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Review

Trichuriasis in Selected Deer (Cervidae) Species: A Geographical Perspective

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Abstract: *Trichuris* spp. are endoparasites found in a wide range of mammalian species. Some of these host species include humans, non-human primates, dogs, cats, pigs, wild ruminants and domesticated ruminants. However, it had been noted that *Trichuris* are host specific, therefore the parasites that infects wild ruminant species may be transmitted to domesticated animals such as cattle, sheep and goat. Thus, the aim of this review was to identify species of *Trichuris* that parasitise deer species and to categorise the prevalence of this disease at various geographical locations. It must be noted that the prevalence and intensity of this parasite within deer species was low and rarely showed any signs of clinical disease. However, deer can be a source of infection to domesticated ruminants that may be housed in closed proximity. The review is divided into several sections based on the geographical location of the deer species. In summary, the review shows that most of the identification of various species of *Trichuris* in deer is based on morphological techniques. However, the use of molecular techniques in the identification of various species of *Trichuris* is more accurate. In closing, there is a need for more molecular investigations to be done in identifying the species of *Trichuris* that are present in deer living in the neo-tropical region.

Keywords: cervidae; *Mazama*; *Odocoileus*; neo-tropical; *Trichuris*; wild ruminants

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1. Introduction

This review attempts to provide insight into the *Trichuris* species that inhabit the gastrointestinal tract of selected deer species. Deer species were chosen as they play a major ecological role in many wildlife reserves. In some locations, deer species are under threat due to the destruction of habitat as well as severe hunting pressure. Whipworm is one of the least studied endoparasites that affect Cervidae. The deer species that will be highlighted were categorized into four groups based on geographic regions. Recently, Jones et al. [1] reviewed endoparasites found in neo-tropical mammals and the red brocket deer (*Mazama americana*) was found to have *Trichuris* spp. present in its gastrointestinal tract but the species was not identified. Further to this, Jones [2] reviewed *Trichuris* spp. found in rodents. The review is a continuation of this series that investigated *Trichuris* spp. present in mammals.

It is well known that endoparasites can have a detrimental effect on wildlife populations as well as infect domestic ruminants, thus causing detrimental effects to health and performance. *Trichuris* spp. are commonly known as whipworm and they inhabit the caecum and colon of animals causing diarrhea when the level of infestation is high [3]. Hendrix and Robinson [4] stated that *Trichuris ovis* infections are usually asymptomatic but melena, anorexia and anemia can be seen with high levels of infestation. It is hypothesised that deer species that are located in the neo-tropics will have a higher prevalence of trichuriasis in comparison to other geographical regions. One reason may be the more favorable environmental conditions, which are conducive for ova development throughout the year. There has not been a published review that investigates the prevalence of *Trichuris* spp. in deer at various geographical locations. Thus, the objectives of this review were to show the prevalence and clinical signs of *Trichuris* spp. in selected species of deer at various localities. The laboratory techniques for the identification of whipworm will also be investigated. The disease is transmitted through the oro-faecal route; bi-polar eggs are produced in the faeces of the infected animal and contaminate the environment. Susceptible animals become infected when these eggs are consumed.

2. Methodology

An exhaustive literature search was conducted on several search engines. These engines included Google Scholar, UWI Linc, Pubmed and Scopus. The keywords used in the search included deer, Cervidae, *Trichuris* and Trichuriasis. The number of articles attained from these searches were 256. The inclusion criteria included prevalence as well as clinical signs of disease. Of the 256 articles searched, only 70 were appropriate to be included in this review. The literature search spanned over fifty years (1966–2021).

