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Prevalence, etiology and risk of lymphedema among residents of Mt. Elgon region in Kenya

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Abstract

Cases of lymphedema have been observed in the Mt. Elgon region, but its prevalence, etiology, and risk factors are unknown. A cross-sectional field survey was conducted to determine the prevalence, etiology and risk of lymphedema in the region. Human cases and mosquito sample specimens were examined for filarial worm infection, while soil samples were analysed for elements potentially linked to the condition. The study recorded a lymphedema prevalence of 17.4 per 100,000, with 38 cases identified across the study sites. The distribution of cases varied significantly (χ^2 = 15.76, d.f. = 3, p = 0.0013), with a significantly higher occurrence among females (71.05%, n = 27) compared to males (28.95%, n = 11) (χ^2 = 17.64, d.f. = 1, p < 0.0001). All human and mosquito samples tested negative for filarial worm infection. Most affected individuals did not regularly wear shoes, and both cases and controls were largely unaware of the condition's cause, often attributing it to witchcraft. The use of mosquito nets differed significantly based on socioeconomic status (χ^2 = 45.83, d.f. = 1, p < 0.0001). None of the affected individuals or controls were aware of treatment options. Additionally, most residents lived in poor housing conditions with inadequate hygiene. Soil analysis revealed that iron and potassium concentrations correlated positively with lymphedema prevalence (R = 0.867 and R = 0.897, respectively). Based on these findings, the study concludes that lymphedema in the region is podoconiosis-related, caused by exposure to high levels of iron and potassium in the soil. Women in low-income households face the highest risk. Targeted interventions should prioritize the most vulnerable residents, with a particular focus on women.

Key words: *Lymphedema, filarial worms, soil elements, risk factors, Mt. Elgon, Kenya*

1. Introduction

Elephantiasis of lymphatic filariasis etiology is caused by filarial worms that are transmitted through infected mosquito bites (Morrison, 2019). It is characterized by lymphedema of the lower limbs, arms and genitalia (John & Petri, 2006). Elephantiasis disease has been reported to increase the frequency of bacterial infections that harden and thicken the skin in the affected sections of the body (Dufera & Negasa, 2021). On the other hand, lymphedema can be of non-filarial origin. In such cases, it is believed that irritant elements such as silicon, aluminium, magnesium, sodium, potassium and iron in red clay soils derived from volcanic deposits penetrate the skin of exposed populations. This exposure, coupled with genetic complications, can cause non-filarial elephantiasis (Korevaar & Visser, 2012). Non-filarial lymphedema leads to a condition called podoconiosis characterized by swelling of the lower limbs only without the signs of genital hydrocele (Korevaar & Visser, 2012). The colloid-sized silicate (aluminium, magnesium, sodium, potassium and iron) particles are believed to enter through the skin and are taken up into macrophages in the lower limb's lymphatic causing endolymphangitis and obliteration of the lymphatic lumen (Davey et al., 2007).

The highest prevalence of podoconiosis has been reported in Uganda (Onapa et al., 2001, Ario et al., 2015, Deribe et al, 2018), Tanzania (Deribe et al, 2018), Kenya (Deribe et al, 2018, Sultani et al., 2019), Rwanda (Deribe et al., 2019), Burundi (Deribe et al., 2019), Sudan (Senkwe et al., 2022), and Ethiopia (Deribe et al., 2018, Davey, 2007).

According to Korevaar and Visser (2012), podoconiosis can be clinically distinguished from lymphatic filariasis. It is characterised by ascending podoconiosis, beginning in the foot and progressing to the knee, but rarely affecting the upper leg or the groin. Furthermore, the condition is commonly bilateral, yet asymmetric and occurs at altitudes higher than 1500m (5000 ft.), which exceeds the altitude at which filarial worm transmission occurs (WHO, 2021). Filarial worm disease affects men and women equally in the poorest societies in the tropical and subtropical areas (Asfaw et al., 2021). Both filarial elephantiasis and podoconiosis are associated with living in low-income countries in the tropics and sub-tropics (Asfaw et al., 2021). Furthermore, podoconiosis is found in regions with high altitude and high seasonal rainfall (Korevaar and Visser, 2012).

In Africa, lymphatic filariasis transmission is predicted to occur across much of coastal and savannah West Africa (Cano et al, 2014), but is restricted mainly to the coastal areas of the East and Southern Africa (Cano et al., 2014). Lymphatic filariasis afflicting humans in Kenya is caused by *Bancroftian* filariasis, which is endemic along the Indian Ocean coastal Counties of Kwale, Kilifi, Malindi, Tana River and Lamu (Kiliku et al., 2001). The disease has not been documented in high altitude Counties in Kenya (Sultan et al., 2019).

As a result of its appearance, lymphatic filariasis and podoconiosis can cause social stigmatisation and discrimination (Davey et al., 2014). People with lymphatic filariasis or podoconiosis also report a lower quality of life compared to people living in similar circumstances but without lymphatic filariasis or podoconiosis (Davey et al., 2013). The victims also exhibit higher levels of mental distress (Davey et al., 2015) and depression (Amberbir et al., 2016; WHO 2018).

Podoconiosis may also be confused with lymphatic filariasis and is of interest to parasitologists. It is therefore important to determine the prevalence, aetiology and risk determinants of lymphedema with the aim of generating data that will help design appropriate interventional strategies. If the lymphedema is due to filarial infection, the intervention should target the control of the mosquito vector and if it is due to podoconiosis, the intervention should target reduction of exposure to the irritant soil element(s).

Sultan et al (2019) conducted the first nationwide mapping of podoconiosis in Kenya, which showed that the highest prevalence rates were found in Siaya (3.1%) and Busia (0.9%) which are counties in western Kenya and Meru (1.1%) a county in the central highlands. Low prevalence rates were identified in Makueni (0.2%), Marsabit (0.2%), and Tana River (0.1%) counties, which are in the lowland areas. Mt. Elgon region in Bungoma County was not included in the population-based survey for podoconiosis mapping.

Gachohi et al., (2017), researched on soil iron and aluminium concentrations and feet hygiene as possible predictors of podoconiosis occurrence on the foot of volcanic Mt. Longonot in the Great Rift Valley region in Kenya. The study concluded that iron and aluminium are the predictors of podoconiosis. However, some of their findings were inconsistent with some previous reports about podoconiosis being associated with certain other minerals in the soil, hence they recommended for more research to be done on these aspects.

The presence of lymphedema cases in the Mt. Elgon region of Kenya, coupled with the lack of research on its prevalence and causes, justified the need for this study. This research aimed to identify the etiology of lymphedema in the region and investigate soil elements associated with the condition. Additionally, the study aimed to educate local residents on potential risk factors and encouraged to adopt preventive and control measures to reduce their susceptibility to the disease.

2. Materials and Method

Study Sites

Mt. Elgon region is located on the Kenya-Uganda border in western part of Kenya covering parts of Trans-Nzoia and Bungoma Counties. The region is located to the north of Kakamega and west of Kitale towns. The highest peak of Mt Elgon has an elevation of 4321m. Although there is no verifiable evidence of its earliest volcanic activity, geologists estimate that Mt. Elgon is at least 24 million years old, making it the oldest extinct volcano in east Africa. The mountain soils are mostly composed of red laterite (Britannica, 2024).

