PREVALENCE AND RISK FACTORS FOR PAPILLOMATOUS DIGITAL DERMATITIS AMONG DAIRY CATTLE HERDS IN REGION X, CHILE

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PREVALENCIA Y FACTORES DE RIESGO PARA DERMATITIS PAPILOMATOSA DIGITAL EN GANADO LECHERO EN LA X REGION, CHILE.

SUMMARY

Con el objeto de determinar la presencia y los factores de riesgo de la dermatitis digital papilomatosa en ganado lechero de la X Región de Chile, se examinaron 3.884 vacas en lactancia en 23 granjas lecheras. La prevalencia de PDD en los hatos participantes se obtuvo examinando las patas de todas las vacas en lactancia durante el ordeño. La prevalencia de PDD en vacas en lactancia fue de 8,5% (e.s.=1.1).

La introducción de vaquillas de reemplazo provenientes de otros predios fue un factor de riesgo estadísticamente asociado (P< 0.05) con una alta prevalencia en hatos. El confinamiento de las vacas y el uso de establos de cama caliente también fueron factores de riesgo significativo en comparación con granjas que usaron pastoreo durante todo el año. Esta asociación estadística se mantuvo cuando la variable dependiente se analiza en forma continua y en forma binaria. También se encontró una diferencia en prevalencia de PDD en hatos dependiendo de la raza de ganado (overo negro=9%; overo colorado=6%); aunque la diferencia no fue estadísticamente significativa.

El examen histológico de biopsias obtenidas de 31 vacas confirma que las lesiones diagnosticadas clínicamente como PDD realmente fueron PDD.

Estos resultados sugieren que la prevalencia de PDD y los factores de riesgo en granjas lecheras de la X Región de Chile no han cambiado significativamente desde que se realizó un estudio similar en 1996.

Keywords: Dairy cattle, Papillomatous digital dermatitis, Digital dermatitis, Lameness, Chile
Palabras claves: Vacas lecheras, Dermatitis digital papilomatosa, Dermatitis digital, Cojeras, Chile

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INTRODUCTION

Papillomatous digital dermatitis (PDD), commonly known as footwarts in the United States, is a painful, inflammatory condition that has been described primarily in dairy cattle (Allenstein 1992; Read and Walker, 1998a). In Chile, the disease is often mistakenly referred to as "hongo" (fungus). The disease typically is characterized by erosive or proliferative lesions of the interdigital skin-horn junction region of the hind limb feet (Read and Walker, 1994). Digital dermatitis, a disease with gross and histologic characteristics similar to PDD (Read and Walker, 1998b), was first identified in 1974 in Italy (Cheli and Mortellaro, 1974), and has since been recognized as an important cause of lameness in dairy cattle worldwide (Gourreau *y col.*, 1992). The disease is thought to be of multifactorial pathogenesis (Frankena *y col.*, 1991), but the causal complex has not been completely elucidated. It is likely that causality involves infectious, environmental, farm management, and individual animal factors (Rodriguez *y col.*, 1998). Recent studies have suggested the involvement of spirochetes of the genus *Treponema* (Read *y col.*, 1992; Walker *y col.*, 1995;1997).

Although some epidemiological factors associated with PDD have been elucidated, much remains unknown. In a recent herd-level case control study conducted in southern California, muddy corrals and purchasing of replacement heifers were found to be significant risk factors for high farm-level PDD prevalence (Rodriguez-Lainz *y col.*, 1996a). Another study reported greater odds of herd-level PDD positivity in herds using confinement housing or maintaining a herd with greater than 50% Holstein cows (Rodriguez-Lainz *y col.*, 1996b). Economic impact associated with PDD has been attributed to decreased milk production (Gourreau *y col.*, 1992) and impaired reproductive performance (Argaez-Rodriguez *y col.*, 1997).

In Chile it has been reported that 91% of 43 dairies screened in two large milk production associations had endemic PDD (Rodriguez-Lainz *y col.*, 1998). In this study, an overall herd-level prevalence of 9.3% was estimated. The purpose of the current cross-sectional, observational study was to investigate potential herd-level risk factors for higher PDD prevalence among dairy herds in southern Chile and determine if PDD prevalence had changed significantly since a similar study was conducted in 1996 (Rodriguez-Lainz *y col.*, 1998). In addition, biopsies and photographs were taken to confirm grossly and histopathologically that the lesions observed in Chile were representative of the same PDD disease process observed in other countries.