3. *Trichuris* in Deer Located in the Neo-Tropics

In this section, we will focus on Trichuriasis in two neo-tropical deer species, which are the brocket deer (*Mazama* spp.) and the white-tailed deer (*Odocoileus virginianus*). Knight et al. [5] analysed the morphometry of adult (male and female) *Trichuris* found in the caecum of the white-tailed deer. Based on the morphometry of this helminth, he proposed a new species called *Trichuris odocoileus*. Prior to this, endoparasites in white-tailed deer was studied and several authors identified *Trichuris ovis* in the caecum of deer (based on morphometry) [6–8]. *Trichuris ovis* and *T skrjabini* has also been reported in sheep that share similar pastures to deer [9]. The prevalence of *Trichuris ovis* in white-tailed deer is relatively low and it seems to have little clinical effect on the animal. The prevalence was reported as 3.3% [8], 15% [9], and 3.4% [7] (also see Table 1). Similar prevalence values have been reported in cattle: 3.8% [10], 1.26% [11], 7.3% and 13.2% [12]. Large ruminants such as the bison were found to have a low rate of infection, as low as 1% [13]. In contrast, small ruminants (sheep and goats) had a wide range of prevalence for *Trichuris* [14,15]. Using faecal flotation, sheep and goats had a prevalence of 40.46% and 50.51% [15], 4.9% and 4.1% [14]. Using morphological techniques, the prevalence in sheep and goat was 8.9% and 6.7% [14]. Further research on sheep reported a variable prevalence of 6.25% (using faecal flotation) and 27.42% (using morphology of adults) [16]. Recently, Yevstafieva et al. [17] reported 65% of sheep were infected with *Trichuris* spp. using morphological techniques. Knight and Tuff [18] identified *Trichuris skrjabini* in Sika deer (*Cervus Nippon*) based on morphological analysis but the animals showed no overt signs of disease. Cook et al. [19] noted that whipworms in the white-tailed deer had a prevalence of 4.76% (4/84) but failed to identify the species of the parasite. It must also be noted that one study failed to identify *Trichuris* spp. in white-tailed deer but found it in the Sambar deer living in the same population [19]. Interestingly, there were few studies that investigated the causes of morbidity and mortality of farmed white-tailed deer. In this review, based on morphological data, only one (1/347) case of *Trichuris* spp. infestation was identified as a cause of death in farmed white-tailed deer [20].

In recent times, archaeological studies have identified *Trichuris* spp. in deer that inhabited the neo-tropics [21,22]. These samples were found in Brazil and Argentina and shed some light on parasitism by *Trichuris* in wild deer species before colonisation. It also shows that these parasites were present in these animals before the arrival of domesticated livestock. Disease surveys have been conducted on free-ranging grey brocket deer in Bolivia and Brazil [23,24]. The authors noted that these animals were in good body condition before samples were taken. The prevalence was very low, which was similar to other reports in neo-tropical deer species with 9.09% (1/11) in Bolivia [23]. Lux Hoppe [24] was unable to detect *Trichuris* in deer samples that were collected. However, it must be noted that Lux Hoppe [24] did not analyse caecal or colonic contents which are the predilection sites for this parasite. Some work was done on the causes of mortality in Key deer (*Odocoileus virginianus clavium*) in Florida [25]. The authors identified several causes of morbidity and mortality in these animals such as haemonchosis, highway mortality and chronic purulent infection [25]. However, the effect of endoparasites on mortality was overlooked as well as the effect of individual parasites such as species of *Trichuris*. *Trichuris* spp. was identified in the gastrointestinal tracts of white-tailed deer and pampas deer in Mexico and Uruguay [26,27]. Thus, in these neo-tropical regions more work has to be done to investigate the prevalence of this parasite and its effect on wild populations. There were numerous investigations on gastrointestinal parasites found in deer in the neo-tropics. Most of these reports did not identify *Trichuris* spp. in the gastrointestinal tracts of white-tailed deer and fallow deer [28–34]. Interestingly, the studies mentioned above used morphological techniques as the method of parasite identification. This shows that the use of this technique as the sole means of identification of parasites can be inaccurate. In summary, the prevalence of this parasite found in deer within the neo-tropics is generally low (see Table 1)

Table 1. Prevalence of *Trichuris* in neo-tropical deer species.

