Cochran's Q-Test on Soil Helminth Prevalence

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SUMMARY

A study was made of the prevalence of nine geohelminth egg types in 184 soil samples from 16 recreational parks in Abuja metropolis, Nigeria. Cochran's Q-test was applied to determine whether the difference in the proportions of the egg types found in the soil samples was significant. At a 5% significance level, it was found that the prevalence of the egg types was significantly different in the 184 soil samples from 16 parks. To identify which of the geohelminth eggs had a significantly larger mean proportional prevalence, a minimum required difference mean comparison technique was applied. The mean comparison test showed that *Taenia* and *Coccocidia* eggs were highly prevalent, with significantly larger mean proportions than the other analyzed geohelminth eggs in the 184 examined soil samples.

Keywords: Cochran's Q-test, Minimum required difference, Geohelminth eggs, Soil, Recreational parks

1. Introduction

Helminth infections are the most common parasitic infections in humans, with the highest prevalence in tropical countries. Due to provision of food, where invertebrate vectors such as insects and molluscs flourish, and unhygienic conditions, food becomes infected with parasite eggs (Lindquist and Cross, 2017). According to Galaktionov (2017), helminths are a group of worms that are habitually parasitic in birds, and they include flatworms, further subdivided into cestodes (tapeworms) and trematodes (flukes), as well as nematodes (roundworms) and acanthocephala (thornyheaded worms). Also, Khana *et al.* (2019) noted that some species of seabirds often come into interaction with

humans (harvested species or gulls), and thus may be a basis for zoonotic disease. However, Pal and Chakravarty (2020) made it clear that helminths do not reproduce within a host; hence, they differ from protozoa. Thus, the number of helminths existing in an individual is equal to the number that found entry into it. Most animals host few worms, but a few host a great number of worms. The magnitude of the parasitic load in a host is controlled by genetic features and the host's response to these parasites. Helminths are easily diffused to humans through food, water, soil, and arthropod and molluscan vectors. They can infect every organ and organ system, including the liver, lungs and blood; they have high prevalence in the intestines, and occasionally the brain and other organs (Lindquist and Cross, 2017). Many studies have demonstrated that helminth infections lower the risk of autoimmunity or allergy. For instance, an inverse correlation between autoimmune liver diseases and *Strongyloides stercoralis* infection was demonstrated in Okinawa, Japan (Aoyama, 2007).

Cross-sectional studies on the relationship between skin prick tests and helminth infections suggested a general protective effect on the atopic reaction (Flohr *et al.*, 2009). Those authors summarized the effects of geohelminths on the risk of asthma, according to previous studies: hookworm lowered the risk of asthma, while *Ascaris* increased the risk and *Trichuris* had no effect. Overall, it is concluded that at least some helminths seem to have anti-allergic or anti-inflammatory effects in humans. A disproportionate burden of helminthiasis in human populations occurs in marginalized, low-income, and resource-constrained regions of the world, with over 1 billion people in developing areas of sub-Saharan Africa, Asia, and the Americas infected with one or more helminth species. The morbidity caused by such infections imposes a substantial burden of disease, contributing to a vicious circle of infection, poverty, decreased productivity, and inadequate socioeconomic development. Furthermore, helminth infection accentuates the morbidity of malaria and HIV/AIDS, and impairs vaccine efficacy (Lustigman, 2012). Soil transmitted helminth (STH) infections remain a significant health problem in resource-limited countries due to difficulties in the implementation of control measures. In Nigeria, for instance,

despite several community-based and provincial reports, national data on prevalence, burdens and risk zones (RZs) for STH infections are lacking (Karshima, 2018).

