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PREVALENCE AND ASSOCIATED RISK FACTORS OF *Cysticercus tenuicollis* IN THE SMALL RUMINANTS IN DIFFERENT DISTRICTS OF PUNJAB AND KPK PROVINCES OF PAKISTAN.

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ABSTRACT

Taenia hydatigena causes taeniasis in dogs and wild canids, with *Cysticercus tenuicollis* infecting small ruminants. Data on its incidence and risk factors in Pakistan are limited. This research work was carried out to determine the prevalence of *C. tenuicollis* in sheep and goats across Punjab and Khyber Pakhtunkhwa (KPK). A cross-sectional research study examined 9,273 randomly selected small ruminants from abattoirs in Faisalabad, Lahore, Multan, Bahawalpur, Sialkot, Rawalpindi, and Peshawar. Pre-slaughter and post-mortem investigations identified *C. tenuicollis* in 552 animals (5.95%). Punjab had a higher prevalence (6.84%) than KPK (3.35%). Faisalabad recorded the highest prevalence (8.14%) with a significant odds ratio of 2.43 (95% CI: 1.80–3.29). Males (6.20%) had a slightly higher infection rate than females (5.47%). Adults (8.08%) were more affected than young animals (4.08%). Irrigated plains (Lahore, Faisalabad, Multan) exhibited an 8.00% prevalence, significantly higher than wet mountainous areas like Peshawar, with an odds ratio of 2.39. These findings suggest *C. tenuicollis* is prevalent in both provinces with higher rate in Punjab, posing economic losses to the small ruminant industry. Factors such as region, sex, age, and climate influence infection rates. Molecular studies are needed to identify genetic variations and improve control strategies.

Keywords: *Cysticercus tenuicollis*, Prevalence, Risk factors, Small ruminants.

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INTRODUCTION

Globally, livestock diseases have a major economic impact. Among pathogens, gastrointestinal (GIT) parasite infections in ruminants negatively affect feed consumption, growth rate, carcass weight, composition, wool growth, fertility, and milk output (Fitzpatrick, 2013; Khattak *et al.,* 2023; Carag, 2021). Many parasites are found in the gastrointestinal tract (GIT) of animals (Batool *et al*., 2023; Kebzai *et al*., 2024 Velazquez-Antunez *et al*., 2023). The parasite *Taenia hydatigena* is a cestode that leads to taeniasis in dogs and wild canids as definitive hosts. It also causes cysticercosis in various herbivorous animals as intermediate hosts, including cattle, goats, sheep, pigs, and wild ungulates (Al-Hamzawi and Al-Mayali, 2020; OIE, 2018). The adult tapeworm lives in the small intestine of its definitive host. Its eggs or gravid proglottids are then excreted through the host's feces and released into the environment. Unknowingly the ingestion of eggs or whole proglottids by intermediate hosts, while grazing or drinking, makes them infected. In the intermediate host, the oncosphere migrates through the liver tissue and develops into a *Cysticercus*. The fully developed Cysticercus is typically located in the liver, mesenteries, or omentum, where it appears as a fluid-filled, bladder-like structure of varying sizes, containing one scolex. The transmission cycle is complete when a canid ingests cysts from an infected carcass, typically when dogs feed on offal or carcasses of dead livestock having cysticercosis (El-Beskawy *et al.,* 2021; Jarošová *et al.,* 2022; Ng-Nguyen *et al.,* 2021; OIE, 2018).