Host	Parasite	Method of Identification	Habitat	Prevalence% (x/y)	Refs.
Odocoileus virginianus (White-tailed deer)	*Trichuris ovis*	Morphology of adult and faecal flotation	Free range	3.3 (4/120)	[6]
Odocoileus virginianus (White-tailed deer)	*Trichuris ovis*	Morphology of adult and faecal flotation	Free range	3.4 (4/117)	[7]
Odocoileus virginainus (White-tailed deer)	*Trichuris ovis*	Morphology of adult	Free range	16 (5/31)	[8]
Odocoileus virginianus (White-tailed deer)	*Trichuris* spp.	Morphology of adult	Free range	9.1 (4/44)	[19]
Mazama gouazoubira (Grey Brocket deer)	*Trichuris ovis*	Faecal flotation	Free range	9.1 (1/11)	[23]
Alces alces (Moose)	*Trichuris* spp.	Morphology of adult	Free range	4.83 (3/62)	[35]
Mazama amerciana (Red Brocket deer)	*Trichuris* spp.	Faecal flotation	Free range	31.3 (5/16)	[36]
Fallow deer (*Dama dama*)	*Trichuris* spp.	Faecal flotation	Free range	1/68 (1.15)	[37]
Odocoileus hemionus (Mule deer)	*Trichuris discolor*	Morphology of adult	Free range	4 (1/25)	[30]
Odocoileus virginianus (White-tailed deer)	*Trichuris* spp.	Faecal flotation	Free range	4 (7/28)	[29]
Rusa unicolor (Samba deer)	*Trichuris* spp.	Faecal flotation	Free range	20 (2/10)	[38]
Odocoileus virginianus (White-tailed deer)	*Trichuris* spp.	Faecal flotation	Free range	17 (1/6)	
Odocoileus virginianus (White-tailed deer)	*Trichuris ovis*	Faecal flotation	Free range	6.49 (5/77)	[39]
Odocoileus virginianus (White-tailed deer)	*Trichuris* spp.	Faecal flotation	Free range	5.26 (4/76)	[40]
		Morphology of adult		1.32 (1/76)	
Odocoileus virginianus (White-tailed deer)	*Trichuris ovis*	Faecal flotation	Free range	3.82 (26/681)	[41]
		Morphology of adult		7.14 (1/14)	

4. *Trichuris* in Deer Located in Europe

Research was done in Czechoslovakia on endoparasites in roe deer. Two species of whipworm were identified as *Trichocephalus* (syn. *Trichuris*) *capreoli* and *T. globulosa*, which had a prevalence of 8.9% and 21.4%, respectively [42]. In Ireland, *Trichuris* spp. was found in red deer (*Cervus elaphus*) and fallow deer (*Dama dama*). *Trichuris* spp. occupied the large intestines of young or sick deer but never occurred in healthy deer. *Trichuris ovis* was found in red deer and an unidentified species of *Trichuris* was found in a fallow deer fawn. In the unidentified species, no males were recovered, which made identification based on morphology impossible [43]. In France, the relationship between helminth infestation and body condition in roe deer was investigated. Roe deer were hunted and the gastrointestinal tract and content were observed for adult helminths and eggs. *Trichuris capreoli* was found in the caecum and young animals had a higher infestation of helminths [44]. In a follow-up study done in roe deer, *Trichuris capreoli* infected males more often than females for each age and class category [45].

In Slovenia, wild fallow deer were hunted and gastrointestinal contents were analysed for helminths. These animals were clinically healthy when they were hunted with low number of parasites found in single animals [46]. Surprisingly, there were no gross pathological lesions attributed to the presence of nematodes in any of the infested digestive tracts. Three species of *Trichuris* were identified based on morphological analysis. They were *T. globulosa*, *T. capreoli* and *T. ovis*. Only a few deer were infected, 7% were infested with *T. globulosa*, 2% with *T. capreoli* and 2% with *T. ovis* [46]. Recently, a survey that lasted twenty months was done to investigate Cervidae kept in zoos in Belgium. The Cervidae under investigation included fallow deer (*Dama dama*), Dybowski's deer (*Cervus nippon dybiwski*), puda (*Puda puda*) and reindeer (*Rangifer tarandus tarandus*) [47]. Adult helminths were collected from the carcasses of the animals and it was noted that the *Trichuris* spp. was present in one of the two zoos surveyed. The reindeer at the zoo were found to have a prevalence of 25% ($n = 4$). All other cervid species were negative for *Trichuris* spp. based on morphological identification of the adult worms [47].

