. Majority 449 (54.1%) of surveyed people used unsafe water source for drinking while about 381 (45.9%) used safe water source (tap) water for drinking.

Information on personal hygiene showed that the traditional handwashing by all people dipping their hands in the same bowl of water (dipping method) was the most dominant (54.3%). A substantial number also responded that they washed hands with running water (45.9%). No respondent reported eating without somehow washing their hands.

Univariate analysis of risk factors for human cysticercosis using chi-squared statistical analysis test showed only sex, being confirmed carrier by Copro-AgELISA and hand washing practices appeared to be statistically significantly associated with human cysticercosis, that is active and exposure to human cysticercosis. While age group was statistically significantly associated with active human cysticercosis and source of drinking water with exposure to human cysticercosis ($p<0.05$). Results in table 6.

Table 7. Univariate analysis on symptoms suggestive to be associated with human cysticercosis (Ag and Ab ELISA) in Mbozi district, Mbeya region

Symptoms	Total	Ag-LISA+VE		p-value	Ab-ELISA+VE		p-value
		n	(%)		N	(%)	
Epileptic seizures							
Yes	123	28	(22.8)	0.050	66	(53.7)	0.044
No	707	111	(15.7)		310	(43.8)	
Chronic severe headache							
Yes	431	83	(19.3)	0.050	202	(46.9)	0.306
No	397	56	(14.1)		174	(43.1)	
Lossof consciousness							
Yes	142	23	(16.2)	0.847	65	(45.8)	0.901
No	688	116	(16.9)		311	(45.2)	
Partial seizure							
Yes	422	67	(15.9)	0.495	193	(45.7)	0.799
No	408	72	(17.6)		183	(44.9)	

The information on suggestive symptoms to be associated with human cysticercosis showed 14.8% had previous history of epileptic seizures. Of all participants who reported previous history of epileptic seizures, 22.8% were sero-positive by Ag-ELISA and 53.7% by Ab-ELISA. About 431 (52.1%) reported previous history of chronic severe headache, however only 83 (19.3%) were sero-positive for Ag–ELISA compared to 202 (46.9%) by Ab–ELISA.

Furthermore, less than a quarter (17.1%) reported previous history of loss of consciousness while about a half (50.8%) had a previous history of partial seizures. Among all participants reported previous history of unconsciousness, 23 (16.2%) were sero-positive by Ag-ELISA and 65 (45.8%) by Ab–ELISA. With regard to

previous history of partial seizures, about 67 (15.9%) were sero-positive by Ag-ELISA while 193 (45.7%) were sero-positive by Ab-ELISA.

Univariate analysis on suggestive symptoms for human cysticercosis using chi-squared statistical analysis test showed only previous history of epileptic seizures was statistically significantly associated with active and exposure to human cysticercosis. While previous history of chronic severe headache showed to be statistically significantly associated with active human cysticercosis ($p<0.05$). (See table 7)

Table 8: Multivariate analysis on factors for human cysticercosis that were considered in the logistic regression analysis

Proposed risk factor	Level	OR (95% C.I)	p-value
Risk factor associated with active human cysticercosis (Ag-ELISA)			
Age group	15-25years	Ref	0.02
	26-35years	1.8 (0.9-3.8)	
	36-45years	2.5 (1.2- 5.0)*	
	46 -60years	2.6 (1.3 – 5.3)*	
Hand washing	Running water	Ref	0.0001
	Dipping (traditional handwashing)	3.8 (2.5 - 5.9)*	
Confirmed carrier by Copro-AgELISA	Negative Copro-AgELISA	Ref	0.03
	Positive Copro-AgELISA	2.6 (1.3- 5.2)*	
	Non response	1.7 (0.2-9.2)	
Risk factor associated with exposure to human cysticercosis (Ab-ELISA)			
Sex	Female	Ref	0.005
	Male	1.6 (1.1-2.1)*	
Hand washing	Running	Ref	0.001
	Dipping (traditional handwashing)	5.0 (3.7 - 6.9)*	
Confirmed carrier by Co-AgELISA	Negative Copro- Ag ELISA	Ref	0.05
	Positive Copro- Ag ELISA	2.6 (1.3- 5.2)*	
	Non response	0.9 (0.2- 3.7)	
Source of water	Safe water source	Ref	0.0001
	Unsafe water source	1.9 (1.4 – 2.5)*	

Key: OR= Odds ratio C.I= 95% confidence interval * = Significant factor at 95% confidence level

Multivariate analysis on the risk factors associated with human cysticercosis using logistic regression statistical analysis showed seropositivity with Ag-ELISA (active human cysticercosis) to be statistically significantly associated with increase in age. The risk is higher in the age group 36-45 years (OR= 2.5; 95 % CI = 1.2-5.0) and in the age group between 46-60 years (OR= 2.6; 95% CI= 1.3-5.3). In addition, hand washing practices shows significant association with seropositivity with Ag-ELISA (active human cysticercosis).

The risk was higher in those using dipping method (traditional hand washing) with (OR=3.8; 95% CI =2.5-5.9). Furthermore, being confirmed carrier of *Taenia* species by Copro-AgELISA shows to be significantly associated with seropositivity with Ag-ELISA (active human cysticercosis), with higher risk in Copro-AgELISA positive participants(OR=2.6; 95% CI=1.3-5.2).

Significant association was found between sex and seropositivity with Ab-ELISA (exposure to human cysticercosis), with males more likely to be infected compared to females (OR= 1.6; 95% CI= 1.1- 2.1). Similarly, hand washing practices show to be significantly associated seropositivity with Ab-ELISA (exposure to human cysticercosis) with those used the dipping (traditional hand washing) method being more likely at risk for the disease, (OR=5.10: 95% CI=3.7- 6.9). On the other hand, seropositivity with Ab- ELISA (exposure to human cysticercosis) showed to be significantly associated with the source of water. Participants using unsafe water source were more likely to be at risk for the disease (OR=1.9; 95% CI= 1.4-2.6. In addition, being confirmed carrier of *Taenia* species by Copro-AgELISA makes a person to be more likely to be at risk for the exposure to human cysticercosis (OR=2.48; 95% CI=1.20 - 5.10). See table 8.