MATERIALS AND METHODS

Study population and data collection

Twenty-three dairies were chosen for study by convenience as determined by location and access. All dairies were within 200 km of central Osorno (Region X) between (40-50 latitude, 70-80 longitude), Chile's main milkshed. Cattle were either pure German Red Pied (Overo Colorado), pure German Black Pied (Overo Negro), pure Holstein, or a cross between German Black Pied and Holstein (Friesian Negro). For the purpose of analysis, all farms with pure Holsteins, pure Overo Negro, and Holstein-Overo Negro crosses were categorized as Friesian Negro dairies. One dairy, which milked pure Jersey and Jersey-Overo Colorado cross cattle, was included in the Overo Colorado category for analysis. Confinement facilities included free stall, covered straw corrals (cama caliente), or open corrals. Seasonality of confinement was described as year-round (for any portion of the day) or full confinement in winter ± fall. Some dairies used pasture only with no confinement. Replacement heifers were either raised on the dairy farm, sent uniformly to another single premises (custom rearing), or purchased from more than one source.

Each dairy was visited once by the senior author in May or June, 1998. Information about herd-level management factors (herd size, percentage of cows in milk, confinement practices, hoof care practices, and policy of introduction of adult cattle and heifers) was collected in person from each dairy's manager or owner by means of a standardized questionnaire.

Lesion screening technique and case definition have been described in detail previously (Rodriguez-Lainz *y col.*, 1998). At each dairy, all milking cows were examined for PDD lesions as they came through the milking parlor. Cows' feet were cleaned with a water hose as they entered the parlor. All four feet of each cow were then inspected for lesions using a strong flashlight. A cow was determined to be PDD positive if she had a well-demarcated, erosive, moist, alopecic foot lesion with either a red granular or grey/brown tufted or papillary surface and a hyperkeratotic ridge and/or hypertrophic hairs. Bleeding and apparent pain after foot hosing were supportive of PDD diagnosis.

Biopsy collection

Seven dairy farms were visited during periodic veterinary hoof treatment visits. Five of these seven farms were also included in the epidemiological analyses. On these instances, clinically lame cows were restrained in a chute and treated. Following restraint, the animals' affected limb was tied securely with heavy rope. If an animal was determined to have a PDD lesion, photographs and biopsies were taken. Biopsies were performed with a 5 mm biopsy punch and local anesthesia using 2.0% lidocaine. Biopsies were fixed in neutral buffered formalin and transported to the California Veterinary Diagnostic Laboratory System for histopathological examination.

Statistical analysis

The unit of analysis was the herd. Initial univariate screening of the independent variables was done examining herd prevalence (number cows in milk with PDD lesions/total number cows in milk in that herd) as a continuous outcome variable with the two-sample t-test (for dichotomous variables) or Kruskal-Wallis test followed by multiple comparisons (for variables with 3 or more possible outcomes). Statistical significance for all tests was set at $p<0.05$. Additional comparisons were performed using herd prevalence as a dichotomous outcome variable. The herd median PDD prevalence of 0.08 was used to define high (≥ 0.08) and low (<0.08) prevalence herds. Analyses using the dichotomized outcome were performed using the chi-square test for independence or Fisher's exact test as appropriate. Following dichotomized analyses, the Egret exact method (SERC, 1993) was used to perform stratified analyses in order to evaluate potential confounding effects. Confounding was concluded to be present between two variables if the stratified adjusted odds ratio (OR) differed from the crude OR by $\geq 10\%$. Data could not be fit into a multivariate model due to small sample size.

RESULTS

Descriptive information

Prevalence distribution was determined to be normal using the Shapiro and Wilk's test. Of 3884 lactating cows examined, 330 (8.50%) were diagnosed with PDD by the parlor screening technique. Herd-level median PDD prevalence for milking cows was 8.0% (range 0 to 21%). Only two of the 23 farms included in the study were apparently free of PDD. Median number of milking cows per dairy was 168. More than half of farms kept cows confined only in winter ± fall (Table 1). The most commonly used mode of confinement was covered straw corrals (cama caliente). Approximately half of dairies reported never to have bought replacement heifers. Most farms managed hoof disease by treating only animals that were clinically lame.