Helminth fauna in cervids in Belarus was investigated and *Trichuris ovis* was identified in moose (*Alces alces)*, roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*). The intensity was low in the animals sampled and the prevalence of parasites in deer species were 33.3%, 37.5% and 37.5%, respectively [48]. In northern Poland, the prevalence in red deer and fallow deer was 1.9% and 3.64% respectively. However, *Trichuris* spp. was not detected in roe deer using morphological techniques. The maximum faecal egg load was 30 eggs per gram (EPG) [49]. Similar work was conducted in various countries and the prevalence in Turkey was 13.3% [50], 2.4% for Croatia [51] and 14.7% in Austria [52]. In the Iberian Peninsula, wild roe deer was found with *T. capreoli* and *T. ovis* in 53.1% and 10.4%, respectively, of the animals sampled. It was also noted that the prevalence of *Trichuris* was higher in males (59.4%) in comparison to females (22.6%) [53]. Free-ranging red deer was found to contain several endoparasites, one of which was *Trichuris ovis*. The authors showed that a low level of endoparasites caused reduction in the body condition of the animals [54].

In Norway, several studies have been done investigating the effect of endoparasites on body condition in moose (*A. alces*) [55] as well as the effect that supplemental feeding has on nematode infection [56]. The prevalence of *Trichuris* spp. was 2.2% [57] and 33.3% [56] with the level of endoparasites having an inverse relationship to body condition [57]. In addition, supplemental feeding had no impact on the level of endoparasites in the sampled animals [56]. Researchers also investigated the parasites in Norwegian red deer in an isolated reserve and found *Trichuris globulosa* in 30.8% of the samples, but the mean helminth count was relatively low [55].

In most of the investigations previously recorded, deer were usually hunted or reared semi-intensively with limited information on the health of the animal. In contrast, a study was done in Sweden investigating gastrointestinal parasitic infection in dead or debilitated moose (*A. alces*) [58]. *Trichuris* eggs were found in 38% of faecal samples but worms were found in 10% of caecum and 2% in the ascending colon [58] (See Table 2). Jokelainen et al. [59] reviewed gastrointestinal parasites in reindeer located in Fennoscandia (Finland, Sweden, Norway and Russia). It was stated that historically, the *Trichuris* spp. was not commonly found in reindeer or moose from Europe but recent evidence has shown that they can be found in these species. Recently, *T. globulosa* was found in 38.9% of roe deer that were sampled in Russia [60]. In summary, the prevalence of this parasite in European deer was quite variable. In some regions, the prevalence was high (>75%) whilst it was low (<2%) in others (See Table 2). Variability in the prevalence may be due to several reasons, such as the method of identification, geographical location and environmental factors such as season.

Table 2. Prevalence of *Trichuris* in European deer species.