According to Kenya National Bureau of Statistics (KNBS) (2019), Mt Elgon Sub-County is estimated to have a total population of 218,529 people. The local communities are primarily small holder famers engaging in milk production and subsistence and cash crop cultivation, including maize, wheat, beans, Irish potatoes, coffee, tea, tomatoes and onion production.

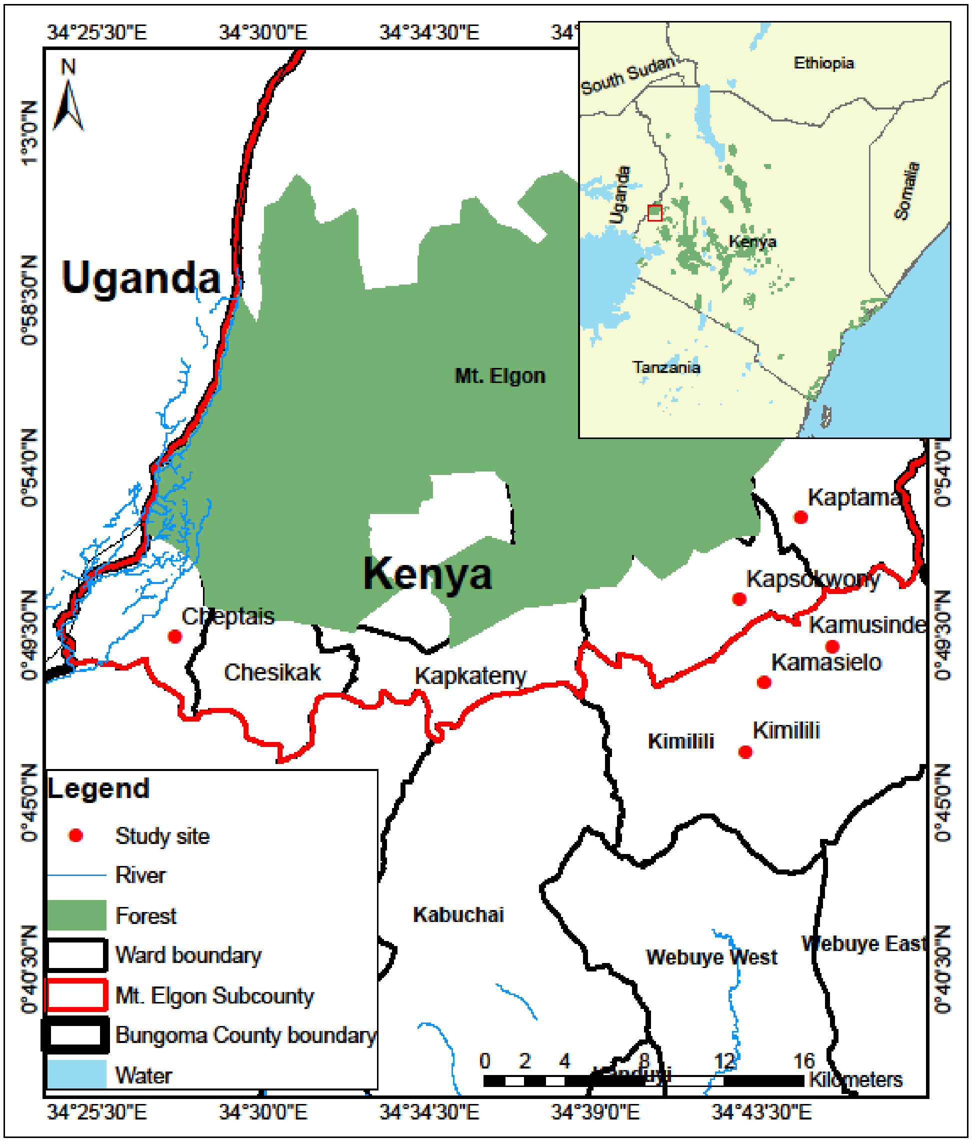

Figure 1: A map of Mt. Elgon showing the location of the Study sites (Source: Generated by a Geographic Information System (GIS Software)

Study Design

Cross sectional field surveys sampling human residents, mosquitoes and soils in selected sites were conducted. The sites included Kaptama Ward (0°53'12.6"N, 34°46'06.9"E), on an elevation of 2044M, Kapsokwony Ward (0°51'08.0"N, 34°42'07.0"E) on an elevation of 1971M, Cheptais Ward (0°80'78.56"N 34°.46'72.7"E) on an elevation of 2,025M and Kamasielo and Kamusinde in Maeni Ward (0°48'40.9"N, 34°43'41.8"E) on an elevation of 1725M. The sites were investigated to determine the prevalence of lymphedema among the residents, and diagnose filarial worm infection in the human cases and mosquitoes in the study sites. The composition of soil mineral elements in the study sites was also determined.

Consenting individuals with lymphedema symptoms were matched with consenting controls (without lymphedema symptoms) in the same area for risk factors assessment. A systematic sampling method was used to select participants for risk factors assessment which included 11 randomly selected cases of lymphedema and members of households without lymphedema in the six assessed sites. In collaboration with a clinical officer and a medical laboratory technologist, blood sample were collected from consenting cases and analysed microscopically for presence of filarial worms.

Soil samples were also collected from randomly selected homesteads/farmlands in the study areas for analysis to determine constituent elements. The soil samples were analysed as composites for the selected study sites using Infrared Spectroscopy as previously described (Gachohi et al., 2017; Jackson, 1967; Svensson, 2017)

Mosquitoes were collected from the study sites using CDC light traps baited using CO_2 from dry ice and sticky traps. The mosquito specimens were sorted by sex and morphologically identified in the field and in the laboratory to species level as previously described (Service, 2012). The female mosquito species were cleaned and immediately processed for filarial worm evaluation following the procedures described by (Cross, 1996; Mathison et al, 2019). The male mosquitoes were not tested for filarial worms since they are not vectors.

Ethical Consideration

Research approval was obtained from the National Commission for Science, Technology and Innovation (licence reference number 872618). Ethical approval was obtained from the Baraton University Ethical Review Board (permit reference number B0319012023). Human participants were recruited after signing informed consent forms which specified the risks and benefits of participating in the study. The parents/guardians of children below 18 years gave their consent to the participation of minors.

Data Management and Analysis

Descriptive statistics were used to summarise the data which was analysed using t-test and chi-square tests to determine and compare prevalence of lymphedema between study sites, sexes and age groups. Correlation analysis was performed to determine the relationship between the soil mineral concentration and lymphedema prevalence.

3. Results

Spatial Distribution and Prevalence of Lymphedema in the Study Sites

During the study period, a total of 38 lymphedema cases were recorded in the assessed wards. All cases involved swelling confined to the lower limbs, which did not extend beyond the knees, suggesting that the lymphedema was due to podoconiosis. The distribution of cases across the wards was as follows: Cheptais had 15 cases, representing 39.47% of the total; Kapsokwony had 10 cases, accounting for 26.32%; Kaptama recorded 9 cases which was 23.68% of the total; and Kamasielo had the fewest cases, with only 4, making up 10.53% of the total, as shown in Figure 2. No cases of lymphedema were reported in Kamusinde. A statistically significant variation was observed in the distribution of lymphedema cases among the four wards ($\chi^2 = 15.76$, d.f. = 3, $p = 0.0013$).