Table 9. Table showing the results of taeniosis by villages in surveyed villages of Mbozi district, Mbeya region

Village	Number tested in a village	Number of Copro-Ag ELISA Positive	Number onfirmed *T. solium* taenisois by western blot (rES38)	Number of participants with *Taenia* species ova (by microscopy)
	N	n (%)	n (%)	n (%)
Itaka	109	2 (1.9)	2 (1.9)	1 (0.1)
Iyula	145	21(14.5)	14 (9.7)	2 (0.2)
Itepula	81	9 (11.3)	8 (9.9)	1 (0.1)
Chitete	51	0 (0.0)	0 (0.0)	0 (0.0)
Mbozi	92	1 (1.1)	1 (1.1)	1 (0.1)
Nambala	55	1 (1.8)	1 (1.8)	0 (0.0)
Mpela	34	1 (2.9)	1 (2.9)	1 (0.1)
Sakamwela	61	2 (3.3)	2 (3.3)	2 (0.1)
Namole	33	4 (12.7)	3 (9.1)	0 (0.0)
Nandanga	38	0 (0)	0 (0)	0 (0.2)
Nkangamo	59	1 (1.7)	1 (1.7)	1 (0.1)
Chipumpu	36	0 (0.0)	0 (0.0)	0 (0.0)
Mkutano	34	1 (4.8)	1 (4.8)	0 (0.0)
Total	**820**	**43 (5.2%)**	**34 (4.1%)**	**9 (1.1%)**

Among 820 stool samples analyzed, 43 (5.2%) cases of *Taenia* species taeniosis were detected by Copro-AgELISA and nine 9 (1.1 %) cases by microscopy. While 34 (4.1%) cases of *Taenia solium* taeniosis were detected by western blot among Copro-AgELISA positive stool samples. Majority of cases that were detected by Copro-AgELISA and western blot (rES38) were from Iyula 21 (14.5%); Itepula 9

(11.1%); and Namole 4 (12.7%). As shown in Table 8, there was no single case of taeniosis detected in villages of Chitete, Nandanga, and Chipumpu.

Table 10. Univariate analysis on risk factors associated with taeniosis

Risk factor	Number tested (N)	Copro-AgELISA positive		p-value
		n	(%)	
Age groups				
15-25	122	3	(2.5)	
26-35	240	19	(7.9)	
36-45	255	15	(5.9)	0.096
46-60	213	6	(2.8)	
Sex				
Male	476	28	(5.9)	
Female	354	15	(4.2)	0.518
Pork consumption				
Yes	720	43	(5.2)	
No	110	0	(0.0)	0.029
Frequency of pork consumption				
More frequently	460	34	(7.4)	
Frequently	187	5	(2.7)	
Less frequently	73	4	(5.5)	0.020
Non pork consumers	110	0	(0.0)	
Pork preparation				
Raw pork	14	4	(28.6)	
Poorly cooked pork	561	39	(7.0)	
Properly cooked pork	145	0	(0.0)	0.001
Non pork consumers	110	0	(0.0)	
Previous history of passing ploglottides				
Yes	134	14	(10.4)	
No	546	25	(4.6)	0.012
I don't know	150	4	(2.7)	

Most participants 720 (86.7%) were pork consumers. Among pork consumers, 55.4% consumed pork very frequently, 22.5% reported to consume pork frequently while 8.8% consumed pork less frequently. Of all pork consumers, majority (67.6%) consumed poorly cooked pork (traditional roast or barbecue), only (17.5%) consumed properly cooked pork (boiling and frying) and (1.7%) consumed raw pork.

Out of 820 participants, 7.9% of Copro-AgELISA positive participants were in age group 26-35 years, 5.9% age group 36-45 years and few cases (2.5%) were found in the age group of 15-25 years. More Copro-AgELISA positive males 28 (5.9%) were found than females 15 (4.2%). Among Copro-AgELISA positive pork consumers, 34 (7.4%) consumed pork more frequently while 4 (5.5%) less frequently and 5 (2.7%) frequently. Apart from that most of Copro-AgELISA positive 39 (7.0%) were found in people reported to consume poorly cooked pork and 4 (28.6%) raw pork. About 25 (4.6%) of Copro-AgELISA positive participants did not report previous history of passing ploglottides. Only 14 (10.4%) reported previous history of passing ploglottids and 4 (2.7%) did not know if they had passed ploglottides.

Univariate analysis on the risk factors associated with taeniosis (Table 9) showed pork consumption, frequency of pork consumption, pork preparation and previous history of passing ploglottides to be statistically significantly associated with taeniosis ($p<0.05$).

Table 11: Multivariate analysis on factors for taeniosis that were considered in the logistic regression analysis

Proposed risk factor	Level	OR (95% CI)	p-value
Previous history Of passing ploglottids	Yes	2.8 (1.4 - 5.8)	0.004*
	No	ref	
Frequency of pork Consumption	More frequently	1.5 (0.5 - 5.5)	0.2
	Frequently	0.7 (0.2 - 2.9)	
	Less frequently	ref	
Pork preparation	Raw pork	7 (1.8 - 33.4)	0.05
	Poorly cooked pork	ref	

Key * Significant factor

The factors that were considered in the analysis of risk factors associated with prevalence of taeniosis are shown in Table 11. While adjusting for other factors in the model, only previous history of passing proglottides was found to be statistically significant (OR = 2.8; 95% CI = 1.4 - 5.8).

Table 12. Results of Coproparasitologic examinations of 820 persons sampled in villages of Mbozi district

Species	Infected	
	N	(%)
Helminths		
Hookworm eggs	116	(14)
Schistosoma mansoni eggs	13	(1.6)
Ascaris lumbricoides eggs	8	(1)
Enterobius vermicularis eggs	6	(0.7)
Hymenolepis nana eggs	4	(0.5)
Trichuris trichiura eggs	2	(0.2)
Strongyloides stercoralis larvae	2	(0.2)
Protozoa		
Entamoeba coli cysts	10	(1.2)
Giardia lamblia cysts	1	(0.1)

***Samples were analyzed by the formal-ether concentration technique.**

Examination of stool specimens from 820 participants revealed cysts, eggs and larvae of parasitic protozoa or helminths (Table 12). Large number of participants had hookworm 123 (14%) eggs, followed by 13 (1.6%) *Schistosoma mansoni* eggs, 10 (1.2%) *Entamoeba coli* cysts and 8 (1.0%) *Ascaris lumbricoides* eggs.