Recently, Ngwese *et al.* (2020) stated that globally about 1.5 billion people are infected with STHs worldwide. Of these, 270 million are preschool children and over 568 million are school-aged children who require treatment and prevention interventions. People hosting heavy infections have a higher morbidity, while people carrying low-intensity infections are typically asymptomatic. The most susceptible groups are predominantly children of school age between the ages of 5 and 15 years, as well as pregnant women (Bethony *et al.*, 2006; Goodman *et al.*, 2007; Adegniko *et al.*, 2007). Infections are greater in tropical and endemic countries with poor hygienic environments, limited potable water and restricted healthcare facilities (WHO, 2002; Bethony *et al.*, 2006; Lammie *et al.*, 2006). The risk of infection is greater in farmers during their monotonous agricultural work, and women and children during their domestic and recreational activities, where they come in contact with polluted water (WHO, 2002).

Karshima (2018) used Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) to determine the prevalence, distribution and RZs for STH infections among Nigerian children through a meta-analysis of data published between 1980 and 2015. A pooled prevalence estimate (PPE) was determined by the random-effects model, while heterogeneity was evaluated using Cochran's Q-test. They examined a total of 34,518 children aged 0–17 years across 19 Nigerian states, of whom 18,901 were infected with one or more species of STH. They found an overall PPE for STH infections of 54.8% (95% CI: 54.2–55.3) with sub-group PPEs ranging from 13.2% (95% CI: 11.5–15.1) to 80.9% (95% CI: 80.0–81.7). The highest PPEs for STH infections were observed among children within community settings (59.0%, 95% CI: 57.7–60.4) and school-aged children (54.9%, 95% CI: 54.3–55.5). Also, they found that *Ascaris lumbricoides* was the most prevalent species (44.6%, 95% CI: 44.0–45.2). Over 36% (15/41) of the studies published are from south-western Nigeria, making it

the only high-risk zone (HRZ) for STH infections; the other regions are classified as low-risk zones (LRZs). Isaac *et al.* (2019) studied the prevalence of STHs in primary school playgrounds in Edo state, southern Nigeria, for both the wet and dry seasons. They used ANOVA to test differences in monthly variation, and the Student *t*-test to compare variations between seasons for prevalence and parasite density data. Post hoc analysis using the Newman–Keuls multiple comparison test was applied to data on monthly *Strongyloides* density for the dry season. Differences in mean values were significant at $p < 0.05$. Their findings showed that out of the six parasites found in both seasons, *Ascaris* was preponderant in the dry season, followed by *Strongyloides* and hookworm. In the wet season, *Strongyloides* was predominant, followed by *Ascaris* and hookworm. The frequency of occurrence of hookworm in the wet season was larger than in the dry season, and *Trichuris* parasites were comparatively infrequent in both seasons.

According to Vickers (2005), the reason for recommending nonparametric over parametric techniques, unless certain conditions are met, is often not made obvious. But techniques for statistical inference from randomized trials can fail only in one of two ways, that is, they can inappropriately reject the null hypothesis of no difference between groups (false positive, type I error) or inappropriately fail to reject the null hypothesis (false negative, type II error). Data type is also of concern in parametric and nonparametric techniques. Nominal data which has no explicit pattern, no numerical significance and is differentiated by a naming system is often not normally distributed, and it is typically suitable for most nonparametric methods. Also, ordinal data which has a specific order on the scale of measurement with limiting numerical meaning is mostly analyzed using nonparametric techniques. However, interval and ratio scaled data are often analyzed with parametric methods, except when the assumption of normality is not met even after transformation (Vonk, 2011). In this setting, Cochran's Q-test (CQT) is a typical nonparametric technique for handling binary responses, that is, nominal responses measured two or more times from the same sample (or from two or more samples that have been matched to one or additional vital variables).

In another approach, two or additional comparable qualitative variables are measured from an identical sample (typically at equal times). In both applications, the CQT is used to compare the distributions of the two or more qualitative variables. The CQT is an extension of McNemar's test enabling more variables to be handled (Sheskin, 2011). The CQT was applied in a study of the detection of heterogeneity in meta-analyses (Pereira, 2010) and it was found that the CQT's power is low in detecting between-study variance in some cases, when 1011 meta-analyses of clinical trials with ≥ 4 studies and binary outcomes were evaluated. Okeh *et al.* (2016) compared the CQT with a modified chi-square, χ^2 statistic using data comparing four different types of drugs on 60 patients grouped into blocks (4×15). They found that their modified χ^2 statistic was less powerful than the CQT. In this research, soil contamination with geohelminth eggs in 16 different recreational parks in Abuja, Nigeria was assessed using the CQT to determine whether the presence [+] or absence [-] of the contaminants were equally distributed across the recreational parks.