<table>
<tr><th>Host</th><th>Parasite</th><th>Method of Identification</th><th>Habitat</th><th>Prevalence% (x/y)</th><th>Refs.</th></tr>
<tr><td rowspan="2">Capreolus capreolus (Roe deer)</td><td>Trichuris capreolus</td><td rowspan="2">Morphology of adult and faecal flotation</td><td rowspan="2">Free range (Czech)</td><td>8.9% (10/112)</td><td rowspan="2">[42]</td></tr>
<tr><td>Trichuris globulosa</td><td>21.4% (24/112)</td></tr>
<tr><td>Rangifer tarandus (Reindeer)</td><td>Trichuris spp.</td><td>Morphology of adult and faecal flotation</td><td>Captive reared (Belgium)</td><td>25% (1/4)</td><td>[47]</td></tr>
<tr><td>Cervus elaphus (Red deer)</td><td rowspan="2">Trichuris spp.</td><td rowspan="2">Faecal flotation</td><td rowspan="2">Free range (Northern Poland)</td><td>1.8% (9/500)</td><td rowspan="2">[49]</td></tr>
<tr><td>Dama dama (Fallow deer)</td><td>3.6% (16/440)</td></tr>
<tr><td>Alces alces (Moose)</td><td rowspan="3">Trichuris ovis</td><td rowspan="3">Faecal flotation</td><td rowspan="3">Free range (Belarus)</td><td>33.3% (6/18)</td><td rowspan="3">[48]</td></tr>
<tr><td>Capreolus capreolus (Roe deer)</td><td>37.5% (6/16)</td></tr>
<tr><td>Cervus elaphus (Red deer)</td><td>31.3% (5/16)</td></tr>
<tr><td rowspan="2">Dama dama (Fallow deer)</td><td>Trichuris capreoli</td><td rowspan="2">Faecal flotation</td><td rowspan="2">Farmed (Slovenia)</td><td>2.3% (10/43)</td><td rowspan="2">[46]</td></tr>
<tr><td>Trichuris ovis</td><td>2.3% (10/43)</td></tr>
<tr><td>Cervus elaphus (Red deer)</td><td rowspan="2">Trichuris spp.</td><td rowspan="2">Morphology of adult and faecal flotation</td><td rowspan="2">Free range (Croatia)</td><td>2.4% (10/41)</td><td rowspan="2">[51]</td></tr>
<tr><td>Capreolus capreolus (Roe deer)</td><td>0% (0/25)</td></tr>
<tr><td>Capreolus capreolus (Roe deer)</td><td>Trichuris ovis</td><td>Morphology of adult</td><td>Free range (Turkey)</td><td>13.3% (2/15)</td><td>[50]</td></tr>
<tr><td rowspan="2">Capreolus capreolus (Roe deer)</td><td>Trichuris capreoli</td><td rowspan="2">Morphology of adult</td><td rowspan="2">Free range (Iberian Peninsula)</td><td>53.1% (116/218)</td><td rowspan="2">[53]</td></tr>
<tr><td>Trichuris ovis</td><td>10.5% (23/218)</td></tr>
<tr><td>Dama dama</td><td>Trichuris globulosa</td><td>Morphology of adult</td><td>Free range (Austria)</td><td>14.3% (1/7)</td><td>[52]</td></tr>
<tr><td>Alces alces (Moose)</td><td>Trichuris spp.</td><td>Faecal flotation</td><td rowspan="3">Free range (Norway)</td><td>33% (8/24)</td><td>[56]</td></tr>
<tr><td>Cervus elaphus (Red deer)</td><td>Trichuris globulosa</td><td>Morphology of adult and faecal flotation</td><td>30.8% (4/13)</td><td>[55]</td></tr>
<tr><td>Alces alces (Moose)</td><td>Trichuris spp.</td><td>Faecal flotation</td><td>2.2% (1/45)</td><td>[57]</td></tr>
<tr><td rowspan="2">Alces alces (Moose)</td><td rowspan="2">Trichuris spp.</td><td>Morphology of adult</td><td rowspan="2">Free range (Sweden)</td><td>Caecum [10% (10/50)]
Rectum [2% (1/50)]</td><td rowspan="2">[58]</td></tr>
<tr><td>Faecal flotation</td><td>3.8% (2/50)</td></tr>
</table>