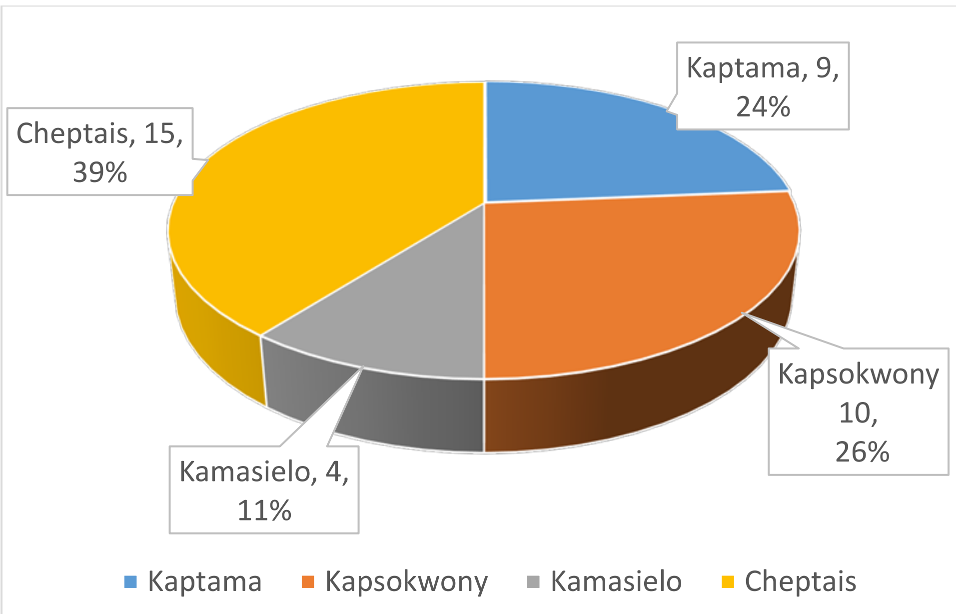

Figure 2: Distribution of lymphedema recorded cases in the assessed wards in the study areas

Distribution of lymphedema cases by sex

Majority of the lymphedema cases were female with 27(71.05%) cases compared to male with 11(28.95%) cases as shown in Figure 3, with a significant ($\chi^2 = 17.64$, d.f. =1, $p < 0.0001$) sex ratio distribution difference.

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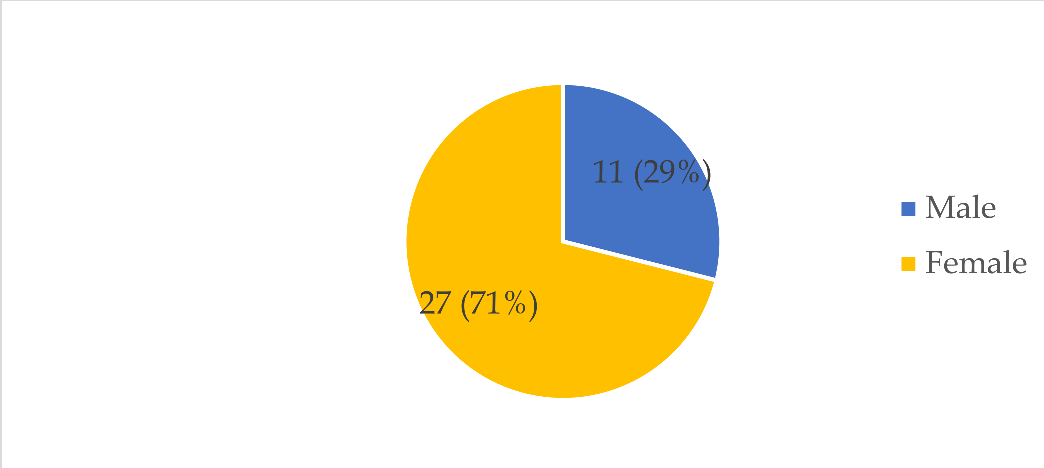

Figure 3: Proportional distribution of lymphedema cases by sex

Regarding the spatial distribution of lymphedema and its prevalence by sex, Kamasielo recorded all cases among females (100%). In Kapsokwony, 90% of the cases were female, showing a statistically significant sex distribution difference ($\chi^2 = 64.0$, d.f. = 1, $p < 0.0001$). In Kaptama, 66.67% of the cases were female and 33.33% male, with a significant sex ratio difference ($\chi^2 = 11.56$, d.f. = 1, $p = 0.0007$). In contrast, Cheptais Ward had a more balanced distribution, with 53.33% of cases in females and 46.67% in males, showing no significant difference between the sexes ($\chi^2 = 0.36$, d.f. = 1, $p = 0.5485$), as illustrated in Figure 4.

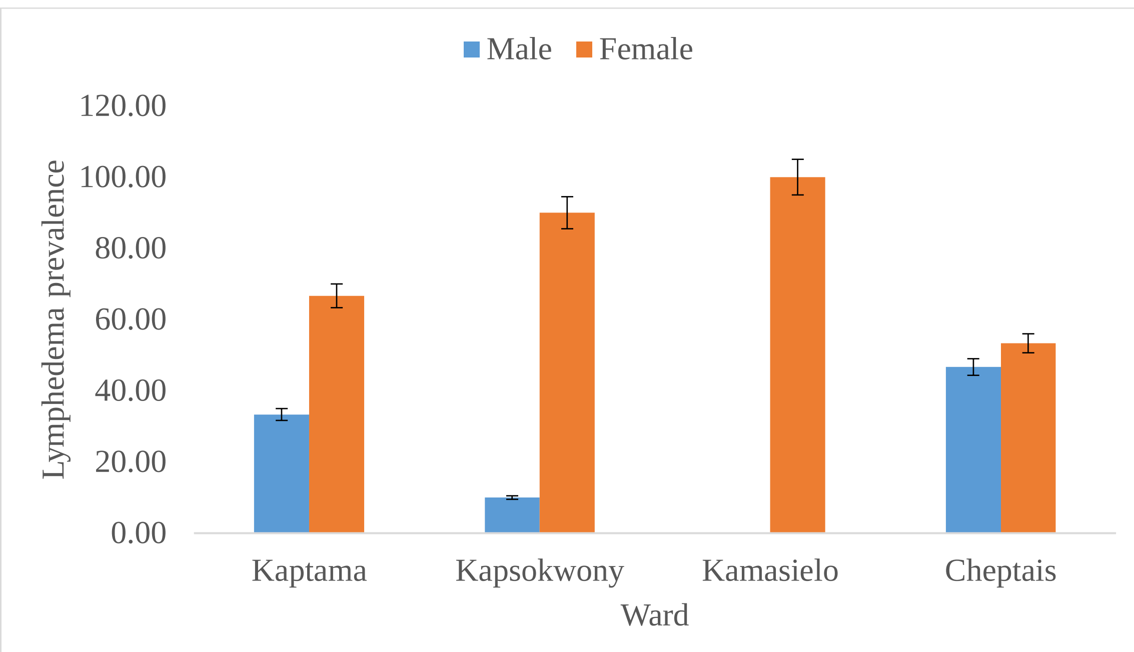

Figure 4: Distribution of lymphedema prevalence by sex in the Wards

Distribution of lymphedema cases by age

The age distribution of lymphedema cases in the study areas exhibited a clear pattern, with the majority occurring in individuals over 18 years old (36 out of 38 cases, 94.74%), a statistically significant difference ($\chi^2 = 81.0$, d.f. = 1, $p < 0.0001$). Among affected adults, Cheptais had the highest number of cases (15, all above 18 years, 100%), followed by Kaptama (9 cases, 100%) and Kamasielo (4 cases, 100%), as shown in Figure 5. In contrast, only 2 out of 10 cases in Kapsokwony ward were observed in children under 18 years.