Table 13. Polyparasitic intestinal infection seen upon microscopic examination of stool samples in surveyed villages of Mbozi district

Parasite eggs, larvae or cysts seen	n	(%)
Hookworm eggs+ *Schistosoma mansoni* eggs	7	(6)
Hookworm eggs + *Taenia* species eggs	5	(4.3)
Hookworm eggs + *Ascaris lumbricoides* eggs	3	(2.6)
Hookworm eggs + *Strongyloides stercoralis* larvae	2	(1.7)
Hookworm eggs + *Enterobius vermicularis* eggs	1	(0.9)
Hookworm eggs + *Entamoeba coli* cysts	1	(0.9)
Hookworm eggs + *Hymenolepis nana* eggs	1	(0.9)
Hookworm eggs + *Giardia lamblia* cysts	1	(0.9)
Ascaris lumbricoides eggs +*Enterobius vermicularis* eggs	1	(25)
Hookworm eggs+ *Ascaris lumbricoides* eggs+ *Enterobius vermicularis* eggs	1	(0.1)
Hookworm eggs + *Taenia* species eggs+ *Schistosoma mansoni* eggs	1	(0.1)

Polyparasitism with intestinal parasites was also observed during microscopic examination of stool samples. Seven (6%) participants had Hookworm eggs + *Schistosoma mansoni* eggs; 5 (4.3%) had Hookworm eggs + *Taenia* species eggs; 3 (2.6%) Hookworm eggs + *Ascaris lumbricoides* eggs; and 2 (1.7%) had Hookworm eggs+ *Strongyloides stercoralis* larvae. Two participants had three parasitic infections. Of the two, participants with three parasite eggs, one had Hookworm eggs+ *A. lumbricoides* eggs + *E. vermicularis* eggs and the second one had Hookworm eggs + *Taenia* species eggs+ *Schistosoma mansoni* eggs.

5.2 Qualitative results

5.2.1 Observational results

Through observation, free range grazing of pigs was common in all surveyed villages. Most of pigs in these villages are not confined, making them to roam around for searching food source. This practice could be the major source of infection in pigs, in turn intestinal infection (taeniosis) in humans. In general, sanitation condition is very poor in all study villages, majority households had latrine without permanent walls or door making roaming pigs easily accessible when not in use. Surprisingly, despite the presence of latrine in most of households, the habit of outdoor defecation and promiscus defecation in children was also common in the community as faeces can be seen around the roads on grass or banana farms during field visits. This behavior increases the risk of infection in pigs and humans due to environmental contamination with the parasite eggs.

Furthermore, personal hygiene is a problem in most surveyed communities of study areas. People tend to wash hand traditionally by dipping hands in a shared bowl of water starting from the head of family to young ones (traditional handwashing). In most cases people wash hands only during heavy meals such as lunch and dinner when they are at home, none of them wash hands before eating when at local clubs or eating street food. Surprisingly, the habit of hand washing after toilet (defecation) is not practiced at all.

Regarding pork eating practices, majority purchases already cooked pork from local brew where it is sold. In most villages it is cooked by traditional deep frying, and most people don't want pork to be cooked longer because they believe the amount will be reduced. Eating already cooked pork from this source can be a source of infection in pork eaters of that community.

CHAPTER SIX

6.0 DISCUSSION, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

6.1 Discussion

Disease conditions in human caused by *Taenia solium* especially cysticercosis is largely under-recognized in most developing countries (Tsang and Wilson, 1995; Garcia et al., 1999) including Tanzania. The occurrence and prevalence of *T. solium* in endemic areas is associated with several factors such as social-cultural practices like eating raw or poorly cooked pork, poor social economic condition, human behavior, high levels of taeniosis and porcine cysticercosis and poor sanitary conditions (Sarti et al., 1992). Garcia et al. (1999) suggested that determining the percentage of the porcine population that is infected is a better epidemiological indicator of *T. solium* infection in human.

The current study is the first community-based study in Tanzania to determine the magnitude of human *T. solium* infection in areas previously reported to have high prevalence of porcine cysticercosis. An estimate of the prevalence of cysticercosis and taeniosis in the district was undertaken using four assays. In addition, CT-scan test was used to see whether participants tested positive by Ag-ELISA (B158/B60) have infection of central nervous system (neurocysticercosis).

The first assay was Copro-AgELISA that detected the presence of genus–specific antigen in the faeces of infected individuals (i.e. taeniosis). Confirmation for *Taenia solium* specific taeniosis prevalence was done using western blot (rES38) as the second assay. The third assay was Ag-ELISA (B158/B60) that detected the parasite circulating cysticercus antigen and the fourth assay was Ab-ELISA (rT24h) detected circulating cysticercus antibodies. While Ag-ELISA measures active cysticercosis, detection of circulating antibodies indicates exposure and not merely active infection. Thus, a positive antibody test would indicate active or past

infection, or a transient antibody response (Garcia et al., 2001; Deckers and Dorny, 2010).

A total of 830 participants were enrolled and among enrolled participants the overall sero-prevalence of exposure to human cysticercosis using Ab-ELISA (rT24h) was 45.3% while sero-prevalence of active human cysticercosis was 12.3% by Ag-ELISA (B158/B60). The seroprevalence found in this study was higher in comparison to that reported in Rwanda 2.8% (Newell et al., 1997), 12.1% in Mozambique (Vilhena et al., 1999) and 0.4%-3% in western province of Cameroon (Nguekam et al., 2003). Furthermore, results on Ag-ELISA showed that 51(11.2%) of participants were positive for Ag-ELISA but negative for Ab-ELISA, this can be explained as early or new infection whereby antibody is absent or is at low level to be detected by the test.

The sero-prevalence of active human cysticercosis in studied communities showed to increase with age and reached a maximum in participants aged 36-60 years. Similar observation was reported by Sarti et al. (1994); Vora et al. (2008) and Carrique-Mas et al. (2001). This could be due to continual exposure to eggs of *T. solium* in contaminated environment.

Findings in this study also showed sex (male/female) to be associated with human cysticercosis (exposure to human cysticercosis) in contrast to findings reported by Carrique-Mas et al., (2001), Wandra et al., (2006) and Willingham et al., (2003). The difference in disease rate between sexes may possibly reflect exposure to parasite through gender related behavioral practices.

Humans are exposed to eggs of *T. solium* direct by autoinfection, contact with another tapeworm carrier, or indirectly by ingestion of food or water contaminated with human faeces (Sarti et al., 1992). A number of risk factors that are closely linked with cysticercosis and taeniosis similar to those reported by other authors were also confirmed in this study.

Strong association between taeniosis and cysticercosis was also found like in other studies done in different areas (Samir et.al, 2008). The sera of the subjects diagnosed with active taeniosis by Copro-AgELISA was positive with Ag-ELISA test (active human cysticercosis). Whether the antibody or antigen response in these individuals was stimulated by the intestinal taeniid infection or by possible concurrent cysticercosis could not be ascertained. One possible interpretation of these findings is that a substantial proportion of human cysticercosis cases could be a result of autoinfection. However, further investigation is required to confirm this possibility. Besides, the finding is in agreement with the previous findings reported by Sarti et al., (1992).

Despite the finding that showed the presence of sanitary facilities (latrines) in 98.4% of enrolled households, only 25% of households had latrine with good structure that could not allow roaming pigs to enter when not in use. Indeed, risk factors for taeniosis-cysticercosis such as outdoor defecation and free roaming of pigs are very prominent in the studied villages of Mbozi district. In this area pigs have been seen to cover wide distances in search of feed and water, which increases the risk of infection to pigs, and in turn, to humans. Similar situation had been reported by Silva- Vergara et al., (1998) and Arruda et al. (1990) in Brazil. The presence of this behavior can facilitate dispersion of *Taenia* eggs excreted by chronic carrier and coprophagia by free roaming pigs. Furthermore, presence of eggs in the environment can contaminate water source such as springs, shallow wells and water streams used for domestic purpose as well as fruits and vegetables cultivated backyard (Silva-Vergara et al., 1998; Samir et al., 2008).