Table 2. *Cont.*

Host	Parasite	Method of Identification	Habitat	Prevalence% (x/y)	Refs.
Capreolus capreolus (Roe deer)	*Trichuris globulosa*	Morphology of adult	Free range (Russia)	38.9% (7/18)	[60]
Capreolus capreolus (Roe deer)	*Trichuris globulosa*	Morphology of adult	Free range (Poland)	9.43% (5/53)	[61]
Capreolus capreolus (Roe deer) and *Dama dama* (Fallow deer)	*Trichuris* spp.	Faecal flotation	Free range (Poland)	10.48% (11/105)	[62]
Capreolus capreolus (Roe deer)	*Trichuris* spp.	Faecal flotation	Free range (German)	7.8% (5/64)	[63]
	Trichuris globulosa	Morphology of adult		67.2% (43/64)	
	Trichuris ovis	Morphology of adult		4.7% (3/64)	
Alces alces (Moose)	*Tricuris* spp.	Morphology of adult	Free range (Poland)	83.3% (10/12)	[64]
		Faecal flotation		68.9% (137/199)	
Capreolus capreolus (Roe deer)	*Trichuris* spp.	Faecal flotation	Free range (Southwest Poland)	9.2% (12/131)	[65]
Dama dama (Fallow deer)	*Triichuris capreoli*	Morphology of adult	Free range (German)	20% (10/49)	[66]
	Trichuris ovis			2% (1/49)	
Capreolus capreolus (Roe deer)	*Trichuris* spp.	Morphology of adult	Free range (Galacia, Spain)	59.4% (111/187) male	[67]
				22.6% (7/31) female	
Capreolus capreolus (Roe deer)	*Trichuris* spp.	Faecal flotation	Free range (Galacia, Spain)	47.2% (173/367)	[68]
Capreolus capreolus (Roe deer)	*Trichuris* spp.	Faecal flotation	Free range (North-western Spain)	3% (4/128)	[69]
				4% (15/367)	

5. *Trichuris* in Deer Located in Canada

In Canada, the gastrointestinal tracts of wild moose (*Alces alces*) and elk (*Cervus elaphus*) were examined for endoparasites. These endoparasites were identified using morphological characteristics. *Trichuris* spp. were identified in the caecum of both the moose (n = 140) and the wapiti (n = 186) in 34% and 20% of the respective samples. Only female worms were identified and worms had characteristics similar to the vulva and uteri of *T. ovis* [70]. In eastern Ontario (Canada), two species of *Trichuris* were identified in wild moose (*Alces alces*) [71]. *T. ovis* and *T. discolor* were identified using morphological analysis and it was the first time the latter species had been identified in moose. The prevalence of *T. ovis* and *T. discolor* was 13% and 25%, respectively. The intensity of these parasites was not considered large enough to have affected the health of the animals. The two species of *Trichuris* identified have also been found in domestic ruminants and it should be mentioned that moose that were captured were present in a forest reserve in close proximity to agricultural areas [71]. Farmed and wild woodland caribou (*Rangifer tarandus*) in north-western Ontario (Canada) were found to have *Trichuris* spp. eggs in their faeces. Adult *Trichuris ovis* were discovered in the gastrointestinal tract of farmed woodland caribou [72]. The Atlantic-Gaspesie caribou (*Rangifer tarandus caribou*) is a small isolated population of an endangered species. Faecal samples were taken to assess the level of parasitism present in these animals. *Trichuris* eggs were found in 6% of the animals sampled with a low level of infection detected [73]. In summary, the prevalence of this parasite in Canadian deer was at an intermediate level (See Table 3).

Table 3. Prevalence of *Trichuris* in Canadian deer species.

Host	Parasite	Method of Identification	Habitat	Prevalence% (x/y)	Refs.
Alces alces (Moose)	*Trichuris* spp.	Morphology of adult	Free range	34% (48/140)	[70]
Cervus elaphus (Red deer)				20% (37/186)	
Alces alces (Moose)	*Trichuris ovis*	Morphology of adult	Free range	13% (2/16)	[71]
	Trichuris discolor			25% (4/16)	
Rangifer tarandus (Reindeer)	*Trichuris ovis*	Morphology of adult and Faecal flotation	Free range	40% (2/5)	[72]
Rangifer tarandus caribou (Caribou)	*Trichuris* spp.	Faecal flotation	Free range	6% (2/32)	[73]