T. hydatigena cysticerci are commonly observed adhered to the liver, mesentery, peritoneum, and omentum (Admasu *et al.,* 2019; Jenkins *et al.,* 2018). Infections with *T. hydatigena* in intermediate hosts often do not cause any symptoms; nevertheless, a common aftereffect of the infection is hepatitis cysticercosa, which is caused by migrating cysticerci (Nourani *et al.,* 2010; Dehghan *et al*., 2024) and may be lethal in cases of severe infections that severely damage the liver parenchyma (Scala *et al.,* 2015; Sgroi *et al*., 2020)

Parasitic infestations are reported to cause heavy economic setbacks to the livestock sector across the globe (Hassan *et al*., 2024; Iqbal *et al*., 2024; Kandil *et al*., 2023; Nurhidayah *et al*., 2023). According to estimates

made using lamb liver condemnations, the yearly economic losses in Ethiopia and Italy, respectively, were estimated to be $65,000 and $370600. Whereas, in Europe and Turkey, it is also estimated that cysticercosis leads to at least 18035 Euros loss in terms of condemnation of offals and up to 315622 Euro per annum due to infestation of the liver. Poor weight gain, leading to a loss of around 0.40 Euros per kg has also been observed (Braae *et al.,* 2015; Kilinc *et al.,* 2019; Scala *et al.,* 2015; Sgroi *et al*., 2020).

The prevalence of *C. tenuicollis* varies widely depending on the region and the type of animal. However, it is generally considered to be a highly prevalent parasite, especially in developing countries (Abbas *et al.,* 2021). It is especially prevalent in areas with a high population of stray dogs, and small ruminant production units (Morais *et al.,* 2017). The prevalence of *T. hydatigena* infection in small ruminants has been predominated in several Asian countries of the world within the last several years. There have been reports of cysticercosis in sheep and goats from Bangladesh (Dey *et al.,* 2022), Egypt (Abbas *et al.,* 2021), Turkey (Kilinc *et al.,* 2019), Iraq (Al-Hamzawi and Al-Mayali, 2020; Farhan *et al.,* 2022), Saudi Arabia (Bakhraibah andAlsulami, 2018), Tanzania (Braae *et al.,* 2015), China (Ma *et al.,* 2014), Iran (Khanjari *et al.,* 2015), India (Moudgil *et al.,* 2022), Sudan (Muku *et al.,* 2020), and Nigeria (Ohiolei *et al.,* 2019).

Pakistan is a South Asian country that boasts a diverse landscape, spanning from the coastal areas along the Arabian Sea to the deserts and mountains in the north. With a notable agricultural sector, the country is also known for its diverse range of resources (Shah *et al.,* 2021; Tahir *et al.,* 2019). In this regard, Pakistan's livestock resources are quite significant and play a crucial role in the economy. Especially in rural regions, livestock plays a significant role in fostering socio-economic growth. Raising animals provides over eight million families with almost three-quarters of their income (Lashari *et al.,* 2016; Ali *et al*., 2021). Like in other poor nations, Pakistani households rely on the rearing of ruminants in their backyards for their primary source of income. According to the recent Livestock Census, Pakistan is endowed with more than 100 million heads of sheep and goats and this population is increasing in leaps and bounds with every passing year (Pakistan Economic Survey, 2021-22). There is a significant knowledge gap regarding the prevalence of *Cysticercus tenuicollis* (*T. hydatigena*) in small ruminants in Pakistan. While gastrointestinal parasite infections, including those caused by *T. hydatigena*, are known to have major economic impacts globally, especially in developing countries, limited data exist on the prevalence of *C. tenuicollis* in Pakistani livestock. Despite the critical role of livestock in Pakistan's economy, particularly in rural areas where millions rely on small ruminants for their livelihood, there has been a lack of surveillance data to understand the extent of these infections. This study aims to fill this gap by providing crucial data on the prevalence of *C. tenuicollis* in small ruminants, thus contributing to better management and control strategies for this economically significant parasite. This study hypothesizes that *Cysticercus tenuicollis* is prevalent in small ruminants in Pakistan, with significant regional variations influenced by livestock density and management practices.