Regarding the source of drinking water, findings from this study showed source of water to be statistically significantly associated with only exposure to human cysticercosis. The researcher also observed that, some households had uncovered a shallow well that is closer to pit latrine (within 5m from pit latrine), hence the risk for water contamination with *T. solium* eggs could be very high in this area.

Although previous study on environmental contamination did not show significant amount of eggs in sampled soil, water, and vegetables (Sarti et al., 1992). This information could be an indicator for water contamination with *Taenia* species eggs. Further studies should be carried using more sensitive technique to detect environmental contamination with *T. solium* eggs in water sources.

In transmission of human cysticercosis, practices such as poor hand washing is very crucial determinant for maintenance of the disease in the community. Schantz et al. (1992) reported that cysticercosis may also occur in humans if eggs are conveyed to the mouth by unclean fingers after defecation or eating without washing hands. Significant association between hand washing practices and human cysticercosis was found in this study. Surprisingly, through observation, the habit of hand washing after toilet was not practiced at all and they wash hands only during heavy meals like breakfast, lunch and dinner. This behavior can increase the risk of ingestion of Taeniid eggs and other intestinal helminth eggs in that community.

The *T. solium* larval infection invokes neurocysticercosis, which is one of the major causes of neurological diseases worldwide (White, 2000). Although the symptoms and signs of neurocysticercosis (NCC) are highly protean, neurocysticercosis is commonly presented/associated with symptoms such as late onset of epileptic seizures, focal neurological signs (e.g. partial seizures), severe chronic headache, intra-cerebral hypertension, and cognitive behavioral dysfunctions (Garcia et al., 2003; Da Costa Barcelos et al., 2005; Chung et al., 2005).

Previous history of severe chronic headache was reported in 19.3% Ag-ELISA seropositive and 46.9% Ab-ELISA seropositive while previous history of epileptic seizure was reported by 22.8% of Ag-ELISA positive and 53.7% Ab-ELISA. Results on univariate analysis showed severe chronic headache and previous history of epileptic seizure appeared to be significantly associated with human cysticercosis. Similar findings were reported by Samir et al., (2008) and Sarti et al.,

(1992). Furthermore, high correlation was found between being epileptic seropositive by Ag-ELISA and features suggestive for neurocysticercosis. In addition, 64% of Ag-ELISA positive epileptics had features suggestive of neurocysticercosis on CT-scan. This figure is higher compared to that reported in Rwanda by Zoli et al. (2003).

However, multivariate statistical analysis using logistic regression both previous history of epileptic seizures and severe chronic headache appeared to be not statistically significant. As information these symptoms obtained from participants, there might be a misunderstanding between asked symptom and other symptoms like faint, dizziness and normal headaches or answers influenced and overestimated by the benefit offered by project such as further medical investigations and hospital care.

The determined prevalence of *Taenia* species taeniosis in all surveyed communities of Mbozi district was 5.2% by Copro-AgELISA while the prevalence of *T. solium* specific taeniosis was 4.1% by Ab-ELISA (rES38). Microscopic examination of stool for *Taenia* species eggs using formal-ether concentration technique revealed 9 (1.1%) *Taenia* species positive eggs. Although direct microscopy is a simple and cheap method for diagnosis of taeniosis, the method has low sensitivity and specificity (Mayta et al, 2007). As a result, immunological method such as Copro-AgELISA for detection of *Taenia* species taeniosis and eRS38 ELISA as confirmatory test for detection of *Taenia solium* species taeniosis was introduced (Allan et al., 2003). The use of Copro-AgELISA test increases the detection of parasitological proven intestinal *T. solium* cases by a factor of at least 2.6 times in comparison to microscopy (Allan et al., 1990; 1993).

About 10.4% Copro-AgELISA positive participants reported previous history of passing ploglottides. In contrast to the study done by Silva-Vergara et al. (1998), this study found statistically significant association between previous history of

passing ploglottides and taeniosis. Findings showed Copro-AgELISA positivity increased in age group 26-35 years and 36-45 years, this findings correlates with the findings from a study done in Bali (Indonesia) by Sutisna et al., (1999). However, no statistically significant association between age and taeniosis obtained was found in this study.

Although 65.1% males were positive by Copro-AgELISA compared to 39.4% females, the difference was not statistically significant. With this finding, one cannot confirm that the risk is higher in males than females. This is however contrary to the previous report from Guatemala, which showed females to be at more risk of infection as compared to males (Allan et al., 1996).

The habit of eating pork and derived products is widely diffused in this area, as pork is the widely available meat in all villages. Univariate analysis showed significant association between pork consumption and taeniosis is similar to that reported in a study done by Silva-Vergara et al. (1998) in Brazil. The study also showed the frequency of pork, and pork preparation to be statistically associated with taeniosis. This is attributed to the fact that frequently consumption of pork increases the risk for consuming cysticercus as most of pigs are slaughtered home, sold/ purchased without being inspected by veterinary officers and eaten raw or inadequately cooked. However, Multivariate analysis showed only previous history of passing proglottides appeared to be significant. Inspite of these findings, pork consumption continues to be the main risk factor for acquiring taeniosis.

Other intestinal parasites were detected in all surveyed communities during microscopic examination of stool. Large proportion of participants had Hookworm eggs (14.8%), followed by 1.7% *Schistosoma mansoni* eggs, 1.2% *Entamoeba coli* cysts and 1.1% *Ascaris lumbricoides* eggs and 1% *Enterobius vermicularis* eggs. Multiple gastro intestinal parasitic infestations, was also observed during microscopic examination of stool samples. Majority of them had two parasites,

about 0.9% of participants had *Hookworm* eggs + *Schistosoma mansoni* eggs and 0.6% *Hookworm* eggs and *Taenia* species eggs.

6.2 Conclusion

On the basis of this study, it is concluded *Taenia solium* infection (human cysticercosis and or taeniosis) is hyperendemic in Mbozi district. The most important risk factors associated with maintenance of disease transmission in Mbozi district were poor pork consumption practices, poor personal hygiene practices such as hand washing before eating / after toilet and outdoor defecation practices.

6.3 Recommendations

In practice, communities should be given health education in order to create awareness on how *Taenia solium* infections are transmitted to humans and pigs. The health education should focus on proper way of cooking pork, personal hygiene practice, and proper construction/use of latrine in order to avoid infection transmission in humans and pigs.