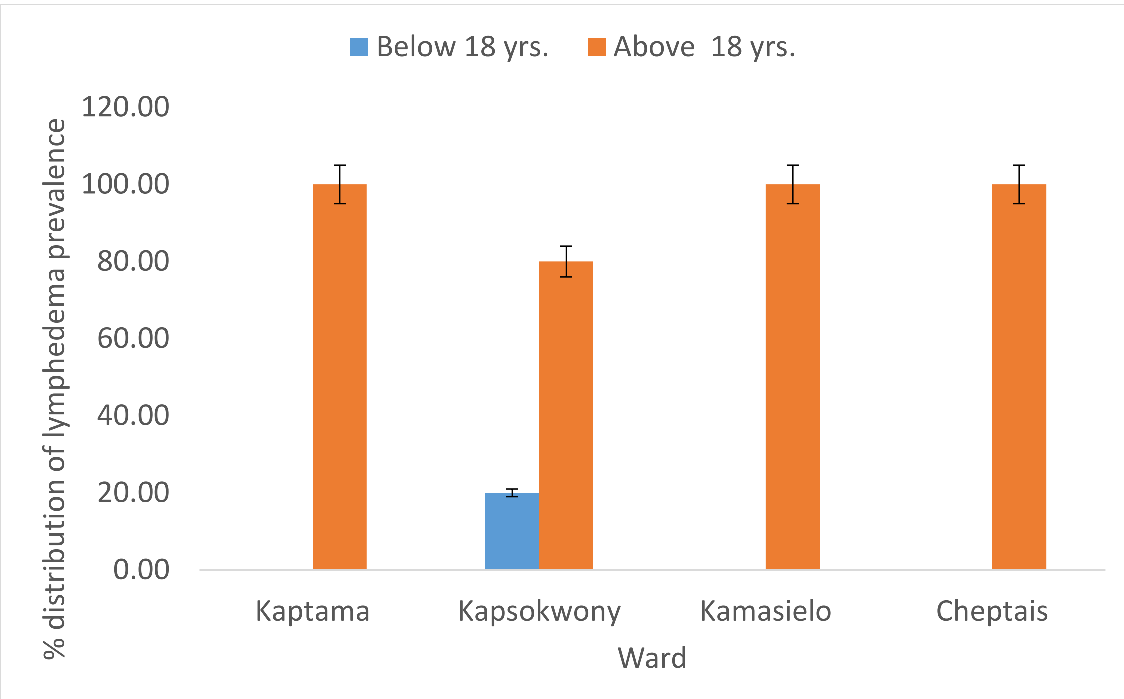

Figure 5: Distribution of lymphedema cases in the wards by age

Filarial test in cases

The Filarial worm test conducted on each of the suspected human case specimens recorded negative results, as shown in Table 1.

Table 1: Filarial worm test results for lymphedema cases in the assessed wards

WARD	LYMPHEDEMA CASES	FILARIAL TEST RESULT
Kaptama	09	Negative
Kapsokwony	10	Negative
Maeni (Kamasielo)	04	Negative
Cheptais	15	Negative
TOTAL	**38**	**Negative**

Filarial worm infection test in mosquitoes collected from the study area

CDC light traps and sticky traps captured a total of two hundred three (203) mosquitoes, consisting of *Culex* and *Anopheles* species. The female mosquitoes were dissected and microscopically observed for filarial worm detection and recorded by species. The tested female mosquitoes were 175 (f=175) as presented in Table 4.2. Based on the species, more *Anopheles* mosquito species were captured and all were negative for filarial worm infection.

Table 2: Proportion of mosquito species collection by sex (%) and proportion of tested female outcome for filarial worms by the mosquito genus

Mosquito species	Sex (sub-total)	Total	Proportion collection by sex (%)	Filarial worm test outcome in females
Anopheles	male	18	13.04	
	Female	120	86.96	0/120
	(Subtotal)	138	100.00	
Culex	male	10	15.38	
	Female	55	84.62	0/55
	(Subtotal)	65	100.00	
Total		**203**	**85.79**	**0/175**

Soil elements composition in the study areas

The assessed soil element composition in the study areas showed that the mean density (mg-1kg) of Silicone was high in Kamasielo (271.00±19.00), followed by Kapsokwony (172.67±10.02). The lowest density was in Cheptais (98.58±18.50) with a significant difference (F 0.05 (3, 8) =68.96, p<0.0001) in its mean density distribution. Aluminum density (mg-1kg) in soil was high in Kaptama (71.74±8.60) and Kapsokwony (74.30±3.52) and low in Cheptais (30.84±7.01) with a significant difference ($F_{0.05\ (3,\ 8)}$ =33.07, p=0.0001) in mean density distribution.

Regarding Magnesium density (mg-1kg) in soil samples, the highest mean was recorded in Kapsokwony (3.81±0.15) while the lowest mean was recorded in Kaptama (1.02±0.01) with a significant difference ($F_{0.05\ (3,\ 8)}$ =790.50, p=0.0001) in mean density distribution. The highest mean of Sodium density (mg-1kg) in soil samples was recorded in Cheptais (4.29±0.08) while the lowest was recorded in Kaptama (1.93±0.03) with a significant difference ($F_{0.05\ (3,\ 8)}$ =735.90, p=0.0001) in mean density distribution.

The highest mean Potassium density (mg-1kg) was recorded in soil samples from Cheptais (0.42±0.02) and lowest in soil samples from Kamasielo (1.03±0.03) with a significant difference ($F_{0.05\,(3,\,8)}$ =69.71, $p<0.0001$) in mean density distribution. Similarly, the highest mean Iron density (mg-1kg) in the soil samples was recorded in Cheptais (17.87±0.35) followed by Kapsokwony (17.32±0.10) while the lowest mean iron density of 13.52±0.08 was recorded in soil samples from Maeni with a significant difference ($F_{0.05\,(3,\,8)}$ =183.60, $p=0.0001$) in mean density distribution as shown in Table 3.