Univariate statistical analysis

Using prevalence as a continuous outcome variable (Table 1), the seasonality of confinement was a statistically significant risk factor ($p<0.05$). When multiple pair-wise comparisons were performed, herds utilizing confinement in winter ± fall were significantly more likely to have greater PDD prevalence than those using pasture only. Type of confinement and heifer management practices were also found to be statistically significant risk factors. Multiple comparisons identified covered straw corral (cama caliente) confinement as a significant positive risk factor when compared to pasture. In addition, herds with a policy of not purchasing heifers were significantly less likely to have high PDD prevalence than herds using a custom rearing policy. Mean herd prevalence was higher among Friesian Negro herds (9.38%) than those milking Overo Colorados (6.14%), but the

difference was found to be only marginally significant (p=0.19).

Risk factors were also examined treating prevalence as a dichotomous outcome variable separated into the categories low and high using the median herd PDD prevalence of 0.08 as the cutoff (Table 2). As with the continuous outcome analysis, statistically significant differences were identified by the dichotomized analyses of the potential risk factors use of confinement and heifer buying policy. Several potential risk factors that were not statistically significant had odds ratios (ORs) that were suggestive of further examination. Although herd size was not a statistically significant risk factor for PDD prevalence (p=0.66), a small herd size was protective against high PDD prevalence (OR=0.51). For cattle breed (p=0.65), herds milking Overo Negro cattle were 2.2 times more likely to have high PDD prevalence relative to Overo Colorado herds. The p-value for a farm's

TABLE Nº 1 **DESCRIPTIVE FREQUENCIES AND UNIVARIATE ANALYSES OF HERD-LEVEL RISK FACTORS FOR HIGH PREVALANCE (≥0.08%) OF PAPILLOMATOUS DIGITAL DERMATITIS ON 23 DAIRY FARMS (3884 MILKING COWS) IN SOUTHERN CHILE (MAY-JUNE,1998), EXAMINING HERD PDD PREVALENCE AS A CONTINUOUS OUTCOME VARIABLE.**

Risk Factor	Categories	Number in Category (Percent)	Mean Prevalence[e]	p-value[f]
Number of Milking Cows[a]	≤168	12 (52.2)	0,08	0,46
	>168	11(47.8)	0,09	
Total Cows[b]	≤260	11(52.4)	0,08	0,44
	≤260	10(47.6)	0,1	
Breed[a,c]	Overo colorado	7 (30.4)	0,06	0,19
	Frisian negro	16 (69.6)	0,09	
Purchase adult cattle[b]	Yes	6 (28.6)	0,09	0,98
	No	15 (71.4)	0,09	
Risk Factor	**Categories**	**Number in Category (Percent)**	**Rank Sum[g]**	**p-value[h]**
	Year-round (partial)	4 (19.1)	43,5	0,01
Seasonality of confinement[b]	Winter ± Fall	12 (57.1)	167,5 X	
	Never (pasture only)	5 (23.8)	20,0 X	
Type of confinement[b]	Freestall	5 (23.8)	55,5	0,01
	Covered straw corral	9 (42.9)	142,0 Y	
	Open corral	2 (9.5)	13,5	
	None (pasture only)	5 (23.8)	20,0 Y	
Heifer managementb	Buy	2 (9.5)	25,5	0,05
	Do not Buy	11 (52.4)	87,0 Z	
	Custom[d]	8 (38.1)	118,5 Z	
Hoof managementb	None	1 (4.8)	8,0	0,63
	Treat all cows	5 (23.8)	46,0	
	Treat lame cows	15 (71.4)	177,0	

[a] Based on all 23 dairy farms visited.
[b] Based on 21 dairy farms for which questionnaire data were available.
[c] Friesian Negro=all herds milking Overo Negro (German black pied), Holstein, and their crosses. Overo Colorado=German Red Pied.
[d] Custom is rearing of all heifers at a single other premise
[e] Prev=number cows in milk with PDD lesions in a herd/total number cows in milk in that herd
[f] analyzed by t-test.
[g] Categories sharing the same superscript were significantly different in multiple comparisons test.
[h] analyzed by Kruskal-Wallis test; p-value for test of overall significance.

TABLA Nº 2

UNIVARIATE ANALYSES OF HERD-LEVEL RISK FACTORS FOR PREVALENCE OF PAPILLOMATOUS DIGITAL DERMATITIS IN 3884 MILKING COWS ON 23 DAIRY FARMS IN SOUTHERN CHILE (MAY-JUNE,1998), USING THE DICHOTOMOUS OUTCOME VARIABLE, HERD PDD PREVALENCE.