Keeping in view the foregoing, the objective of this study was to determine the prevalence of *Cysticercus tenuicollis* (*Taenia hydatigena*) in small ruminants in Pakistan, addressing the existing gap in surveillance data. Given the crucial role of livestock in Pakistan's economy, particularly in rural areas where millions depend on small ruminants for their livelihood, understanding the extent of *C. tenuicollis* infections is essential. This study aimed to assess the impact of the parasite on the livestock sector and its potential economic consequences. Additionally, the findings provide baseline data for future research and the development of effective control strategies to mitigate losses associated with *C. tenuicollis* infections.

MATERIALS AND METHODS

Study areas: The research was conducted in Punjab and KPK provinces with different agroclimatic zones. From KPK, the Peshawar Central abattoir (71.5249° E and 34.0151° N) was visited to collect the cystic samples. Whereas from Punjab, abattoirs located at Lahore (74.3587° E and 31.5497° N), Rawalpindi (73.0551° E and 33.6844° N), Multan (71.5249° E and 30.1575° N), Sialkot (74.5313° E and 32.4927° N), Faisalabad, and Bahawalpur (71.6766° E and 29.3588° N) were visited to collect the cysts from the omentum, liver, lungs, spleen, and peritoneum of slaughtered animals. The selected districts likely represent diverse ecological and geographic conditions in Punjab and Khyber Pakhtunkhwa (KPK) that influence the prevalence of *Cysticercus tenuicollis* in small ruminants.

Ethical approval*:* This study was conducted in strict accordance with ethical standards for animal research. The study was approved by the Directorate of Graduate Studies, University of Agriculture, Faisalabad, Pakistan, under letter number DGS/24425-28 dated 05-07-2023. All animals were selected from abattoirs, where they were slaughtered for commercial purposes, ensuring minimal discomfort to the animals. The study adhered to guidelines for humane handling, including the avoidance of unnecessary harm and distress. The research focused solely on post-mortem examination of carcasses and did not involve any live animal experimentation. All necessary precautions were taken to ensure the welfare and ethical treatment of the animals involved in the study.

Data collection was conducted in collaboration with local authorities, and informed consent was obtained where applicable.

Animal history

Animal demographic information like age, breed, sex, body condition score, grazing status, season, flock type, and deworming history were recorded on the questionnaire to ascertain the associated risk factors. The predilection sites of cysts and the total number of cysts infesting the viscera were also recorded.

Sample collection: The selected area's abattoirs were visited for at least 15 days during each season. Sheep and goat carcasses were examined by simple convenient method for the presence of C. tenuicollis. A total of 9273 carcasses were examined which included 6913 carcasses from Punjab and 2360 from Khyber Pakhtunkhwa. For each station of study, at least 384 samples were observed keeping in view the formula (Thrusfield, 2018), keeping the expected prevalence at 50% because no report is available from the study areas. The carcass inspection and identification of cysts was done by the manual of the World Organization for Animal Health (OIE, 2018). All visceral organs including the mesentery, omentum, lungs, and liver were thoroughly observed. Each cyst was then carefully removed from the viscera with the help of scissors and tweezers and carefully placed in screw-capped bottles with proper labeling. Collected cysts were kept at 4℃ and then transported to the Department of Parasitology, University of Agriculture, Faisalabad, Pakistan for further processing.

Statistical analysis: The number of analyzed samples was calculated assuming a 50% C. tenuicollis prevalence, 95% confidence interval, and 5% statistical error. (Newcombe, 1998; Thrusfield, 2018). A Chi-square test was conducted using IBM SPSS Statistics 17.0 for Windows® to determine significant associations ($P < .05$) between variables. The odds ratios were calculated using the WenPepi software (Abramson, 2011).

RESULTS

The presented data provides insights into the prevalence of *C. tenuicollis* in livestock, with a focus on various risk factors associated with its occurrence From Pakistan from the different organs of 9273 small ruminant carcasses (sheep = 4233, goat = 5040) examined for the presence of *T. hydatigena* metacestodes (*C. tenuicollis*), 552 were found positive.