Table 3 Soil mineral composition density (mg-1kg) distribution in the study areas

Soil element composition	**Kaptama**	**Kapsokwony**	**Maeni(Kamasielo and Kamusinde)**	**Cheptais**	**F-Ratio**	**p-value**
Silicone (mg-1kg)	152.07±10.00^{b}	172.67±10.02^{b}	271.00±19.00^{c}	98.58±18.50^{a}	68.96	0.0000
Aluminium (mg-1kg)	71.74±8.60^{c}	74.30±3.52^{c}	47.53±4.50^{b}	30.84±7.01^{a}	33.07	0.0001
Magnesium (mg-1kg)	1.02±0.01^{d}	3.81±0.15^{a}	1.46±0.04^{c}	2.71±0.02^{b}	790.50	0.0000
Sodium (mg-1kg)	1.93±0.03^{d}	2.41±0.03^{c}	3.40±0.10^{b}	4.29±0.08^{a}	735.90	0.0000
Potassium (mg-1kg)	0.95±0.05^{bc}	0.90±0.10^{b}	0.42±0.02^{a}	1.03±0.03^{c}	69.71	0.0000
Iron (mg-1kg)	14.40±0.40^{c}	17.32±0.10^{b}	13.52±0.08^{d}	17.87±0.35^{a}	183.60	0.0000

Note: Means followed by different letters superscripts in the same row are significantly different at $p < 0.05$. Means were separated by Fishers Least Significant Difference (LSD)

Further analysis for soil elements (Figures 6a, b, c, d, e, f) showed that soil iron concentration was highest in Cheptais and lowest in Kamasielo and Kamusinde with descending trend of 17.87, 17.32, 14.40 and 13.52 (mg-1kg) in Cheptais, Kapsokwony, Kaptama and Kamasielo and Kamusinde respectively. This trend was positively associated with lymphedema prevalence in the same areas; 39%, 26%, 24% and 11% in Cheptais, Kapsokwony, Kaptama and Kamasielo and Kamusinde respectively, ($R= 0.867024$). Potassium also showed a similar trend with 1.03 mg/kg in Cheptais, 0.9 mg/kg in Kapsokwony, 0.95 mg/kg in Kaptama and 0.42 mg/kg in Kamasielo and Kamusinde, ($R= 0.897139$).