Risk Factor	Categories	High Prev.	Low Prev.	p-value[b]
Number of Milking Cows	≤168	6	6	0,68
	>168	7	4	
Herd Size	≤260	6	5	0,66
	>260	7	3	
Breed	Overo Colorado	3	4	0,65
	Friesian Negro	10	6	
Purchase adult cattle	Yes	5	1	0,34
	No	8	7	
Use of confinement	Confinement	13	3	<0.01
	Never (pasture only)	0	5	
Heifer management	Buy or customc	9	1	0,02
	Do not buy	4	7	
Hoof management	Treat	13	7	0,38
	Do not treat	0	1	

[a] Prevalence was dichotomized using the overall mean PDD prevalence, 0.08, as the cutoff between high and low.

[b] Analyzed by Fisher's exact test.

[c] Custom is rearing of all heifers at a single, other pre mises.

TABLA Nº 3

STRATIFIED ANALYSIS OF POTENTIAL RISK FACTORS FOR HIGH PREVALENCE (≥0.08) OF PAPILLOMATOUS DIGITAL DERMATITIS ON 21 DAIRY FARMS IN REGION X, CHILE, 1998

Stratifying Variable/Risk Factor	Level	OR (Crude)	OR (Stratified)	Confounding Indicated[c]
Time of confinement/Breed	Winter ± Fall	1	1	ND[d]
	Never (pasture only)	inf[a]	inf	
	Year-round (partial)	1,61	1,55	
Time of confinement /Heifer buying	Winter ± Fall	1	1	ND[d]
	Never (pasture only)	inf	inf	
	Year-round (partial)	1,6	1,41	
Type of Confinement/Breed	Freestall	1	1	ND[d]
	None (pasture only)	inf	inf	
	Covered straw corral	0	0	
	Open corral	1,4	0	
Type of Confinement /Heifer buying	Freestall	1	1	ND[d]
	None (pasture only)	inf	inf	
	Covered straw corral	0	0	
	Corral	1,4	inf	
Heifer buying/Breed	No	0,074	0,097	Yes
	Yes or Custom[b]	1	1	
Heifer buying/Herd size	No	0,074	0,071	No
	Yes or Custom	1	1	
Breed/Herd size	Frisian negro	3,13	2,68	Yes
	Overo colorado	1	1	

[a] inf=infinite due to 0 value in denominator.

[b] Custom is rearing of all heifers at a single other premises.

[c] Confounding indicated by a 10% difference between crude and stratified ORs.

[d] Not determinable due to one or more zero values in ratio.

policy on introduction of adult animals was 0.34, but the odds ratio for introduction of adult animals was 4.3.

Stratified analysis

Several stratified analyses were performed using the dichotomized outcome variable in order to examine potential confounding that might affect the risk factors found to be significant on unstratified analysis (Table 3). When the heifer buying policy versus PDD prevalence relationship was stratified by breed, confounding was found to be present. Dairies that did not buy replacement heifers were at lower risk (OR=0.074) of being high PDD prevalence herds compared to dairies that had bought heifers or raised them in custom ranches. This protective effect of not buying heifers was slightly diminished (OR=0.097) after adjusting for herd breed. In addition, herd size was a confounder of the effect of herd breed on PDD prevalence. Overo Negro dairies were at higher risk of having high PDD prevalence in crude analysis (OR=3.13) and when stratified by herd size (OR=2.68).

Biopsy analysis

Gross and histopathological findings were similar in all the 31 lesions biopsied, and were considered diagnostic for PDD (Read and Walker, 1994). All lesions had circumscribed areas of granular ulceration interspersed with areas of ortho- or parakeratotic hyperkeratosis. The stratum spinosum was hyperplastic and acantholytic. Superficial aspects of stratum spinosum and eroded tips of dermal papillae were consistently invaded by profuse numbers of spirochetes. Neutrophilic inflammation of the papillary dermis and epidermis and lymphoplasmacytic perivascular inflammation of the reticular dermis were also present. Photographs of PDD lesions in Chile confirmed similar gross appearance to PDD lesions observed in the United States.

DISCUSSION

Because the dairy farms included in this study were chosen on a convenience basis, the current findings can only be applied to the 21 herds included in analyses. However, due to consistency of findings between this report and previous work (Rodriguez-Lainz *y col.*, 1998), we consider it likely that these results may be representative of dairy farms in Region X, Chile.