2. Materials and methods

This section presents the method of soil sample collection and processing of the samples in the laboratory for determining the presence or absence of geohelminth eggs. Finally, the CQT procedure for data analysis is presented.

2.1. Soil sample collection and processing

Samples were collected in the months from September to December 2019. Five long strides of the researcher were used to measure an area of approximately 25 m². At every 2 m², a mark was made and a number placed. The marked areas were selected by balloting and replacement, where ballot papers with the names of all twenty parks were placed together in a container and picked randomly, listed and replaced into the container. To collect a sample, the marked site was dug to about 3 cm deep using a hand trowel, after which about 100 g of soil was collected. The collected samples were then stored in sealed labeled polythene

bags and set aside in the dark prior to examination as described by Maikai (2008). The samples were then transported by road to the laboratory in Zaria, a journey of about 4 hours.

Collected samples were taken for pH and texture analysis at the Soil Science Laboratory of the Institute for Agricultural Research (IAR) of Ahmadu Bello University, Zaria, using the method described by Page *et al.* (1982). In the laboratory, egg recovery was performed by the method described by Maikai (2008), which is a modified version of the sieving method devised by Ruiz de Ybanez *et al.* (2000). Briefly, 50 g of soil was weighed, mixed in a plastic container and washed with running tap water into a 250 ml beaker, using three sieves with mesh diameters 100 μm , 400 μm and 850 μm . The filtrate was left to settle for 15 min and the liquid decanted. The sediment was collected in 30 ml centrifuge tubes, shaken with 15 ml zinc sulphate (specific gravity 1.25) floatation solution, and centrifuged at 1500 x g for 5 min. The supernatant was then poured into dropper bottles according to the sample and park. These were used to fill two chambers of McMaster slides. The slides were allowed to settle for 5 min, and were then examined under a light microscope ($\times 10$) for the presence of geohelminth eggs. Two drops of supernatant were also placed on a slide to view the morphological characteristics of eggs as described by Soulsby (1987), which were used to identify the eggs.

2.2. Cochran's Q-test

Suppose that binary responses $\{X_{ij}, j = 1, 2, \dots, c; i = 1, 2, \dots, n_j\}$ are recorded on units exposed to c environments $\{E_j\}$. Let $X_{ij} = 1$ denote a *positive* response to E_j and let the expected values $E(X_{ij}) = \Delta_j, j = 1, 2, \dots, c$. The obvious interest here is to use the observed data $\{x_{ij}\}$ to test the hypotheses

$$H_0: \Delta_1 = \Delta_2 = \dots = \Delta_c \text{ vs. } H_1: \Delta_i \neq \Delta_j \text{ for at least one pair } (i, j). \quad (1)$$

In this study, the c environments are the different geohelminth egg types, and our interest is in comparing the proportions of *positive* ($X_{ij} = 1$) responses to these egg types. It is important to consider how to choose the appropriate method to

perform this test by specifying how the data were obtained. There are two cases that always need to be considered. In **Case I**, X_{il} and X_{jk} are mutually independent if $(i, l) \neq (j, k)$. In **Case II**, X_{il} and X_{ik} ($i = 1, \dots, r$) are recorded on the same unit, and therefore are typically not independent. **Case II** is referred to as an issue of equality testing of *correlated proportions* (Gayle, 2010). The data structure in **Case I** is in the form of a completely randomized, one-way design with n_j binary responses in environment $E_j, j = 1, 2, \dots, c$, as set out in Table 1.