6. *Trichuris* in Deer Located in Asia and Australia

The incidence of helminth infection was investigated in wild Axis deer in India. Direct smears of faecal samples were used to identify helminth ova. In this study, the prevalence of *Trichuris* spp. was 8.5% but the animals' body condition was not recorded [74]. Prior to the published reported, McKenzie and Davidson [75] reported a 30% prevalence of *Trichuris* species in free-ranging Axis deer but these animals had low parasitic intensity and the sample size consisted of only ten animals. Upon post mortem examination, the animal was found to have large volumes of eggs in faeces based on faecal smears (prepared by direct method and faecal flotation) [76]. In Nepal, nine faecal samples were collected from the Musk deer (*Moshus chrysogaster*) and six samples were found to be positive for *Trichuris* spp. However, it must be stated that the small sample size of the above survey may bias the results. Most animals were recorded to have a light infection (<10%) of whipworms [77]. In China, the prevalence of endoparasites of musk deer at various locations and seasons were investigated [78]. The summer had the highest prevalence of *Trichuris* spp. (26.9%) with spring (13.6%) and winter (5.7%) having low values (see Table 4). With respect to location, the southern mountainous regions had higher values (31.1% and 35.0%) as compared to the eastern region (12.4%) [79]. In Indonesia, faecal sedimentation was applied to fifteen faecal samples from samba deer and seven faecal samples from spotted deer. The data showed only *Trichuris* spp. was found in 14.3% (n = 7) of spotted deer and none in the samba deer. The intensity of the infection in the spotted deer was categorised as light [80]. In New Zealand, the red deer (*C. elaphus*) was found to harbour *Trichuris ovis* and the fallow deer (*D. dama*) had an unidentified species of *Trichuris* [81]. Faecal samples were collected from captive wild ruminants in north eastern India. These ruminants included the barking deer, sika deer, mask deer, chital, brow-antlered deer and Himalayan serow. Of the samples taken, 1.77% (10/565) of ruminants were infected with *Trichuris* spp. [82]. A similar study was conducted on captive wild ruminants in the Punjab area. It revealed that most of the deer species were not infected with *Trichuris* spp. with only one spotted deer being infected (25%, n = 4) [83]. In summary, the prevalence of this parasite in Asian and Australian deer was quite variable. In some regions the prevalence was high (>70%) whilst it was low (<2%) in others (see Table 4). These results were similar to European deer.

Table 4. Prevalence of *Trichuris* in Axis, spotted, Samba and musk Deer.

Host	Parasite	Method of Identification	Habitat	Prevalence% (x/y)	Refs.
Cervus axis (Spotted deer)	*Trichuris* spp.	Morphology of adult	Free range	30 (3/10)	[75]
Cervus axis (Spotted deer)	*Trichuris* spp.	Faecal flotation	Free range	8.5 (17/200)	[75]
Moschus chrysogaster (Alpine musk deer)	*Trichuris* spp.	Faecal flotation	Free range	66.7 (6/9)	[77]
Cervus unicolor (Sambar deer)	*Trichuris* spp.	Faecal sedimentation	Free range	0 (0/15)	[78]
Axis chrysobactin (Spotted deer)				14.28 (1/7)	
Moschus chrysogaster (Alpine musk deer)	*Trichuris* spp.	Faecal flotation	Free range	Spring 13.6 (6/44) Summer 24.5 (53/216) Winter 5.7 (4/70)	[79]
Axis chrysobactin (Hog deer)	*Trichuris globulosa*	Faecal flotation	Captive reared	74.4 (64/86)	[84]
Cervus elaphus (Moral)	*Trichuris skrjabini*	Faecal flotation	Captive	1.98 (10/505)	[85]

7. Modern Techniques Used in Identifying *Trichuris* spp. in Cervids

At present, there is a dearth of information on the identification of *Trichuris* species in deer using molecular techniques. However, most of the molecular studies that were conducted were done with roe deer [86,87]. *Trichuris* species that were first found in roe deer used sequencing of the ITS1-5.8S-ITS2 ribosomal DNA fragment [86]. Comparisons were made between morphological and molecular techniques in the identification of this parasite. Interestingly, *Trichuris globulosa* and *Trichuris ovis* were identified using morphological techniques, but *T. globulosa* was identified as *T. discolor* using molecular techniques. *T. ovis* was confirmed using both methods (molecular and morphological) [86].