The current calculated overall PDD prevalence of 8.5 % was similar to the 9.3% prevalence estimated in 1996 for a similar reference population (Rodriguez-Lainz *y col.*, 1998). This suggests that PDD prevalence for the study population has apparently not changed greatly in the two-year interval between the two studies. However, the 1996 data were obtained in summer and fall, whereas the current study was conducted in fall and winter. Seasonal change in PDD prevalence has been reported to the authors by local veterinarians and herdsmen, but has not been thoroughly examined. Thus, it is possible that both seasonal and temporal trends were present, but their contributory effects could not be assessed because of the difference in sampling seasons between the two studies.

Type and seasonality of confinement of cows were both found to be statistically significant predictors of higher PDD prevalence. The greatest likelihood of high PDD prevalence was observed in herds that confined cows in covered straw corrals, and herds that kept cows confined throughout winter ± fall. This may be due to increased viability of, or exposure to, the causal agent(s) of PDD in environments with large quantities of excrement and large numbers of animals. Loose housing previously has been suggested to favor the spread of infectious digital diseases (Greenough and Weavel,1997). Periods of greater ambient humidity and rainfall are also implicated as facilitators of PDD transmission or manifestation (Read and Walker, 1998a). Such conditions are likely to favor PDD infection by causing greater hydropic maceration of the digital epidermis. In this study, herds utilizing pasture all year were least likely to have high prevalence of PDD. Year-round pasture has been reported to be protective for PDD in Chile (Rodriguez-Lainz *y col.*, submitted) and the Netherlands (Goelema *y col.*, 1991).

The increased probability of high PDD prevalence for herds introducing heifers from other premises is consistent with reports from

Chile (Rodriguez-Lainz *y col.*, submitted) and USA (Rodriguez-Lainz *y col.*, 1996b). In Mexico, animal-level analysis indicated that purchased heifers were 3.4 times more likely to have PDD lesions than replacement heifers from within the herd (Argaez-Rodriguez *y col.*, 1997). These findings suggested that new animals may introduce the causal agents into a naive herd. Following introduction of the organisms, other factors may determine PDD transmission. We report that introduction of adult animals was not a significant risk factor for high PDD prevalence. This difference between the effects of introduction of heifers versus adults may be due to the greater number of heifers that are typically introduced and/or the fact that first-parity cows have been shown to have higher odds of PDD relative to older cows (Rodriguez-Lainz *y col.*, submitted).

In the current study, dairies milking Friesian Negro cows had higher overall PDD prevalence than dairies milking Overo Colorados. This finding is consistent with earlier reports that Holstein-Friesian cattle have higher risk of PDD (Goelema *y col.*, 1991;Rodriguez-Lainz *y col.*, submitted), and have more hoof disease overall relative to other breeds (Chesterton *y col.*, 1989). This may represent a true genetic predisposition manifested by hoof conformation or immunological factors. Alternatively, this predisposition may represent differences in management practices between the two breeds. In the current study, herd size was found to be a confounding factor of the breed-PDD relationship, suggesting that the two variables contribute to a joint effect on PDD prevalence.

Causality cannot be definitively concluded for any of the risk factors examined in this study. However, the strong associations between high PDD prevalence and heifer introduction and confinement type are consistent with other studies (Rodriguez *y col.*, 1996a; submitted). Thus, we conclude that these factors are likely to be part of a multifactorial etiology of PDD. Based on these findings, PDD abatement and prevention strategies may include avoiding introduction of animals from other herds, minimizing time of confinement, and providing free-stalls.

SUMMARY

In order to determine herd-level risk factors for papillomatous digital dermatitis (PDD) among dairy cows in Region X, Chile, 3884 lactating cows on 23 dairy farms were screened for PDD lesions. Herd prevalence was determined for each participating farm by examining the feet of all lactating cows during milking. Overall prevalence of PDD for all cows examined was 8.5 % (SE:1.1). Introduction of replacement heifers from another premises was a statistically significant ($p \leq 0.05$) risk factor for high PDD prevalence. Use of confinement housing in winter and confinement utilizing covered straw corrals were also statistically significant risk factors when compared to year-round pasture, in both continuous and dichotomized outcome variable analyses. A breed-specific difference in prevalence was identified (Friesian Negro prev=0.09;Overo Colorado prev=0.06), but was not statistically significant. Histopathologic examination of punch biopsies obtained from 31 cows with apparent clinical PDD lesions confirmed that observed lesions were PDD. These findings suggested that PDD prevalence and risk factors on dairy farms in Region X, Chile have not changed significantly since a similar study was conducted in 1996.