The government should formulate and implement strong rule regarding keeping pigs in pigpen (pig confinement) in order to avoid access of pigs to human faeces.

In policy the Ministry of Health Tanzania (MOH) should incorporates control of *Taenia solium* infection in other control programs such as Schistosomiasis and Soil Transmitted Helminth Control. In addition, control program should be extended to cover all age groups at risk in endemic communities in order to break transmission cycle. Furthermore, If possible health facilities such as Vwawa district hospital and Mbozi mission hospital should have the capability of doing Copro-AgELISA for detection of taeniosis cases.

This is the first study done in Tanzania on human aspect of *T.solium* infection. The study involved only one area among areas reported high prevalence of porcine cysticercosis. Further epidemiological studies should be conducted in remained areas to get a clear picture on the epidemiology of the parasite in the country.

As neurocysticercosis (NCC) the major public health problem in endemic areas, further interventional studies should be conducted on neurocysticercosis confirmed cases by CT-scan to evaluate the treatment outcomes of the disease. Apart from that, a follow-up study to be done on school age children in endemic areas to see the impact of using praziquantel for treatment and control of Schistosomiasis during Mass Drug Administration (MDA). Since previous reports showed using Praziquantel in people with viable cysts (both asymptomatic/symptomatic) in the brain induce epileptic seizures due to inflammation reaction caused by dying or degenerating cysts in the brain.

6.4 Limitations of the study

The time was too short, in such a way the researcher did not have time for conducting a focus group discussion as had been planned. Furthermore, the researcher did not examine stool samples freshly using formal-ether concentration method, instead stool samples were fixed with enough 10% formalin and sent to MUHAS Laboratory for microscopic examination after field work, this could affect sensitivity of microscopic results.

6.5 Possible source of bias

- Non response by some sampled households could be a source of bias.
- Purposeful section of study districts and villages (i.e study area) can introduce selection bias.
- Participants were required to remember previous histories of passing proglottides, severe chronic headaches, and seizures, this can introduce recall bias.

REFERENCES

Allan, J.C., Awila, G., Garcia-Nova, J., and Craig, P.S. (1990). Immuninodiagnosis of taeniosis by copro-antigen detection. *Parasitology*, 101: 477-478.

Allan, J.C., Mencos, F., Garcia Noval, J., Sarti, E., Flisser, A., Wang, Y., Liu, D., and Craig, P.S. (1993. Dipstick dot ELISA for detection of *Taenia* Coproantigens in humans. *Parasitology*, 107:79-85.

Allan, J.C., Velasquez-Tohom, M., Torres-Alvarez, R., Yurrita, P., and Garcia-Noval,J. (1996). Field Trial of the Coproantigen-Based Diagnosis of *Taenia solium* Taeniasis by Enzyme-Linked Immunosorbent Assay. *American Journal of Tropical Medicine and Hygiene*, 54: 352-356.

Allan, J.C., Wilkins, P., Tsang, V.C.W., and Craig, P.S. (2003). Immunodiagnostic tools for taeniasis. *Acta Tropica,* 87: 87-93.

Arruda, W.O., Camargo, N.J., and Coelho, R.J. (1990). Neurocysticercosis: anepidemiological survey in two small rural communitics. *Arquivos de Neuropsiquiatria (São Paulo),* 48: 419-424.

Boa, M.E. (2005). Epidemiology and Control of Porcine Cysticercosis in Tanzania. Thesis for award of PhD at Sokoine University of Agriculture. Morogoro, Tanzania.

Boa, M.E., Kassuku, A.A., Willingham, A.L. III., Keyyu, J.D., Phiri, I.K, and Nansen, P. (2002). Distribution and density of cysticerci of *Taenia solium* by muscle groups and organs in naturally infected local finished pigs in Tanzania. *Veterinary Parasitology* 106: 155-164.

Campbell, G., Garcia, H. H., Nakao, M., Ito, A., and Craig, P.S. (2006). Genetic variation in *Taenia solium, Parasitol International*, 55: 121-126.

Carabin. H., Krecek, R.C., Cowan, L.D., Michael, L., Foyaca-Sibat, H., Nash, T., and Willingham, A. L.III. (2006). Estimation of the cost of *Taenia solium* cysticercosis in Eastern Cape Province, South Africa. *Tropical Medicine and International*, 11 (6): 906-916.

Carpio, A., Escobar, A., and Hauser, W.A. (1998). Cysticercosis and epilepsy: a critical review. *Epilepsia*, 39: 1025-1040.

Carrique-Mas, J., Iihoshi, N., Widdowson, M.A., Roca, Y., Morales, G., Quiroga, J., Cejas, F., Caihuara, M., Ibarra, R., and Edelsten, M. (2001). An epidemiological study of *Taenia solium* cysticercosis in a rural population in the Bolivian Chaco. *Acta Tropica,* 80: 229-235.

Choromanski, L., Estrada, J. J., and Kuhn, R.E. (1990). Detection of antigens of larval *Taenia solium* in the cerebrospinal fluid of patients with the use of HPLC and ELISA. *Journal of Parasitology*, 76: 69-73.

Christopher, M., De Giorgio, M.D., Medina, M.T., Durón, R., Zee, C., and Escueta, S.P. (2004). Neurocysticercosis. *Epilepsy*, 4 (3): 107-111.

Chung, J.Y., Eom, K.S., Yang, Y., Xenming, L.I., Feng, Z., Rim, H.J., Cho, S.Y., and Ykong, Y. (2005). A seroepidemiological survey of *Taenia solium* cysticercosis in Nabo, Guangxi Zhan Autonomous Region, China. *The Korean Journal of Parasitology*, 43 (4): 135-139.

Da Costa Barcelos, I.S., Marcelo, F. S., De Moura, L .P., Biondi, G.F., and Costa-

Cruz, M.J. (2005). Use of the paired samples (cerebrospinal fluid and serum) in immunodiagnostic of active and inactive human Neurocysticercosis. *Mem Inst Oswaldo Cruz, Rio de Janeiro*, 100 (4): 427-429.

Deb, K. P., Carpio, A., and Josemir, W. A. S. S. (2000). Neurocysticercosis and epilepsy in developing countries. *Journal of Neurology and Neurosurgical Psychiatry*, 68: 137-143.

Deckers, N., and Dorny, P. (2010). Immunodiagnosis of *Taenia solium* taeniosis/cysticercosis. *Trends in Parasitology,* 26 (3).

Dorny, P., Brandt, J., Zoli, A., and Geerts, S. (2003). Immunodiagnostic tools for humanand porcine cysticercosis. *Acta Tropica,* 87 (1): 79-86.

Dorny, P., Vercammen, F., Brandt, J., Vansteenkiste, W., Berkvens, D., and Geerts, S.(2000). Sero-epidemiological study of *Taenia saginata* cysticercosis in Belgian cattle. *Veterinary Parasitol*, 88: 43-49.