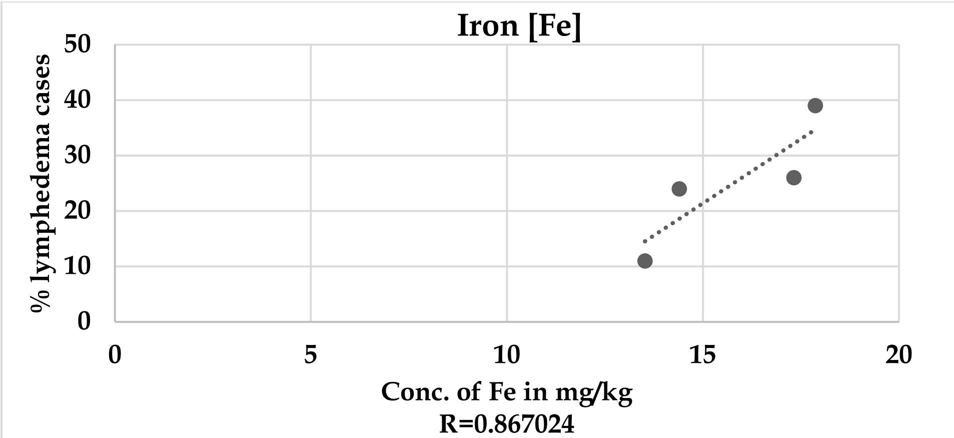

Figure 6a: Correlation plot for iron

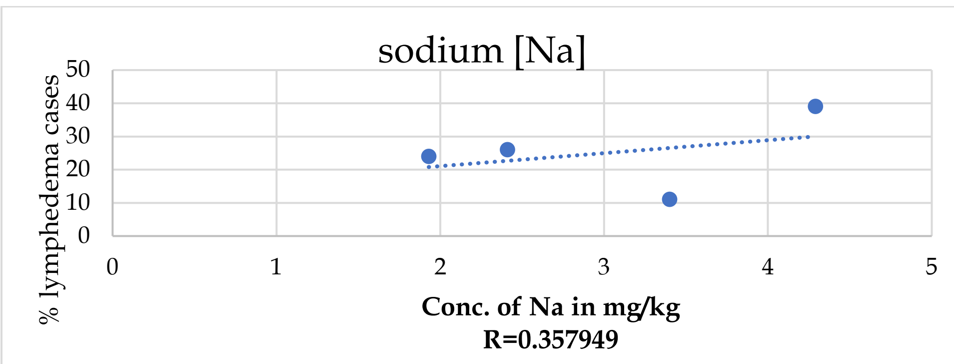

Figure 6b: Correlation plot for Sodium

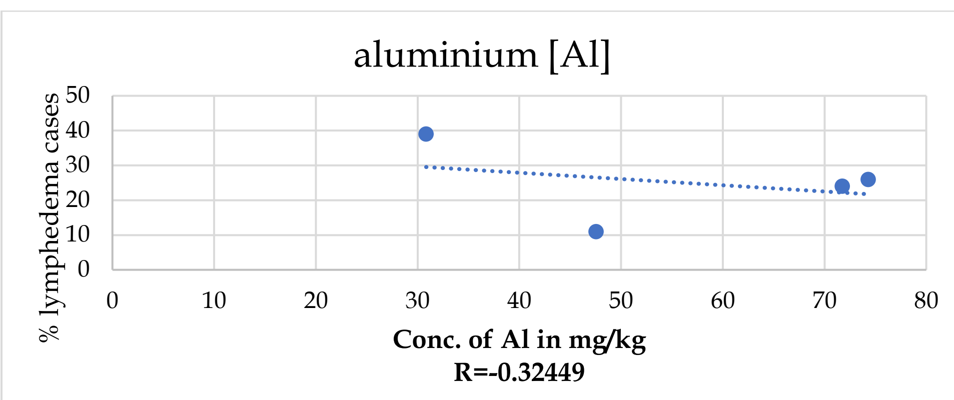

Figure 6c: Correlation plot for Aluminium

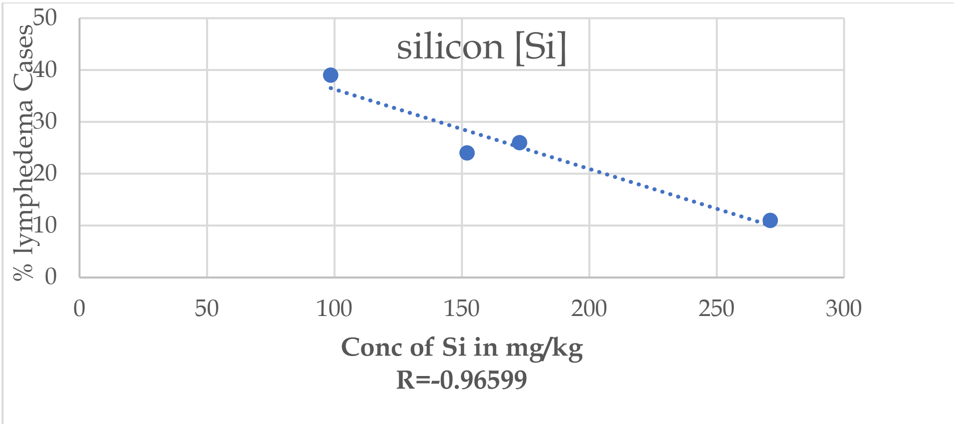

Figure 6d: Correlation plot for Silicon

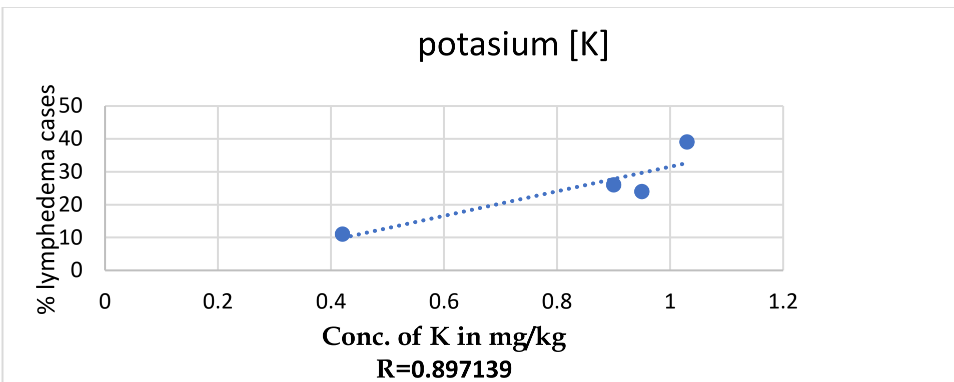

Figure 6e: Correlation plot for Potassium

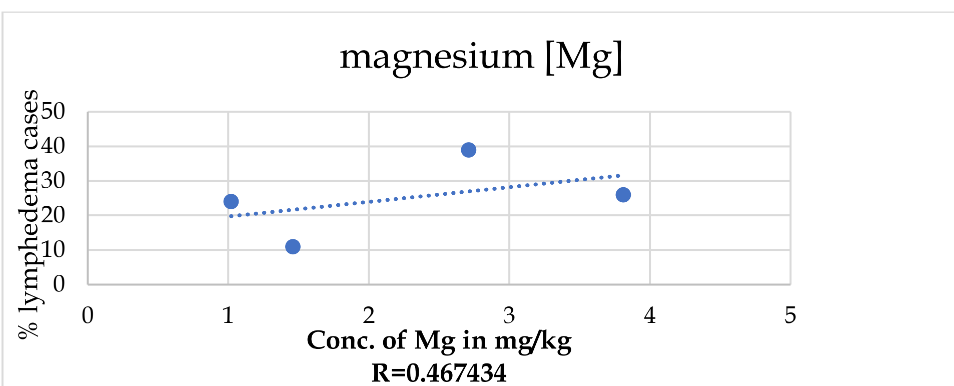

Figure 6f: Correlation plot for Magnesium

Socio-economic factors associated with lymphedema in the study area

A significantly (χ^2 = 85.86, df. = 4, p<0.0001) large number of respondents with lymphedema were in the age bracket of above 18 years old, with 36/38 (94.74%) of cases being above 18 years compared 2/38 (5.26%) cases being below 18 years old. In terms of gender, a majority of the cases were recorded in female, 27/38 (71.05%) compared to male, 11/38 (28.95%). The distribution of age of the male without lymphedema showed that majority of those who consented to be interviewed were in the age bracket of above 18 but less than 43 years (72.94%), with a significant difference (χ^2=57.75, df. =4, p<0.0001) from those above 43 years old. Similar majority observations (92.59%) were made for the female above 43 years who consented to be interviewed as shown in Table 4.

Table 4: Age and gender of respondents with and without lymphedema in Bungoma County

	with Lymphedema				**without Lymphedema**			
Age/Years	**Male**	**%**	**Female**	**%**	**Male**	**%**	**Female**	**%**
<18	2	18.18						
18-30			1	3.70	101	46.33	62	43.36
31-43	1	9.09	1	3.70	58	26.61	39	27.27
43-55	4	36.36	8	29.63	36	16.51	24	16.78
55-67	3	27.27	14	51.85	12	5.50	9	6.29
>67	1	9.09	3	11.11	11	5.05	9	6.29
Total	11	100.00	27	100.00	218	100.00	143	100.00
χ^2		85.8588		85.8588		57.75		48.95
df		4		4		4		4
p value		<0.0001		<0.0001		<0.0001		<0.0001

A majority of those with lymphedema had no formal education (72.73%) while those without lymphedema had formal education. The education levels were noted as primary (52.34%), secondary (31.25%), certificate (5.73%) diploma (4.43%) and degree (4.17%) levels as shown in Table 4.4. There was a significant difference between and within the assessed groups (χ^2=30.45, df. =5, p<0.0001). In terms of employment, none of the cases of lymphedema had formal employment while a proportion of respondents without lymphedema, had formal employment (26.30%). Source of income significantly (χ^2=0.30, df. =5, p=0.9976) varied between those with and those without lymphedema as shown in Table 5. The data further shows that majority of individuals with and without lymphedema in the study areas relied on manual/casual labour to earn income with a large number depending on crop and livestock farming. The largest proportion (45.45%) of those with lymphedema relied on livestock herding as sources of income.

Table 5: Socio-demographic Index Education, formal Employment and Source of Income

Socio demographic index	Attribute	With Lymphedema		without Lymphedema		
		N	%	N	%	Chi square test
Education level	No education	8	72.73	8	2.08	χ^2=30.45, df. =5, p<0.0001
	Primary	3	27.27	201	52.34	
	Secondary	-	-	120	31.25	
	Certificate	-	-	22	5.73	
	Diploma	-	-	17	4.43	
	Degree	-	-	16	4.17	
	Total	11	100.00	384	100.00	
Formal employment	Employed			101	26.30	-
	Unemployed	11	100.00	283	73.70	
	Total	11	100.00	384	100.00	
Source of income	Manual/casual	2	18.18	101	26.30	χ^2=0.30, df. =5, p=0.9976
	Business/trade	1	9.09	31	8.07	
	Livestock	5	45.45	120	31.25	
	Farming	1	9.09	122	31.77	
	Salary	1	9.09	9	2.34	
	Dependent on family support	1	9.09	1	0.26	
	Total	11	100	384	100	

Association of housing characteristics and Lymphedema prevalence

The type of houses included temporary houses that were made of grass roof, stick wall and earthen floors, and permanent/semi-permanent houses made of iron sheet roof or grass with the walls made of mud or bricks. Type of houses in which participants lived in was associated with lymphedema with all cases being recorded in individuals living in temporary houses. A majority of the respondents without lymphedema also resided in temporary houses (65.36%) while the rest of the respondents lived in semi-permanent structures.

The number of rooms in the house was similarly associated with the occurrence of lymphedema cases. Participants living in houses with between 1 to 2 rooms had more cases of lymphedema (90.90%) compared to those living in houses with more than two rooms as shown in Table 5. A majority of participants without lymphedema lived in houses with more than two rooms (78.39) compared to those with less than 2 rooms with a significant difference between the two groups (χ^2= 96.86, d.f.=1, p < 0.0001).

Type of the floor of the house in which an individual lived was associated with lymphedema prevalence with households with earthen floor houses having significantly (χ^2= 70.95, d.f.=1, p < 0.0001) higher prevalence (63.60%) compared to those living in houses with cemented floor as shown in Table 4.5. Type of material used to construct walls of houses was also associated with lymphedema prevalence with houses made of mud (72.70%) being significantly (χ2= 5.51, d.f.=52, p <0.0001) associated with a higher prevalence of lymphedema compared to those living in houses with walls made of other materials as summarized in Table 5.