Table 1. Case I, $\{X_{ij}\}$ independent

Environments			
Egg ₁	Egg ₂	...	Egg _c
X_{11}	X_{12}	...	X_{1c}
X_{21}	X_{22}	...	X_{2c}
...	...	...	...
$X_{n_1 1}$	$X_{n_2 2}$	...	$X_{n_c c}$

In **Case II**, each of r units is exposed to all c environments. The exposures to the environments are independently randomized over each unit. This data structure is a randomized complete block design where the units are blocks and the responses are binary. In this research, **Case II** is characteristic for our data structure, implying correlated proportions, that is, not independent. The reason is that in each recreational park soil sample collected, all geohelminth eggs were checked for presence or absence. **Case II** has the advantage of controlling heterogeneity among units. Table 2 presents the layout of the design.

Table 2. Case II, correlated proportions

Blocks	Egg ₁	Egg ₂	...	Egg _c	Row total
1	X_{11}	X_{12}	...	X_{1c}	R_1
2	X_{21}	X_{22}	...	X_{2c}	R_2
...	...	...	...	...	...
R	X_{r1}	X_{r2}	...	X_{rc}	R_r
Column total	C_1	C_2	...	C_c	Grand total

Recall that $X_{ij} \sim B(1, \Delta_j)$, and X_{ik} is independent of X_{jk} for $i \neq j$ but X_{ik} may be correlated with X_{il} . Thus, the rows of Table 2 are independent random vectors. However, random variables in a row may possibly be correlated with $E(X_{ij}^* X_{ik}) = \Delta_{j,k}$ where $j \neq k = 1, 2, \dots, r$. For this setting, a randomization test was developed by Cochran (1950) which tests a more constrained null hypothesis, given as follows.

$$H_{00}: \Delta_1 = \Delta_2 = \dots = \Delta_c \text{ and } \Delta_{ij} = \Delta_{1,2} = \Delta_{1,3} = \dots = \Delta_{(c-1),c}$$

where $\Delta_{lm} = P(X_{il} = 1, X_{im} = 1)$, $i = 1, 2, \dots, r$, $l \neq m$.

Clearly, H_{00} implies H_0 in (1). But the converse does not hold. Note that H_{00} is equivalent to

$$^*H_{00}: \Delta_1 = \Delta_2 = \dots = \Delta_c \text{ and } \omega_{ij} = \omega_{1,2} = \omega_{1,3} = \dots = \omega_{(c-1),c} \quad (2)$$

where $\omega_{lm} = \text{corr}(X_{il}, X_{im})$, $l \neq m$.

The second condition in equation (2) is commonly called ‘‘compound symmetry’’ (Gayle, 2010). Mandansky (1963) called H_{00} the hypothesis of interchangeability. Also, Berger and Gold (1973), and Bhapker and Somes (1977) showed that the CQT statistic has a restrictive χ^2 distribution only under $^*H_{00}$ or H_{00} .

2.3. Cochran’s Q-statistic

The CQT statistic for binary responses, X_{ij} in c matched groups from r subjects, is computed as

$$Q = \frac{c(c-1) \sum_{j=1}^c (G_j - \bar{G})^2}{c \sum_{i=1}^r L_i - \sum_{i=1}^r L_i^2}$$

where Q is distributed approximately as chi square with $df = c - 1$, G_j is the total number of ‘‘successes’’ in the j^{th} column. $\bar{G}$ is the mean of the G_j , and L_i is the total number of ‘‘successes’’ in the i^{th} row.

A formula which is equivalent and easily derivable, but which simplifies computation, is

$$Q = \frac{(c-1) \left[c \sum_{j=1}^c G_j^2 - \left(\sum_{j=1}^c G_j \right)^2 \right]}{c \sum_{i=1}^r L_i - \sum_{i=1}^r L_i^2}.$$

For 'large' samples, the test statistic Q is distributed as χ^2 with $c-1$ degrees of freedom. As in the McNemar test, only subjects that do not have the same response in all categories contribute to the overall Q statistic. The p-value for the test is computed as:

$$p\text{-value} = Pr(Q > \chi_{1-\alpha, c-1}^2)$$

where $\chi_{1-\alpha, c-1}^2$ is the value of the $(1-\alpha)$ quartile of the χ^2 distribution with $c-1$ degrees of freedom.