Province and district-wise results: Punjab and Khyber Pakhtunkhwa were examined for the prevalence of *C. tenuicollis* in sheep and goats. The statistical results revealed a higher prevalence in Punjab at 6.84% whereas a 3.35% prevalence was observed in KPK (Figure 1.).

Further district-wise comparison was also made. Faisalabad, Lahore, Multan, Bahawalpur, Rawalpindi and Sialkot were targeted from Punjab, and KPK, Peshawar district was selected. According to the data, Peshawar has shown a relatively lower prevalence of *C. tenuicollis* when compared to other districts like Faisalabad, which has shown an 8.14% prevalence rate and a significant odds ratio of 2.43 (95% CI: 1.80-3.29) compared to Peshawar at 3.35%. The other districts of Punjab like Bahawalpur, Multan, Rawalpindi, and Sialkot are also observed with higher prevalence rates and odds ratios compared to Peshawar, indicating a geographical variation in the occurrence of the condition within Punjab (Figure 2).

Livestock type based prevalence results*:* The prevalence and odd ratios of *C. tenuicollis* according to livestock type, age, and sex are shown in Table 1. The cyst picture is mentioned in Figure 3. Based on livestock type, 256 (6.05%) and 296 (5.87%) isolates were of sheep and goat origin, respectively. The prevalence of *C. tenuicollis* was higher in the >1 year age group (351/4342; 8.08%) as compared to the <1 year age group of goats and sheep (201/4932; 4.08%). Concerning sex, a higher prevalence was observed in males (380/6130, 6.20 %) than in females (172/3143, 5.47%).

Agro-geoclimatic zone based prevalence*:* The comparison across different agroclimatic zones in Pakistan highlights varying levels of prevalence and odds ratios for *C. tenuicollis*, shedding light on regional disparities in the occurrence of this factor. The Irrigated Plain, encompassing areas like Lahore, Faisalabad, and Multan, emerges as notably high-risk, exhibiting an 8.00% prevalence significantly higher than the Wet Mountains (Peshawar) and carrying a considerable odds ratio of 2.39. This zone suggests a heightened likelihood of encountering *C. tenuicollis*. In the Subtropical Desert (Bahawalpur) and Barani (Rawalpindi) zones, relatively elevated prevalence rates and odds ratios are evident compared to the Wet Mountains, implying increased susceptibility to the studied variable. The Marshy Zone (Sialkot) shows a prevalence of 4.11% without a significant difference in odds compared to the Wet Mountains, hinting at a comparable likelihood of encountering *C. tenuicollis* in these areas. Overall, these findings underscore the influence of agroclimatic conditions on the prevalence of *C. tenuicollis*, emphasizing the necessity for targeted interventions and region-specific strategies to address and mitigate the risks associated with this variable across diverse geographical zones in Pakistan.

Association between slaughter reasons and *Cysticercus tenuicollis* prevalence*:* Livestock slaughtered due to diseases, fractures, or terminal illnesses exhibit a prevalence of 7.6%. Although the odds

ratio (OR) is 1.35, suggesting a slight association, the result is not statistically significant with a p-value of 0.1072. Animals culled due to old age, infertility, or dead udder have a slightly lower prevalence of 6.82%, and the associated odds ratio is 1.21. Conversely, those slaughtered for meat-selling purposes have a prevalence of 5.63%. These findings imply that the reason for slaughter may influence the prevalence of *C. tenuicollis*, but the associations are not robust.

Impact of feeding practices on the prevalence *of Cysticercus tenuicollis:* Feeding practices play a notable role in the prevalence of *C.tenuicollis*. Livestock under grazing conditions exhibit a significantly higher prevalence of 9.25%, with an odds ratio of 3.17 compared to those in a feedlot (3.43%) or household feeding (2.92%). The chi-square value of 132.77 ($p < 0.0001$) underscores the significance of this association. Grazing practices appear to be a substantial risk factor for *C. tenuicollis*, emphasizing the importance of grazing management in preventing infections.