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REFERENCES

Allenstein LC. (1992). Wart-like foot lesions caused lameness. Hoards Dairyman *137*:696-697.

Argaez-Rodriguez F, Hird DW, Hernandez de Anda JH, Read DH, Rodriguez-Lainz A. (1997). Papillomatous digital dermatitis in a commercial dairy farm in Mexicali, Mexico: Incidence and effect on reproduction and milk production. Prev. Vet. Med. *32*:275-286.

Cheli R, Mortellaro C. (1974). La dermatite digitale del bovino. In: Proceedings of the 8th International Meeting on Diseases of Cattle, Milan:208-213.

Chesterton RN, Pfeiffer DU, Morris RS, Tanner CM. (1989). Environmental and behavioral factors affecting the prevalence of foot lameness in New Zealand dairy herds- a case-control study. N. Z. Vet. J. *37*:135-142.

Frankena K, Stassen, EN, Noordhuizen JP, Goelema JO, Schipper J, Smelt H, Ronkema H. (1991). Prevalence of lameness and risk indicators for digital dermatitis during pasturing and housing of dairy cattle. *In*: Rowlands GJ (Editor), Proceedings of the Annual Meeting of the society of Veterinary Epidemiology and Preventative Medicine, London, Great Britain, 107-118.

Gourreau JM, Scott DW, Rousseau JF. (1992). La dermatite digitee des bovins. Le Point Veterinaire *24*:49-57.

Goelema JO, Jansen J, Frankena K. (1991). Effects of extrabinomial variation on parameter estimates and standard errors in application of multiple logistic regression to veterinary epidemiology. In: Proceedings of the 6th International Symposium on Veterinary Epidemiology and Economics, Ottawa, Canada: 87-90.

Greenough PR, Weaver AD (1997). Lameness in Cattle. 3rd ed. Philadelphia:W.B. Saunders Company, 336 pp.

Read DH, Walker RL, Castro AE, Sundberg JP, Thurmond MC. (1992). An invasive spirochete associated with interdigital papillomatosis of dairy cattle (Letter). Vet. Rec. *130*:59-60.

Read DH, Walker RL. (1994). Papillomatous digital dermatitis and associated lesions of dairy cattle in California: pathological findings. In: Proceedings of the 8th International Symposium on Disorders of the Ruminant Digit, Banff, Canada. 156-158.

Read DH, Walker RL. (1998a). Papillomatous digital dermatitis (footwarts) in California dairy cattle: clinical and gross pathological findings . J. Vet. Diag. Invest. *10*:67-76.

Read DH, Walker RL. (1998b). Comparison of papillomatous digital dermatitis and digital dermatitis of cattle by histopathology and immunohistochemistry. In: Proceedings of 10th International Symposium on Lameness in Ruminants. Lucerne, Switzerland. pp 268-269.

Rodriguez-Lainz A, Hird DW, Carpenter TE, Read DH. (1996a). Case-control study of papillomatous digital dermatitis in Southern California dairies. Prev. Vet. Med. *28*:117-131.

Rodriguez-Lainz A, Hird DW, Walker RL, Read DH . (1996b). Papillomatous digital dermatitis in 458 dairies. J. Am. Vet. Med. Assoc. *209:*1464-1467.

Rodriguez-Lainz A, Melendez-Retamal P, Hird DW, Read DH. (1998). Prevalence of papillomatous digital dermatitis in Chilean dairies and evaluation of a screening method. Prev. Vet. Med. 37:197-207.

Rodriguez-Lainz A, Melendez-Retamal P, Hird DW, Read DH, Walker, RL. (Submitted). Farm- and host-level risk factors for papillomatous digital dermatitis in Chilean dairy cattle.

SERC (1993). Statistics and Epidemiology Research Corporation. Egret reference manual. Seattle, WA, USA.

Walker RL, Read DH, Loretz KJ, (1995). Spirochetes isolated from dairy cattle with papillomatous digital dermatitis and digital dermatitis. Vet. Micro. *47*:343-355.

Walker RL, Read DH, Loretz KJ, Hird DW, Berry SL. (1997). Humoral response of dairy cattle to spirochetes isolated from papillomatous digital dermatitis lesions. Am. J. Vet. Res. *58*:744-748.