When $c = 2$, the CQT becomes equivalent to the well-known McNemar's test (McNemar, 1947). Therefore, the rows are viewed as independent realizations of random variables (X_1, X_2) , where $X_j = 1$ if the response to condition j is a success and 0 otherwise, $j = 1, 2$. A summary of the entries is presented in a 2×2 table in Table 3.

Table 3. Summary counts for two proportions comparison

X_1	X_2		Total
	0	1	
0	e	f	e+f
1	g	h	g+h
Total	e+g	f+h	N

McNemar's test statistic where $c = 2$ is given as

$$\chi^2 = \frac{(f-g)^2}{f+g}. \quad (3)$$

$$H_0: \Delta_1 \equiv P(X_1 = 1) = P(X_2 = 1) \equiv \Delta_2 \text{ vs } H_1: P(X_1 = 1) \neq P(X_2 = 1).$$

H_0 is rejected at the appropriate level of significance α if $\chi^2 > \chi^2_{(1-\alpha),1}$.

Note that this test statistic uses only those blocks in which a unit responds differently to the two environments. This makes sense, since these are the only blocks that contain information about $\Delta_1 - \Delta_2$. By default, compound symmetry holds since $c = 2$.

2.4. Relationship between McNemar's test and Cochran's Q-test

McNemar's test and the CQT are equivalent when there are $c = 2$ responses in each row of Table 2. To verify this statement, we start out by setting $c = 2$ in Q ; we have

$$Q = \frac{2 \sum_{j=1}^2 (G_j - \bar{G})^2}{2 \sum_{i=1}^r L_i - \sum_{i=1}^r L_i^2} \quad (4)$$

and the numerator in equation (4) can be expressed as follows:

$$\begin{aligned} 2 \sum_{j=1}^2 (G_j - \bar{G})^2 &= 2[(G_1 - (G_1 + G_2)/2)^2 + (G_2 - (G_1 + G_2)/2)^2] \\ &= (G_1 - G_2)^2 = (g + h - f - h)^2 = (f - g)^2. \end{aligned} \quad (5)$$

Similarly,

$$2 \sum_{i=1}^r L_i - \sum_{i=1}^r L_i^2 = 2(f + g + 2h) - (f + g + 4h) = (f + g). \quad (6)$$

Dividing equation (5) by (6) gives the desired result of equation (3).

2.5. Mean comparison

When the outcome of the CQT indicates that the null hypothesis of equality of success proportions is to be rejected, it is often necessary to proceed to determine which of the groups are different by computing multiple pairwise comparisons. Pairwise tests between groups "a" and "b" test the null hypothesis

$$H_0: \Delta_1 = \Delta_2 = \dots = \Delta_c \text{ vs } H_1: \Delta_i \neq \Delta_j \text{ for at least one pair } (i, j).$$

Sheskin (2011) described two methods: the minimum required difference (MRD) method, and pairwise McNemar tests among groups. Both methods for pairwise comparison use the Bonferroni alpha adjustment to control the overall experiment-wise error rate of the tests. The adjustment simply divides the overall required alpha, α , by the number of pairwise tests, c , where

$$v = \frac{c(c-1)}{2}.$$

The alpha-level for each individual test, α_{adj} , is

$$\alpha_{adj} = \frac{\alpha}{v}.$$

For this research, the MRD is adopted. This is because it is more robust, since it uses all of the available information in the data in its calculations, while the multiple McNemar tests comparison method uses only the values from subjects that have different responses for the two categories, not all of the data. Hence, the MRD is more powerful for finding the difference among pairs than the McNemar test (Berger and Gold, 1973).