Engels, D., Urbani, C., Belotto, A., Meslin, F., and Savioli, L. (2003). The control of human (neuro) cysticercosis: which way forward? *Acta Tropica*, 87 (1): 177-182.

Erhart, A., Nguyen, V. D., Vien, H.V., Thach, D.C., Toan, N.D., Cong, L.D., Dorny P., Geerts, S., Speybroeck, N., Berkvens, D., and Brandt, J. (2002). *Taenia solium* cysticercosis in a small village in Northern Vietnam: Sero-prevalence study using an ELISA for detecting circulating antigen. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 96: 270-272.

Ferrera, E., Cort´eza, I.M., Cabreraa, Z., Rojasa, G., D´avila, I., Noyac, B.A., P´erezd, H.A., Fernandeze, I., Romer, H.U., Leslie, J.S., Harrisong, M. R. E., G´aratei, P.T. (2005). Oncospheral peptide-based ELISAs as potential seroepidemiological tools for *Taenia solium* cysticercosis/neurocysticercosis

in Venezuela. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 99: 568-576.

Ferreira, A.P., Vaz, A.J., Nakamura, P.M., Sasaki, A.T., Ferreira, A.W., and Livramento, J.A. (1997). Haemagluttination test for the diagnosis of human neurocysticercosis: development of a stable reagent using homologous and heterologous antigens. *Rev. Inst. Med. Trop. Sao Paulo,* 39: 29-33

Flisser, A. (1994). Taeniasis and cysticercosis due to *T.solium*. *In: Sun T, ed. Progress in clinical parasitology. New York: CRC Press*, 77–116.
Flisser, A. (1988). Neurocysticercosis in Mexico. *Parasitology Today*, 4 (5): 131-137.

Flisser, A., and Gyorkos, T. W. (2007). Contribution of immunodiagnostic tests to epidemiological/ intervention studies of cysticercosis/taeniosis in México. *Parasite Immunology,* 29: 637-649.

Flisser, A., and Lightowlers, M.W. (2001). Vaccination against *Taenia solium* Cysticercosis. *Mem Inst Oswaldo Cruz, Rio de Janeiro*, 96 (3): 353-356.

Flisser, A., Madrazo, I., Plancarte, A., Schantz, P.M., Allan, J., Craig, P., and Sarti, E. (1993). Neurological symptoms in occult neurocysticercosis after a single taeniacidal dose of praziquantel. *Lancet 342*: 748.

Flisser, A., Sarti, E., Lightowlers, M., and Schantz, P. (2003). Neurocysticercosis: regional status, epidemiology, impact and control measures in the Americas. *Acta Tropica,* 87: 43-51.

Garci´a-Garci´, M.A., Torres, M., Correa, D., Flisser, A., Sosalechuga, A., Velasco, O., Meza-lucas, A., Plancarte, A., Avila, G., Tapia, R., Aguilar, R., Mandujano, A., Alca´ ntara, 1., Morales, Z., Salcedo, A., de la luz man˜o´

n, M., and Valdespino-gomez, J. L. (1999). Prevalence and risk of cysticercosis and taeniasis in an urban population of soldiers and their relatives. *American Journal of Tropical Medicine and Hygiene*, 61(3): 386-389.

Garcia, H.H, Gonzalez, A.E., Robert, H., Gilman, L.G., Palacios, L.G., Jimenez, I., Rodriguez, S., Verastegui, M., Wilkins, P., Tsang, V.C.W., and the cysticercosis working group in Perú. Transient antibody response in *Taenia solium* infection in field conditions - a major contributor to high seroprevalence. *American Journal of Tropical Medicine and Hygiene*, 65; 31-32.

Garcia, H. H., and Del Brutto, O.H. (2000). *Taenia solium* cysticercosis. *Infectious Diseases Clinicals North America,* 14: 97-119.

Garcia, H.H., Del Brutto, O.H., Nash, T. E., Clinton, A., White, J.R., Tsang, V. C. W., and Gilman, R.H. (2005). New concepts in the diagnosis and management of neurocysticercosis *(Taenia solium*). *American Journal of Tropical Medicine and Hygiene*, 72 (1): 3-9.

García, H.H., Gilman, R.H, Gonzalez, A.E., Verastegui, M., Gavidia, S.R.C., Tsang, V.C.W. Falcon., Lescano, A.G., Moulton, L.H., Bernal, T., Tovar, M. and the cysticercosis working group in Perú. (2003). Hyper endemic human and porcine *Taenia solium* infection in Perú. *American Journal of Tropical Medicine and Hygiene*, 68 (3): 268-275.

García, H.H., Gonzalez, A.E., Evans, C.A.W., and Gilman, R.H. (2003). *Taenia solium* cysticercosis (seminar). *The Lancet,* 362: 547-56.

Garcia, H.H., Gonzalez, A.E., Gilman, R.H., Palacios, L.G., Jimenez, I., Rodriguez, S., Verastegui, M., Wilkins, P., and Tsang V.C.W. (2001). Transient antibody response in *Taenia solium* infection in field conditions—a major

contributor to high seroprevalence. *American Journal of Tropical Medicine and Hygiene,* 65 (1): 31-32.

Garcia, H. H., Gonzalez, A.E., Tsang, V. C. W., and Gilman, R. H.(2006).Neurocysticercosis: some of the essentials (review). *Practical Neurology,* 6: 288-297.

Gonzalez, A.E., Falcon, N., Gavidia, C., Garcia, H.H., Tsang, V.C.W., Bernal, T., Romero, M., and Gilman, R.H. (1998). Time-response curve of oxyfendazole in the treatment of swine cysticercosis. *American Journal of Tropical Medicine and Hygiene*, 59 (5): 832-836.

INFOSAN report. (2006). Control of neglected zoonotic diseases: challenges and the way forward, Geneva.

Ito, A., Plancarte, A., Liang, M.A., Kong, Y., Flisser, A., Cho, S.Y., Liu, Y.H., Kamhawi, S., Lightowlers, M.W., and Schantz, P.M. (1998). Novel antigens for neurocysticercosis: simple method for preparation and evaluation for serodiagnosis. *American Journal of Tropical Medicine and Hygiene*, 59 (2): 291-294.

Ito, A., Takayanagui, O.M., Sako, Y., Sato, M.O., N. S, Yamasaki, H., Nakaya, K., and Nakao, M. (2006). Neurocysticercosis: clinical manifestation, neuroimaging, serology and molecular confirmation of histopathologic specimens.*Southeast Asian Journal of tropical Medical public health,*37 (3).

Komba, E. V.G. (2008). The prevalence of porcine cysticercosis in Mbozi and Mbeya-Rural districts. Thesis for award of MSc at Sokoine University of Agriculture. Morogoro, Tanzania.