Table 6: Association of housing characteristics and Lymphedema prevalence

Social demographic index	Attribute	With Lymphedema	Without Lymphedema	Chi square (χ2)
Type of housing	Temporally	11(100.0%)	251(65.36%)	χ^2= 42.42, d.f.=1, p < 0.0001
	Permanent/ semi-permanent	0(0.0%)	133(34.64%)	
	Total	11(100.0%)	384(100.00%)	
Number of rooms	1-2 rooms	10(90.9%)	83(21.61%)	χ^2= 96.86, d.f.=1, p < 0.0001
	More than 2 rooms	1(9.1%)	301(78.39%)	
	Total	11(100.0%)	384(100.00%)	
Type of floor	Earthen floor	7(63.6%)	28(7.29%)	χ^2= 70.95, d.f.=1, p < 0.0001
	Cemented floor	4(36.4%)	356(92.71%)	
	Total	11(0.0%)	384(100.00%)	
Type of material used to make house wall	Timber	1(9.1%)	32(8.33%)	χ^2= 5.51, d.f.=52, p <0.0001
	Mud	8(72.7%)	161(41.93%)	
	Bricks	2(18.2%)	92(23.96%)	
	Total	11(100.0%)	384(100.00%)	

Use of shoes and use of mosquito nets

Majority of the respondents, both cases and non-cases of lymphedema did not own/use shoes. The non-use of or lack of shoes was associated with higher lymphedema prevalence as shown in Table 7. A large proportion of respondents with lymphedema did not have/use mosquito net (63.64%). There was a significant difference (χ^2= 45.83, d.f.=1, p < 0.0001) in use of mosquito net between the respondents with and without lymphedema as shown in Table 7.

Table 7: Use of shoes and use of mosquito nets by residents in the study area

Social demographic index	Attribute	With Lymphedema N	With Lymphedema %	Without Lymphedema N	Without Lymphedema %	Chi square (χ^2)
	I do not have/use shoes	11	100.00	372	96.88	
	I have shoes and use them regularly	0	0.00	12	3.13	
Use of shoes	Total	11	100.00	384	100.00	χ^2= 3.05, d.f.=1, p < 0.0001
	I have and use a mosquito net	4	36.36	320	83.33	
	I do not have a mosquito net	7	63.64	64	16.67	
Use of mosquito net	Total	11	100.00	384	100.00	χ^2= 45.83, d.f.=1, p < 0.0001

Knowledge on Clinical Aspects of Lymphedema

Respondents with lymphedema indicated that they were aware of the symptoms of the condition which mainly involved swelling of the feet (63.64%). Similar awareness was also indicated by respondents without lymphedema as shown in Table 8. Most of the respondents did not have knowledge of lymphedema cause and transmission mode. The few who had some knowledge of elephantiasis indicated that mosquitos were the main vectors of the condition (cases, 18.18%; non cases, 33.59%). However, majority of the affected cases and controls indicated that the condition was caused by witchcraft (45.45% - 52.34%) A significant proportion of the affected cases believed that lymphedema could not be treated with a small proportion believing in traditional healers (27.27%) and medical amputation (27.27%) of the affected lower limb(s) as shown in Table 8. The affected cases and controls believed that there were no existing preventive measures against the condition.

Table 8: Knowledge on Clinical signs/symptoms of Lymphedema

Socio demo-graphic index	**Attribute**	With Lymphedema N	%	Without Lymphedema N	%	Attribute Chi square
	I do not know the disease symptoms	1	9.09	70	18.23	
	swelling of the feet	7	63.64	283	73.70	
	swelling of the genitals	2	18.18	30	7.81	
	painful breasts	1	9.09	3	0.78	
Knowledge on Lymphedema symptoms	Others		0.00	2	0.52	χ^2= 14.95, d.f.=4,
	total	11	100.00	384	100.00	p = 0.0048
	I do not know about its transmission	9	81.82	243	63.28	χ^2= 10.41,
	Mosquito	2	18.18	129	33.59	d.f.=2,
Knowledge on Lymphedema transmission	Others		0.00	12	3.13	p = 0.0055
	Total	11	100.00	384	100.00	
	I do not know	1	9.09	132	34.38	
	Witchcraft	5	45.45	201	52.34	
	Curses	3	27.27	15	3.91	
	Mosquitos	2	18.18	36	9.38	χ^2=35.11, d.f.=3,
What causes Lymphedema	total	11	100.00	384	100.00	p < 0.0001
	None	5	45.45	322	83.85	χ^2= 34.62, d.f.=2,
Any treatment of Lymphedema	traditional healers	3	27.27	45	11.72	p < 0.0001

	Amputation	3	27.27	17	4.43	
	Total	11	100.00	384	100.00	
	None	3	54.55	231	60.16	
	use of traditional healers	2	18.18	104	27.08	
	use of mosquito nets	6	27.27	49	12.76	$\chi^2 = 40.26$,
Any preventive measures for Lymphedema	Total	11	100.00	384	100.00	d.f.=2, $p < 0.0001$

Discussion

The higher prevalence of lymphedema cases in Cheptais (with 15 cases representing 39.47% of all cases), suggests higher proportion of risk factors or environmental triggers in that area. This finding aligns with studies highlighting the influence of environmental factors such as altitude whereby lymphatic filariasis is negatively associated with increasing elevation (Cano et al, 2014). However lymphatic filariasis was not observed in the current study, therefore, irritant soil element(s) is the cause of the lymphedema observed in this ward. This is supported by the finding of highest iron and potassium densities in the composite soil in the area corresponding to the highest prevalence of lymphedema observed in the same area.

The circumstance and habit of not wearing shoes while working in the farms or at home or delayed foot washing to get rid of irritant soils are strongly associated with developing podoconiosis (Ario et al., 2015). This is supported by the findings in the current study that all the observed cases of lymphedema did not own/use shoes while working in the farm and at home. The findings of the current study support earlier research linking podoconiosis to exposure to irritant red soil of volcanic origin (Cano et al., 2014; Ario et al., 2015). Most households in the study area have non-cemented floors, which increases residents' contact with this soil and raises their risk of developing the condition.

Stagnant water bodies, which serve as breeding grounds for vectors and parasites causing lymphatic filariasis is a common cause of lymphedema in tropical regions (Addiss & Brady, 2007). However, there was no evidence of filariasis during the current study since tests for filarial worms in the cases and in the mosquitoes collected from the region were all negative. Similarly, the 10 cases reported in Kapsokwony (26.32% of total cases) indicate a substantial burden of lymphedema in this ward. Factors such as poor sanitation, lack of access to healthcare services, or limited awareness about preventive measures contribute to this situation. Similar factors have been observed in Cheptais. Studies have shown that inadequate hygiene practices and limited healthcare infrastructure contribute significantly to the prevalence of lymphedema in resource-constrained settings (Budge et al., 2018).

In Kaptama, where 9 cases were recorded, representing 23.68% of the total, specific local factors may be contributing to the occurrence of lymphedema. These could include genetic predisposition, occupational exposure, or cultural practices that increase the risk of lymphatic disorders (Smith et al., 2016).