For sufficiently large sample sizes (i.e. $n \geq 4$ and $nc \geq 24$, where n is the number of subjects for which the responses are not all 0's or 1's), the minimum required difference in proportions for any pair of the c experimental groups to be declared different is

$$MRD = z_{adj} \sqrt{2 \left[\frac{c \sum_{i=1}^r L_i - \sum_{i=1}^r L_i^2}{r^2 c (c-1)} \right]}$$

where all parameters are defined as in the CQT statistic, and z_{adj} is the value of the quantile, that is, $1 - \alpha_{adj} / 2$ from the standard normal distribution.

Two groups are confirmed to be significantly different with protected overall alpha, α , if their absolute difference in proportions is greater than MRD , that is, if $|\Delta_a - \Delta_b| > MRD$.

3. Results and discussion

Table 4 below presents the number and proportion of negatives and positives for the nine geohelminth egg types from 184 soil samples taken from the 16 different sampled parks in Abuja metropolis. MedCalc version 19.2.1 software was used for data analysis.

Table 4. Frequency distribution of geohelminth eggs

Geohelminth eggs	Negative cases	Positive cases	Negative proportion (%)	Positive proportion (%)
Ascaris	172	12	93.48	6.52
Coccidia	137	47	74.46	25.54
Hookworm	166	18	90.22	9.78
Mite	161	23	87.5	12.5
Stongylus	172	12	93.48	6.52
Strongyloides	183	1	99.46	0.54
Taenia	135	49	73.37	26.63
Toxocara	157	27	85.33	14.67
Trichuris	160	24	86.96	13.04

It can be observed that in all of the 184 soil samples from the 16 recreational parks, Taenia and Coccidia have the largest proportions of positives (26.33% and

Figure 1. Positive (1) and negative (0) proportions (%) of geohelminth eggs

25.54% respectively) amongst all geohelminth egg types. The proportion of Strongyloides eggs is the lowest, at 0.54%. Figure 1 presents a bar chart of positive and negative proportions of all nine geohelminth egg types.

Table 5 presents the CQT result for comparison of the proportions of Ascaris, Coccidia, hookworm, mite, Strongylus, Strongyloides, Taenia, Toxocara and Trichuris. The null hypothesis for the test is as follows.

H₀: the proportions of positive geohelminth eggs in all parks from 184 soil samples are equal.

H₁: the proportions of positive geohelminth eggs in at least one sampled park from 184 soil samples are different.

Table 5. Cochran's Q-test result

Number of parks	16
Number of samples, <i>n</i>	184
Cochran's Q	94.8706
Degree of freedom	8
P-value	0.0001

From Table 5 above it can be observed that at a 5% level of significance we reject our stated null hypothesis, because the p-value of 0.0001 is below 5%. Therefore, it can be concluded that the proportions of geohelminth eggs in the 184 soil samples from 16 recreational parks in Abuja metropolis are different.

Based on the CQT result, which showed a significant difference among the proportions of geohelminth eggs, the results of a mean comparison test using the MRD method are presented in Table 6. The proportions of the nine geohelminth egg types are compared to determine which has the highest significant proportion.

The multiple mean comparison result in Table 6 indicates that the proportions of Ascaris, Coccocidia and Taenia eggs are significantly different from each other, with absolute differences of 19.02% and 20.11% respectively. Also, the proportion of Coccocidia eggs is significantly different from the proportions of hookworm, mite, Strongylus, Strongyloides and Trichuris eggs, with absolute