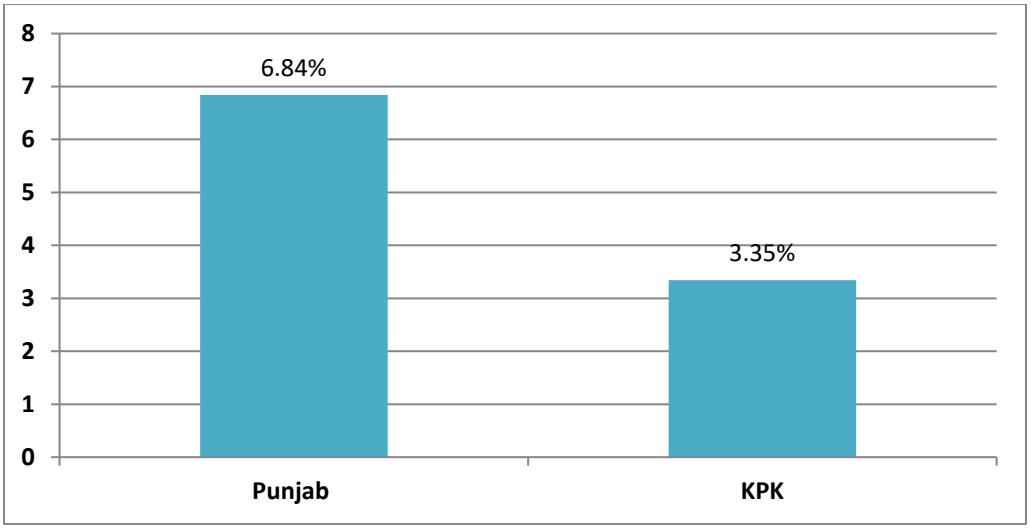

Fig. 1. Graphical comparison of prevalence of *Cysticercus tenuicollis* in Punjab and KPK provinces of Pakistan.

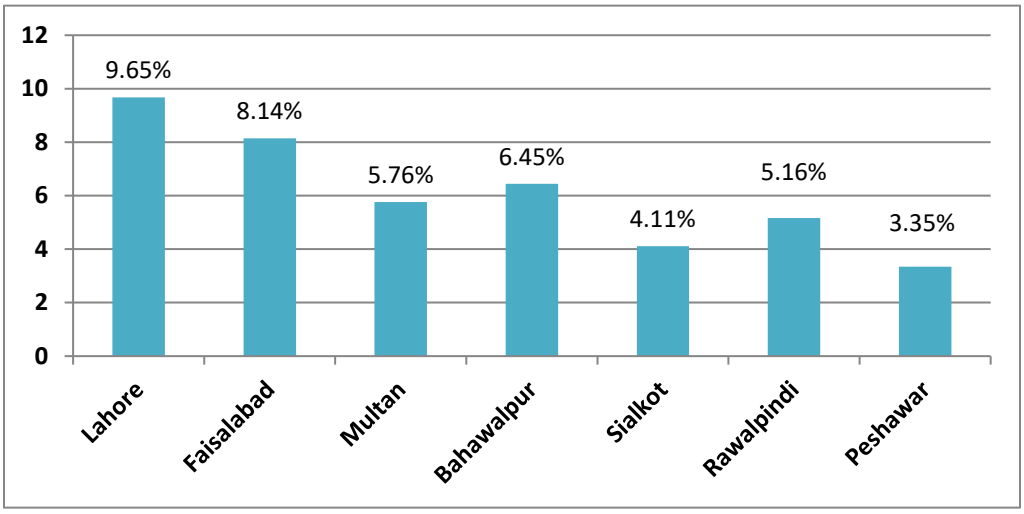

Fig. 2. Graphical presentation of prevalence of *Cysticercus tenuicollis* in the study districts.