Vilhen, M., Santos, M., and Torgal, J. (1999). Seroprevalence of human cysticercosis in Maputo, Mozambique. *American Journal of Tropical Medicine and Hygiene,* 61 (1): 59-62.

Mayta, H., Hancock, K., Levine, M.Z., Gilman, R.H., Farf´an, M.J., Verastegui, M, Lane,W.S., Garcia, H.H, Gonzalez, A.E., and Tsang, C.V.W. (2007). Characterization of a novel *Taenia solium* oncosphere antigen. *Molecular & Biochemical Parasitology,* 156: 154-161.

Mayta, H., Talley, A., Gilman, R.H., Jimenez, J., Verastegui, M., Ruiz, M., Garcia, H.H.,and Gonzalez, A.E. (2000). Differentiating *Taenia solium* and *Taenia saginata* infections by simple hematoxylin-eosin staining and PCR-restriction enzyme analysis. *Journal of Clinical Microbiology*, 38: 133-137.

Mayta, H., Gilman, R.H, Prendergast, E., Castillo, J.P., Tinoco, Y.O., Garcia, H. H., Gonzalez, A.E., and Sterling, C.R. (2008). Nested PCR for Specific Diagnosis of *Taenia solium* Taeniasis. *Journal of clinical microbiology,* 46 (1): 286-289.

Murrell, K.D., Dorny, P., Flisser, A., Geerts, S ., Kyvsgaard, N.C., McManus, D.P., Nash, T.E., and Pawlowski, Z.S. (2005). Guidelines for the surveillance, prevention and control of taeniosis/cysticercosis. WHO/FAO/OIE.

Nakao, M., Okamoto, M., Sako, Y., Yamasaki, H., Nakaya, K., and Ito, A. (2002). A phylogenetic hypothesis for the distribution of two genotypes of the pig tapeworm *Taenia solium* worldwide. *Parasitology*, 124: 657-662.

Nash, .E. T. (2003). Human case management and treatment of cysticercosis. *Acta Tropica,* 87: 61-69.

National Census Report. (2002). http://www.tanzania.go.tz/ 2002 census. PDF. Searched on 17th May 2010.

Ndoye, N.F., Sowa, A.D., Diopa, A.G., Sessoumaa, B., Se´ne-Dioufa, F., Boissya, I., Wonea, I., Toure´a, K., Ndiayea, M., Ndiayea, P., De Boerb, H., Engel, J., Mandlhated, C., Meinardi, H., Prilipkoe, L., and Sander, J.W.A.S. (2005). Prevalence of epilepsy its treatment gap and knowledge, attitude and practice of its population in sub-urban Senegal an ILAE/IBE/WHO study.

Newell, E., Vyungimana, F., Geerts, S., Van Kerckhoven, I., Tsang, V.C.W., and Engels, D. (1997). *Transactions of the Royal Society of Tropical Medicine,* 91: 389-391.

Ngowi, H. A., Mlangwa, J. E .D., Carabin, H., Mlozi, M .R .S., Kassuku, A. A., Kimera, S. I., and Willingham, III A. L. (2007). Financial efficiency of health and pig management education intervention in controlling porcine cysticercosis in Mbulu District, northern Tanzania. Livestock Research for Rural Development 19 (5).

Nguekam, J. P., Zoli, A. P., Zogo, P.O., Kamga, A.C.T., Speybroeck, N., Dorny, P.,Brandt, J., Losson, B., and Geerts, S. (2003). A seroepidemiological study of human cysticercosis in West Cameroon. *Tropical Medicine and International Health*, 8 (2): 144-149.

Nsengiyumva, G., Druet-Cabanac, M., Ramanankandrasana, B., Bouteille, B., Nsizabira, L., and Preux, P. (2003). Cysticercosis as a Major Risk Factor for Epilepsy in Burundi (East Africa). *Epilepsia,* 44 (7): 950-955.

Nyame, P.K., and Biritwum, R, B. (1997). Epilepsy: knowledge, attitude and practice in literate urban population, Accra, Ghana. *West Africa Journal of Medicine, 16* (3): 139-145.

PAHO/WHO. (1995). Consultation on the taeniosis/cysticercosis complex.

Pawlowski, Z.S., and Murrel, K.D. (2001). Taeniosis and Cysticercosis. In: Hui, Y.H.,Sattar,S.A., Murrell K.D., Nip, W-K., and Stanfield, P.S. (Ed.), Foodborne Disease Handbook, Volume 2, 2nd Edition, Marcel Dekker, NY, USA, pp. 217-227.

Pawlowski, S. P. (2006). Role of chemotherapy of taeniasis in prevention of neurocysticercosis. *Parasitology International*, 55(1): 105-109.

Pawlowski, Z., Allan, J, Sarti, E. (2005). Control of *Taenia solium* taeniasis/cysticercosis:From research towards implementation. *International Journal for Parasitology,* 35: 1221–1232

Phiri, I. K., Ngowi, H., Afonso, S., Matenga, E., Boa, M., Mukaratirwa, S., Githigia, S., Saimo, M., Sikasunge, C., Maingi, N., Lubega, G.W., Kassuku, A., Michael, L., Siziya, S., Krecek, R.C., Noormahomed, E., Vilhena, M., Dorny, P., and Willingham, A.L, III. (2003). The emergence of *Taenia solium* cysticercosis in Eastern and Southern Africa as a serious agricultural problem and public health risk. *Acta Tropica,* 87 (1): 13-23.

Prado-Jean, A., Kanobana, K., Druet-Cabanac, M., Nsengyiumva, G., Dorny, P., Preux, P.M., and Geerts, S. (2007). Combined use of an antigen and antibody detection enzyme-linked immunosorbent assay for cysticercosis as

tools in an epidemiological study of epilepsy in Burundi. *Tropical Medicine and International Health.* 12 (7); 895-901.

Preux, P.M., Thiemagni, F., Fodzo, L., Kandem, P., Ngouafong, P., Ndongo, F., Macharia, W., Dongmo, L., and Dumas, M. (2000). Antiepileptic therapies in the Mifi province in Cameroon. *Epilepsia*, 41 (4): 432-439.

Rahalkar, M. D., Shetty, D. D., Kelkar, A. B., Kelkar, A. A., Kinare, A. S., and Ambardekar, S. T. (2000). The Many faces of cysticercosis. *Clinical Radiology*, 55: 668– 674.

Rajkotia, A., Lescano, A.G., Gilman, H. R., Cornejo, C., and Garcia, H.H. (2007). For the Cysticercosis Working Group of Peru. Economic burden of Neurocysticercosis: results from Peru. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 101: 840-846.