Table 6. Pairwise comparison of the nine soil egg types

Comparison	Δ_i	Δ_j	$ \Delta_i - \Delta_j $	MRD	Decision
Ascaris – Coccidia	6.52	25.54	19.02	11.33	YES
Ascaris – Hookworm	6.52	9.78	3.26	11.33	NO
Ascaris – Mite	6.52	12.5	5.98	11.33	NO
Ascaris – Strongylus	6.52	6.52	0	11.33	NO
Ascaris - Strongyloides	6.52	0.54	5.98	11.33	NO
Ascaris - Taenia	6.52	26.63	20.11	11.33	YES
Ascaris - Toxocara	6.52	14.67	8.15	11.33	NO
Ascaris - Trichuris	6.52	13.04	6.52	11.33	NO
Coccidia - Hookworm	25.54	9.78	15.76	11.33	YES
Coccidia - Mite	25.54	12.5	13.04	11.33	YES
Coccidia - Strongylus	25.54	6.52	19.02	11.33	YES
Coccidia - Strongyloides	25.54	0.54	25	11.33	YES
Coccidia - Taenia	25.54	26.63	1.09	11.33	NO
Coccidia - Toxocara	25.54	14.67	10.87	11.33	NO
Coccidia - Trichuris	25.54	13.04	12.5	11.33	YES
Hookworm - Mite	9.78	12.5	2.72	11.33	NO
Hookworm - Strongylus	9.78	6.52	3.26	11.33	NO
Hookworm - Strongyloides	9.78	0.54	9.24	11.33	NO
Hookworm - Taenia	9.78	26.63	16.85	11.33	YES
Hookworm - Toxocara	9.78	14.67	4.89	11.33	NO
Hookworm - Trichuris	9.78	13.04	3.26	11.33	NO
Mite - Strongylus	12.5	6.52	5.98	11.33	NO
Mite - Strongyloides	12.5	0.54	11.96	11.33	YES
Mite – Taenia	12.5	26.63	14.13	11.33	YES
Mite - Toxocara	12.5	14.67	2.17	11.33	NO
Mite - Trichuris	12.5	13.04	0.54	11.33	NO
Strongylus - Strongyloides	6.52	0.54	5.98	11.33	NO
Strongylus - Taenia	6.52	26.63	20.11	11.33	YES
Strongylus – Toxocara	6.52	14.67	8.15	11.33	NO
Strongylus – Trichuris	6.52	13.04	6.52	11.33	NO
Strongyloides – Taenia	0.54	26.63	26.09	11.33	YES
Strongyloides – Toxocara	0.54	14.67	14.13	11.33	YES
Strongyloides – Trichuris	0.54	13.04	12.5	11.33	YES
Taenia – Toxocara	26.63	14.67	11.96	11.33	YES
Taenia – Trichuris	26.63	13.04	13.59	11.33	YES
Toxocara – Trichuris	14.67	13.04	1.63	11.33	NO

YES means an absolute difference value greater than the MRD value, which implies significant difference

differences of 15.76%, 13.04%, 19.02% and 25%. At an absolute difference of 16.85%, the proportion of hookworm eggs is significantly different from the proportion of Taenia eggs, while the proportion for mites is significantly different

from the proportions of *Strongyloides* and *Taenia* eggs, with absolute differences of 11.96% and 14.13% respectively. The proportions of *Strongylus* and *Taenia* eggs are significantly different from each other, with an absolute difference of 20.11%. The proportions of *Taenia*, *Toxocara* and *Trichuris* eggs in the soil are significantly larger than the proportion of *Strongyloides* eggs, with absolute differences of 26.09%, 14.13% and 12.5% respectively. Finally, it was observed that the proportion of *Taenia* eggs is significantly larger than the proportions of *Toxocara* and *Trichuris* eggs, with absolute differences of 11.96% and 13.59% respectively.

4. Conclusions

This research studied the prevalence of geohelminth eggs in 184 soil samples from 16 recreational parks in Abuja metropolis, Nigeria. The CQT was applied to determine whether there was a significant difference in the proportions of the studied egg types in the soil samples, and it was determined which of the egg types had significantly larger proportions using the MRD technique. It was found that the geohelminth eggs occur in significantly different proportions in the 184 soil samples examined. Also, *Taenia* and *Coccidia* eggs are highly prevalent, with proportions significantly larger than the proportions of the other geohelminth eggs in the examined soil samples, based on the MRD mean comparison test.

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