Impact of deworming frequency on the prevalence of *Cysticercus tenuicollis:* The deworming frequency is strongly associated with the prevalence of *C. tenuicollis*. Animals never dewormed exhibit a significantly higher prevalence of 17.71%, with an odds ratio of 18.08 compared to those dewormed once a year (4.28%) or more frequently. The chi-square value of 420.77 ($p < 0.0001$) indicates a highly significant association. This underscores the critical role of regular deworming practices in mitigating the risk of *C. tenuicollis* infection in livestock.

Role of livestock health history in *Cysticercus tenuicollis* prevalence: Livestock with a frequent prior disease history have a prevalence of 7.37%, with an odds ratio of 1.81, while those never ill have a prevalence of 6.66% and an odds ratio of 1.64. Animals with a prior history of illness once or twice have a prevalence of 4.11%. The chi-square value of 26.06 ($p < 0.0001$) indicates a significant association between prior disease history and the prevalence of *C tenuicollis*. This suggests that the health history of animals is a relevant factor in understanding and preventing infections. Our findings demonstrate important risk elements linked to *C. tenuicollis* infestations in livestock which require immediate intervention strategies for infection prevention.

Fig. 3. *Cysticercus tenuicollis* cyst present on liver

Table 1. Analysis of geographical and animal demographics data associated with the prevalence of *Cysticercus tenuicollis*.

Variable	Category	Positive/Tested	Prevalence (95% CI)	OR (95% CI)	Chi-Square (p-value)
Province	Punjab	473/6913	6.84 (6.27-7.46)	2.04 (1.60-2.61)	34.64 (0.0000)
	KPK	79/2360	3.35 (2.70-4.16)	Ref.	
District	Lahore	150/1555	9.65 (8.28-11.22)	2.88 (2.18-3.81)	74.85 (0.0000)
	Faisalabad	102/1253	8.14 (6.75-9.79)	2.43 (1.80-3.29)	
	Bahawalpur	64/993	6.45 (5.08-8.15)	1.93 (1.37-2.70)	
	Multan	70/1215	5.76 (4.58-7.21)	1.72 (1.24-2.39)	
	Rawalpindi	44/852	5.16 (3.87-6.86)	1.54 (1.06-2.25)	
	Sialkot	43/1045	4.11 (3.06-5.49)	1.23 (0.84-1.79)	
	Peshawar	79/2360	3.35 (2.70-4.16)	Ref.	
Species	Sheep	256/4233	6.05 (5.37-6.81)	1.03 (0.87-1.22)	0.11 (0.7386)
	Goat	296/5040	5.87 (5.25-6.55)	Ref.	
Sex	Male	380/6130	6.20 (5.62-6.83)	1.13 (0.94-1.36)	1.74 (0.1868)
	Female	172/3143	5.47 (4.73-6.23)	Ref.	
Age	More than 1 Year	351/4342	8.08 (9.52-11.33)	1.98 (1.66-2.37)	58.71 (0.0000)
	Up to 1 year	201/4931	4.08 (3.56-4.67)	Ref.	
Agro-geoclimatic zones	Irrigated plain (Lahore, Fsd and Multan)	322/4023	8.00 (7.20-8.88)	2.39 (1.86-3.07)	59.29 (0.0000)
	Subtropical desert (Bwp)	64/993	6.45 (5.08-8.15)	1.93 (1.37-2.70)	
	Barani (Pindi)	44/852	5.16 (3.87-6.86)	1.54 (1.06-2.25)	
	Marshy (Sialkot)	43/1045	4.11 (3.06-5.49)	1.23 (0.84.1.79)	
	Wet mountains (Peshawar)	79/2360	3.35 (2.70-4.16)	Ref.	