Rajshekhar, V., Joshi, D.D., Doanh, N.Q., Nguyen, V.D.D., and Xiaonong, Z. (2003).*Taenia solium* taeniosis/cysticercosis in Asia: epidemiology, impact and issues. *Acta Tropica*, 87: 53-60.

Rajshekhar, V. (2010). Surgical management of neurocysticercosis. *International Journal of Surgery* 8 (2010): 100–104.

Rodriguez-Hidalgo, R., Benitez-Ortiz, W., Praet, N., Saa, L.R., Vercruysse, J., Brandt, J., and Dorny, P. (2006). Taeniasis-cysticercosis in Southern Ecuador: assessment of infection status using multiple laboratory diagnostic tools. *Mem Inst Oswaldo Cruz, Rio de Janeiro*, 101 (7): 779-782.

Rwiza, H.T., Matuja, W.B., Kilonzo, G.P., Haule, J., Mbena, P., Mwang'ombola, R., and Jilek-Aall, L. (1993). Knowledge, attitude, and practice toward epilepsy among rural Tanzanian residents. *Epilepsia*, 34 (6): 1017-1023.

Vora, S.H., Mortighare, D.D., Ferreira, A.M., Kulkarn, M.S., and Vaz, F.S. (2008). High prevalence of cysticercosis in a rural in Western India. *Tropical Medicine and Hygiene.* 36 (3): 137-138.

Sarti, E., Schantz, P.M., Plancarte, A., Wilson, M., Gutierrez, O.I., Aguilera, J., Roberts, J., and Flisser, A. (1994). Epidemiological investigation of *Taenia solium* taeniasis and cysticercosis in a rural village of Michoacan state, Mexico. *Trans Royal Socieity Tropical Medecine and Hygiene*, 88 (1): 49-52.

Sarti, E., and Rajshekhar, V. (2003). Measures for the prevention and control of *Taenia solium* taeniosis and cysticercosis. *Acta Tropica*, 87: 137-143.

Sarti, E., Flisser, A., Schantz, P., Gleizer, M., Loya, M., Plancarte, P., Avila, G., Allan, J.C., Craig, P., Bronfman, M., and Wijeyaratne, P. (1997). Development and Evaluation of a Health Education Intervention against *Taenia solium* in a Rural Community in Mexico. *American Journal of Tropical Medicine and Hygiene*, 56 (2): 127-132.

Sarti, E., Schantz, P.M., Plancarte, A., Wilson, M., Gutierrez, I.O., Lopez, A.S., Roberts, J., and Flisser, A. (1992). Prevalence and risk factors for *Taenia solium* taeniasis and cysticercosis in humans and pigs in a village in Morelos, Mexico. *Journal of Tropical Medicine and Hygiene*, 46 (6): 677-685.

Schantz, P.M., Moore, A.C., Munoz, J.L., Hartman, B.J., Schaefer, J.A., Aron, A.M., Persaud, D., Sarti, E., Wilson, M., and Flisser, A. (1992). Neurocysticercosis in an Orthodox Jewish community in New York City. *New England Journal of Medicine,* 327: 692-695.

Schantz, P.M., Wilkins, P., and Tsang, V, C.W. (1998). Immigrants, imaging and immunoblots: the emergence of neurocysticercosis as a significant public health problem. In: Scheld WM, Craig WA, Hughes JM, eds. Emerging infections 2. Washington: ASM Press. 213-2 41.

Sikasunge, C. S., Phiri, I. K., Phiri, A. M., Dorny, P., and Willingham, A. L. III. (2008).Prevalence of *Taenia solium* porcine cysticercosis in the Eastern, Southern and Western provinces of Zambia. *The Veterinary Journal*, 176: 240-244.

Silva-Vergara, M. L., Prata, P., Netto, H. V. S., De Vieira, O. C., Castro, H. J., Micheletti, L. G., Otaño, A.S., and Júnior, J.F. (1998). Risk factors associated with taeniasis-cysticercosis in Largamar, Minas Gerais State, Brazil. *Revista da Sociedade Brasileira de Medicina Tropical*, 31 (1): 65-71.

Smith, J. L. (1994). *Taenia solium* Neurocysticercosis. *Protection.* 57(9): 831-844

Sutisna, P., Fraser, A., Kapti, I. N., Rodriguez-Canul, R., Widjana, D. P., Craig, P. S., and Allan, J. C. (1999). Community prevalence study of taeniasis and cysticercosis in Bali, Indonesia. *Tropical Medicine and International Health volume.* 4(4): 288-294.

Tsang, V. C. W., and Wilson, M. (1995). *Taenia solium* cysticercosis: An under-recognized but serious public health problem. *Parasitology Today,* 11 (3): 124-126.

Tsang, C., Brand, J.A., and Boyer, A.E. (1989). An enzyme-linked immunoelectrotransferblot assay and glycoprotein antigens for diagnosing human cysticercosis (*Taenia solium*). *Journal of Infectious Diseases*, 59: 50-59.

Wandra, T., Sutisna, P., Dharmawan, N.S., Margono, S.S., Sudewi, R., Suroso, T., Craig, P.S, and Ito, A. (2006). High prevalence of *Taenia saginata* taeniasis and state of *T. solium* cysticercosis in Bali, Indonesia 2002- 2004. *Journal of Tropical Medecine and Hygiene*, 100: 346-53.

White, A.C. J. (2000). Neurocysticercosis: Updates on epidemiology, pathogenesis, diagnosis and management. *Annu Rev Med,* 51: 187-206.

WHO. (2002). Control of neurocysticercosis report by the secretariat; World health organization fifty-fifth world health assembly a55/23 provisional agenda item 13.18 5 April 2002.

Willingham, A.L .III., De, N.V., Doanh, N.Q., Cong Le, D., Dung, T.V., Dorny, P, Cam, P.D., and Dalsgaard, A. (2003). Current status of cysticercosis in. Vietnam. *Southeast Asian Journal of Tropical Medicine and Public Health*, 34: 35-50.

Willingham, A.L.III., and Engels, D. (2006). Control of *Taenia solium* Cysticercosis/Taeniosis. *Advances in Parasitology*, 61 : 509-566.

Yamasaki, H., Matsunaga, S., Yamamura, K., Chang, C.C., Kawamura, S., Sako, Y., Nakao, M., Nakaya, K., and Ito, A. (2004). Solitary neurocysticercosis case caused by Asian genotype of *Taenia solium* confirmed by mitochondrial DNA analysis. *Journal of Clininical Microbiology*, 42: 3891-3893.

Zoli, A., Shey-Njila, O., Assana, E., Nguekam, J.P., Dorny, P., Brandt, J., and Geerts, S. (2003). Regional status, epidemiology and impact of *Taenia solium* cysticercosis in Western and Central Africa. *Acta Tropica*, 87 (1): 35-42.