Further to this, a new molecular marker (ITS1-5.8S RNA-ITS2) was used to determine *Trichuris* spp. found in sheep (*Ovis orientalis aries*) and roe deer. *T. ovis* and *T. discolor* was found in both sheep and deer. *T. ovis* was predominantly present in sheep and *T. discolor* in roe deer [87]. Nechybova et al. [87] used the new molecular marker described previously to identify *Trichuris* species in wild ruminants in numerous localities in the Czech Republic. The ruminants investigated included roe deer, sika deer, red deer, fallow deer and mouflons, with *T. discolor* being the predominant trichurid and *T. ovis* identified less frequently [87]. The prevalence of *T. discolor* in roe deer, fallow deer, red deer and sika deer was 54.1%, 38.5%, 5.6% and 5.17%, respectively. *T. ovis* was not found in red deer but the prevalence for the other species of deer was 3.28% (roe deer), 7.69% (fallow deer) and 1.67% (sika deer) [87].

There are many simple techniques for the identification of gastrointestinal parasites. Examination of faeces grossly is not very sensitive, but in some cases adult helminths may be seen [4]. Microscopic examination of faeces and morphological analysis of adult worms are both insensitive in the determination of individual *Trichuris* spp. This is due to the variability noted in both egg and adult measurement of *Trichuris* spp. found in the same host. It must be noted that morphological techniques are needed to assess parasite burden. Some of the microscopic techniques include the use of direct faecal smears, faecal flotation and faecal sedimentation. Direct faecal smears are the most insensitive of the microscopic techniques. However, faecal smears allow for the identification of mobile protozoa. Faecal flotation and sedimentation are the most commonly used techniques. Faecal flotation allows eggs to float in solutions at specific gravity of more than 1.2 in most cases. Common faecal flotation solutions include zinc sulphate, sugar sulphate, sodium chloride (saturated solution). Some helminth eggs will not float, such as trematodes and in these cases, sedimentation techniques are more appropriate. *Trichuris* spp. eggs are easily identified using faecal flotation but some authors also used faecal sedimentation [4]. The use of faecal flotation as a tool to determine the prevalence of endoparasites may give false negative results in cases where the helminth population is immature (larval states) or consists of one sex (either males or females).

In most cases, *Trichuris* species were identified grossly using morphological tools. This method can be used as a screening test and there is a possibility of false negatives being reported. Faecal flotation and sedimentation were also used but molecular techniques are the gold standard for helminth identification. Therefore, the data presented in this review was done using microscopic and gross identification of helminth (adults and eggs) and there may be some under reporting of *Trichuris*-positive animals. Thus, the data described in this review should be used sparingly and future work should identify these helminths using molecular techniques to get a more accurate picture of the prevalence of this parasite at species level in various geographical regions.

8. Conclusions

The prevalence of the *Trichuris* spp. parasite in neo-tropical deer was low whilst in Europe, Asia, and Australia deer the prevalence was variable (2–80%). The prevalence in Canadian deer showed intermediary values (mid-range). Variability in the prevalence may be due to several reasons, such as the methods of identification, geographical location and environmental factors such as season. Morphological diagnosis (faecal flotation of eggs and adults) is not an accurate tool to determine the prevalence of these parasitic species and future studies should focus on molecular identification techniques.

9. Summary

This review revealed that *Trichuris* spp. were present in selected deer species. The parasite does not overtly cause clinical illness in wild or captive deer populations but the sub-clinical effects of this parasite are still unknown. Wild and captive-reared animals usually have a low prevalence and intensity of this parasite. The deer of neo-tropical origin have a low prevalence in comparison with other regions. In most cases, the identification technique used was based on morphometric features of eggs or adult helminths. These techniques were shown to be less accurate than modern molecular techniques. The species identified in this review appear to be *T. skrjabini*, *T. odocoileus*, *T. ovis*, *T. globulosa*, *T. capreoli* and *T. discolor*. Due to the use of morphological and biometric techniques in the identification of this parasite, it is difficult to state with any certainty which *Trichuris* species were present. This is because there has been variability in using morphological and biometric analysis of eggs and adults to determine individual species. Most of the studies failed to identify the species present in the samples and there was no published information on the molecular identification of *Trichuris* spp. with deer of neo-tropical origin. Some authors stated that the low prevalence and intensity of this parasite suggest it will not be transferred to domestic ruminants but this is a topic of major debate.

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