CI: confidence interval OR: odds ratio

Table 2. Analysis of some factors associated with the prevalence of *Taenia hydatigena*

Variables	Category	Positive/ Tested	Prevalence (95% CI)	OR 95% CI	Chi-square (p-value)
Reason for slaughter	Diseases/ Fractures/ Terminal illnesses	13/171	7.60 (4.49-12.57)	1.35 (0.76-2.39)	4.47 (0.1072)
	Old age/ Infertility/ Dead udder	151/2214	6.82 (5.84-7.95)	1.21 (1.00-1.47)	
Feeding practices	Meat Selling	388/6888	5.63 (5.11-6.20)	Ref.	132.77 (0.0000)
	Grazing	389/4204	9.25 (8.41-10.16)	3.17 (2.41-4.15)	
	Feedlot	100/2913	3.43 (2.83-4.15)	1.17 (0.85-1.62)	
	Household	63/2156	2.92 (2.29-3.72)	Ref.	
Deworming Practice	Never	288/1626	17.71 (15.93-19.64)	18.08 (9.58-34.13)	420.77 (0.0000)
	Once a Year	170/3973	4.28 (3.69-4.95)	4.37 (2.30-8.29)	
	Twice a Year	76/1969	3.86 (3.10-4.80)	3.94 (2.03-7.65)	
	More frequent	8/684	1.17 (0.59-2.29)	1.19 (0.47-3.04)	
	Thrice a Year	10/1021	0.98 (0.53-1.79	Ref.	
Prior Disease History	Frequently ill	134/1817	7.37 (6.26-8.66)	1.81 (1.41-2.33)	26.06 (0.0000)
	Never	292/4387	6.66 (5.96-7.44)	1.64 (1.32-2.03)	
	Yes Once/ Twice	126/3069	4.11 (3.46-4.87)	Ref.	

CI: confidence interval; OR: odds ratio

DISCUSSION

The agricultural value-added sector in Pakistan receives more than 60% of its contributions from livestock while this sector provides 14% of the national GDP. Approximately 35-40% of rural households earn income that depends on animal husbandry because they number around 8 million families. The value addition in livestock products grew by 3.8% during FY2022 to FY2023 until it exceeded Rs 5,593 billion in value as the sector delivers about 2.1% of Pakistan's exports. Like sheep and goats represent a major segment in this industry whose combined population totals more than 100 millions, according to the Pakistan Economic Survey of 2023. These animals produce vital resources such as milk, meat and wool in addition to their skin (Pakistan Economic Survey, 2023).

The parasitic diseases endanger animal health through their influence on disease ranges and seasonal dynamics as well as infection severity levels that reduce livestock productivity and decrease animal welfare (Issa and Mero, 2023; Kozhabaev *et al*., 2023; Mero *et al*. 2023; Myint *et al*. 2023). The productivity of livestock faces substantial economic losses due to *T. hydatigena* parasites since these parasites reduce meat and milk production and result in condemned visceral organs (Ahmad *et al*., 2023; Al-Saeed *et al*., 2023). *T. hydatigena* has become a common infection among small ruminants leading to reduced production performance that causes major economic losses according to Anteneh *et al*. (2011), Scala *et al*. (2015), and Sgroi *et al*. (2020). Knowing the spread and identification factors of this parasite serves as a base for developing successful control programs.

The research sought to measure the occurrence of *Cysticercus tenuicollis* within Pakistani territory. Sheep and goats from Punjab along with Khyber Pakhtunkhwa (KPK) provinces had a *C. tenuicollis* infection prevalence rate of 5.95% which corresponds to Indian reports (Singh *et al*., 2015; Moudgil *et al*., 2022). Global infection rates show significant differences across different regions because they span from 0.7% up to 83% (Almeida *et al*., 2018; Borai *et al*., 2013; Mekuria *et al*., 2013; Lamb *et al*., 2021; Lawan *et al*., 2024). The observed differences stem from environmental factors as well as management practices and natural variation in sheep and goat susceptibility.