The lowest number of cases observed in Kamasielo which is located outside Mt. Elgon sub-county (4 cases representing 10.53% of total cases) suggests possible deposits of irritant soil elements in this area. This is due to soil erosion which carries volcanic soil from the adjacent highlands containing the irritant minerals ions to the lowlands. It may also be as a result of some people resident in this ward going to do farming work in the higher slopes of the mountain.

Distribution of lymphedema prevalence by sex

The distribution of lymphedema cases by sex reveals important insights into potential gender disparities in disease prevalence and susceptibility. The significant difference observed in the distribution of cases between female and male gender underscores the need for gender-specific interventions and further investigation into underlying factors contributing to this disparity. The predominance of lymphedema cases in females, as highlighted by 71.05% of cases being recorded in females compared to 28.95% in males, aligns with existing literature documenting higher prevalence rates among women (Addiss & Brady, 2007; Budge et al., 2018).

The gender imbalance may be attributed to various factors including biological differences, such as hormonal influences on lymphatic function or differences in lymphatic anatomy (Shaitelman et al., 2015), as well as socio-cultural factors affecting healthcare-seeking behaviour and differential exposure opportunities to the risk factors (Smith et al., 2016). In the study region, women are culturally expected to do chores which expose them to soil elements such as tilling in the farms and smearing mud on house walls and floors using soil, sometimes mixed with cow dung. Women carry out these activities without wearing shoes and hand gloves. Thus, the women have higher exposure risk to soil elements compared to men.

Although a majority of cases was recorded in Kaptama were females (66.67%), a substantial proportion (33.33%) was also reported in males. This finding underscores the importance of considering gender-specific risk factors and healthcare access in disease management strategies, even in areas where females are predominantly affected (Budge et al., 2018). Interestingly, Cheptais ward did not exhibit a significant difference in lymphedema cases between male and females, with 53.33% of cases reported in female and the remainder in males. This suggests that there may be other influencing factors at play in this particular locality, such as environmental, cultural or genetic factors, which warrant further investigations (Addiss et al., 2018).

Distribution of Lymphedema Prevalence by Age

The distribution of lymphedema cases by age groups highlights an important trend, with the majority of cases occurring in individuals above the age of 18 years. This finding is consistent with existing literature that suggests an increased risk of lymphedema with advancing age, possibly due to age-related changes in lymphatic function and immune response (Moffatt et al., 2017). The statistically significant difference observed in the distribution of cases between age groups underscores the importance of age as a risk factor for lymphedema. This finding is supported by studies demonstrating a higher prevalence of lymphedema in older populations, particularly in regions endemic for lymphatic filariasis (World Health Organization, 2018). It is also consistent with studies that have identified older age as a risk factor for lymphedema, possibly due to age-related changes in the lymphatic system function (Stout et al., 2016). It may also suggest that the development of lymphedema requires prolonged exposure to the causative agent(s).

The analysis of lymphedema cases by age groups in the sampled wards provides additional insights. In Cheptais, for example, where all cases were reported in individuals above 18 years old, there may be specific local factors contributing to the higher prevalence of lymphedema in adults. These factors could include occupational hazards, lifestyle factors, or limited access to healthcare services for older individuals (Addiss et al., 2018). Similarly, in Kaptama, where most cases were reported in females above 18 years old, there appears to be a concentrated burden of lymphedema in this demographic group. This finding suggests the need for targeted interventions aimed at reducing the risk of lymphedema in adult male and female in the area (Budge et al., 2018).

In contrast, Kamasielo had the least number of cases, all in females above 18 years old. While the reasons for this lower prevalence are not immediately clear, further investigation into local factors influencing disease distribution in this ward is warranted (Smith et al., 2016). The negative results of the filariasis test in the victims suggest that factors other than filariasis may be contributing to the development of lymphedema in this population. Further research is needed to explore alternative etiologies and potential co-morbidities associated with lymphatic disorders in the study area.

Soil Mineral Composition in the Study Area

The results of the soil element composition assessment in the study area indicate significant variations in the concentration levels of different elements across the sampled locations. These variations can have implications for soil fertility, plant growth, and overall ecosystem health which encourages farming activities in the region. The elements in the region makes the soil suitable for farming hence exposing the locals to irritant volcanic soil while working in the fertile farmlands. This finding aligns with studies that have shown the influence of colloid-sized silicate (or aluminium, magnesium, sodium, potassium and iron) particles in the red volcanic soils which penetrate through the skin and are taken up into macrophages in the lower limb lymphatic's, thereby causing endolymphangitis and obliteration of the lymphatic lumen (Davey et al., 2007).

4. Conclusions

The study revealed several important findings regarding lymphedema prevalence and the possible etiology in the study area. A total of 38 cases were recorded, with the highest number of cases being reported in Cheptais ward, followed by Kapsokwony, Kaptama, and Kamasielo. Females were disproportionately affected, with 71.05% of cases being recorded in females compared to 28.95% of the cases in males. Age also plays a significant role, with the majority of cases occurring in individuals above 18 years old. All cases tested negative for filarial worms, an indicator that the possible cause of lymphedema in the region is podoconiosis. These findings underscore the need for further research to understand any other underlying cause of lymphedema in the study area. The study on soil mineral composition in the area revealed significant variations in the concentrations of several key minerals across different locations. The study concluded that the observed elephantiasis observed in the region was of non-filarial worm etiology caused by iron and potassium elements in the region's soil.

Recommendations

Based on the findings, several recommendations are proposed to address the risk factors and prevalence of lymphedema in the Mt. Elgon region. Targeted health interventions should be implemented in high-risk areas such as Cheptais and Kapsokwony wards, where a higher prevalence of lymphedema was observed. These interventions should include improved access to healthcare services and the provision of specialized footwear for affected individuals to minimize further exposure to irritant soil. Additionally, gender-specific health programs should be introduced to address the disproportionately higher prevalence of lymphedema among females. These programs should focus on mitigating gender-related risk factors, enhancing healthcare accessibility for women, and promoting gender-sensitive healthcare practices.

Community-based health programs should be strengthened to raise awareness about lymphedema, its causes, and preventive measures. Such programs would also encourage early detection and treatment, thereby reducing the disease burden. Moreover, improving housing conditions is crucial, particularly addressing the prevalence of temporary floor structures, which have been linked to a higher risk of lymphedema. Efforts should be made to support housing upgrades and improve access to clean water and sanitation facilities.

Health education initiatives should also be prioritized to enhance knowledge of lymphedema symptoms, modes of transmission, prevention strategies, management, and treatment options. This would help dispel misconceptions about the disease and encourage early diagnosis and timely intervention. Lastly, further research is needed to explore alternative etiologies and potential co-morbidities associated with lymphatic disorders in the region. Such research would contribute to a deeper understanding of the disease and inform better management strategies for affected communities.

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Photos of some of the affected cases in the region showing the ascending lymphedema taken by Techno Spark Air phone by the investigator (Source: Author 2022)

Photo of an affected case showing delayed feet cleaning in the Mt. Elgon region taken by Techno Spark 4 Air phone by the investigator (Source: Author 2022)