The prevalence of *C. tenuicollis* depends on various characteristics such as animal age and sex together with breed types and management methods along with environmental conditions (Alishani *et al*., 2017; Mekuria *et al*., 2013; Lawan *et al*., 2024). Research results show that infection rates increase with age in both sheep and goats because prolonged exposure to *C. tenuicollis* increases the risk of infection as reported by multiple studies (Dey *et al*., 2022; Khanjari *et al*., 2015; Shuvo *et al*., 2021; Degefaw *et al*., 2025). According to Abdulatif *et al*. (2015) Ethiopian young ruminants demonstrated a higher infection rate than those studied in other regions which indicates possible differences in transmission patterns.

The infection prevalence between males and females exhibited minor variations since males presented

rates at 6.20% while females maintained lower rates at 5.47%. Evidence indicates that males which are produced for meat and killed at young ages face greater exposure risks from infected environments. The assessment of infection rates from Bangladesh revealed that females had significantly elevated infections at 18.90% and males had reduced infections at 8.80% because pregnant or nursing females suffer from reduced immune efficiency (Dey *et al*., 2022). Females experience extended exposure because they live longer as breeding members in herds (Hama-Soor *et al*., 2021; Mandonnet *et al*., 2005; Agrawal *et al*., 2015).

The execution of management techniques directly affects the occurrence of *T. hydatigena* infection. Our research confirmed that extensive grazing systems hosting animals had higher infection rates than intensive systems which is line with the results reported by Abebe & Esayas (2001), Addy *et al*. (2021), Darfour & Rosentrater (2016), and Negash *et al*. (2023). Animals in extensive systems who can roam unrestricted encounter a higher risk of infection because they spend more time in areas potentially contaminated with disease agents.

A cross-zone analysis in Pakistan showed different areas having distinct prevalence measurements. The Irrigated Plain from Lahore along with Faisalabad and Multan demonstrated an 8.00% infection prevalence followed by odds ratio of 2.39 in relation to the Wet Mountain area in Peshawar. This indicates *C. tenuicollis* infection is more prevalent throughout the Irrigated Plain. However, analysis of both Subtropical Desert (Bahawalpur) and Barani (Rawalpindi) areas indicated higher prevalence rates as well as odds ratios indicating higher vulnerability. The prevalence of infection at the Marshy Zone (Sialkot) reached 4.11% which parallels the levels detected in the Wet Mountains. The survival and transmission capabilities of parasitic species thrive more in humid tropical areas according to research by Yadav *et al*. (2023).

The research shows agroclimatic factors produce substantial impact on *C. tenuicollis* prevalence levels. The research demonstrates why specific control plans with management solutions distinctive to each area need to address environmental elements. The successful reduction of infectious risks and improved small ruminant output in Pakistan's endemic areas should focus on better pasture management combined with targeted deworming programs and biosecurity improvements.

Limitations and future perspective : An analysis of potential confounders like age and sex with management differences and regional variations should be included to properly evaluate the odds ratios throughout the study. Multivariable adjustments for these confounding variables are not possible because the analysis does not include them. The study benefits from a spacious participant sample of 9273 animals which strengthens reliability through predictable patterns discovered among factors linked to disease risk. These patterns now enable better planning of interventions including improved feed management and parasite control programs.

The prevalence of *Cysticercus tenuicollis* turned out higher in older animals but additional factors such as grazing habits and lack of deworming treatments demonstrated higher impact on disease risk rates. The study's design restricts determining direct causes between factors while the data from slaughterhouses could present lower than actual infection rate results. Molecular epidemiology combined with stray dog monitoring should become the focus of future research for improving transmission modeling and developing efficient control plans.

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Conflict of interest: All the authors declare that there is no conflict of interest.

Authors contribution: The study was designed by WQ and RZA. Sampling, analysis, and write-up was performed by WQ. The original draft was prepared by WQ, while MI and MSM provided feedback to improve the quality of the manuscript. The project was supervised by RZA. All authors have read the manuscript and approved the final version.

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