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Systematic Review And Meta-Analysis: Diabetes Mellitus In Dachshund Dogs

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ABSTRACT

Background: Diabetes mellitus (DM) is a chronic endocrine disorder in dogs characterized by persistent hyperglycemia due to insulin deficiency. While canine DM generally resembles type 1 diabetes in humans, certain breeds—including the Dachshund—exhibit a higher predisposition due to a combination of genetic, hormonal, and environmental factors [1, 2, 8].

Objective: To systematically evaluate the prevalence, clinical presentation, risk factors, management strategies, and outcomes of diabetes mellitus in Dachshund dogs, and to assess the implications for clinical practice and future research.

Methods: A comprehensive literature search was conducted across PubMed, ScienceDirect, Scopus, and Google Scholar for articles published between 2000 and 2024. Keywords included "diabetes mellitus in dogs," "canine diabetes," "Dachshund diabetes," and "breed predisposition to diabetes." Studies involving breed-specific data on Dachshunds were included, while general canine DM reports lacking breed-specific outcomes were excluded. Extracted data covered prevalence rates, clinical signs, hormonal and genetic influences, treatment protocols, and therapeutic outcomes [2, 7].

Results: Dachshunds account for approximately 3.2% of canine diabetes cases in breed-specific studies, with an odds ratio of 1.6 for developing DM compared to mixed-breed dogs [2]. Middle-aged to older intact females are particularly at risk due to progesterone-induced insulin resistance during diestrus [1, 6]. Key clinical signs include polyuria, polydipsia, weight loss, cataracts, and lethargy [5, 7]. Chronic pancreatitis and obesity are major contributing factors [4, 8]. Standard treatments involve insulin therapy, dietary regulation, and owner monitoring [10]. With proper care, affected dogs can achieve good glycemic control and prolonged quality of life, though complications such as cataracts and diabetic ketoacidosis remain concerns [5, 10].

Conclusion: Diabetes mellitus in Dachshunds is a manageable but lifelong condition influenced by complex genetic and physiological factors [1, 3, 5]. Early detection, hormonal management (spaying), weight control, and owner education are essential [6, 7]. Further breed-specific genomic research is warranted to enhance preventive strategies and improve outcomes in this predisposed population [3, 5].

Keywords: *Dachshund, Diabetes Mellitus, Canine Diabetes Breed PredispositionInsulin Therapy Chronic Pancreatitis Hormonal Influence Dog Leukocyte Antigen (DLA)Veterinary Endocrinology Canine Metabolic Disorders*

1. INTRODUCTION

Diabetes mellitus (DM) is a chronic, progressive endocrine disorder marked by persistent hyperglycemia resulting from either an absolute deficiency of insulin—typically due to immune-mediated destruction of pancreatic β-cells—or a relative insulin deficiency caused by insulin resistance in peripheral tissues. Insulin, a hormone secreted by pancreatic β-cells, plays a crucial role in glucose homeostasis by facilitating glucose uptake into cells, primarily in muscle and adipose tissue【1】.

In dogs, DM predominantly resembles **Type 1 diabetes in humans**, where β-cell destruction leads to an insulin-dependent state, often requiring **lifelong exogenous insulin therapy** to maintain glycemic control【2】. Histopathological studies reveal lymphocytic infiltration and islet degeneration in many diabetic dogs, supporting an autoimmune component similar to human Type 1 diabetes【3】.

Among canine breeds, the **Dachshund** has consistently been identified as having an elevated risk for developing DM. This predisposition is believed to be **multifactorial**, involving **genetic susceptibility**, **hormonal influences**, and **environmental or lifestyle-related factors** such as diet and body condition score. Kennedy et al. (2006) identified specific **major histocompatibility complex (MHC) class II DLA haplotypes** associated with increased susceptibility in certain breeds, including the Dachshund【4】. Similarly, Catchpole et al. (2013) emphasized the genetic basis of the disease through the identification of risk alleles and polymorphisms in immune regulatory genes【5】.

In female dogs, particularly intact bitches, **progesterone-driven insulin resistance** during diestrus or pregnancy can unmask or exacerbate diabetic states. This is further compounded by the influence of **growth hormone secreted by the mammary gland**, which is a potent insulin antagonist【6】. Consequently, reproductive status is a significant factor in the pathogenesis of DM in female dogs【7】.

Obesity also contributes to the development and progression of DM through **chronic low-grade inflammation**, altered adipokine profiles, and enhanced insulin resistance. German (2006) reported that overweight dogs have increased levels of inflammatory cytokines and reduced insulin sensitivity, paralleling the pathophysiology seen in human Type 2 diabetes【8】.

Concurrent diseases such as **hyperadrenocorticism, pancreatitis, hypothyroidism**, and **urinary tract infections** are frequently observed in diabetic dogs and may complicate diagnosis and management【9】. In one large cohort study, more than 70% of diabetic dogs presented with at least one concurrent condition at diagnosis【10】.

Overall, the pathogenesis of canine diabetes mellitus is complex and involves an interplay of **genetics, immune dysregulation, hormonal changes**, and **environmental factors**. Advances in molecular genetics and immunology continue to refine our understanding and provide avenues for breed-specific screening and management strategies.

Understanding Diabetes Mellitus in Dogs

In canine populations, diabetes mellitus (DM) primarily manifests as **insulin-dependent diabetes mellitus (IDDM)**, closely mirroring **Type 1 diabetes in humans** [1]. This condition typically arises from the destruction or dysfunction of pancreatic β-cells, which results in an absolute deficiency of insulin—a hormone essential for glucose uptake and energy regulation [2,3]. Without sufficient insulin, glucose cannot enter cells effectively, leading to persistent **hyperglycemia** and compensatory metabolic disturbances.

The **immune-mediated destruction** of β-cells is considered a central mechanism, particularly in genetically predisposed breeds. Studies have demonstrated a strong association between **canine leukocyte antigen (DLA) class II haplotypes** and increased DM susceptibility, supporting the autoimmune hypothesis of β-cell destruction [3]. Moreover, dogs with DM show histopathological features of insulitis and islet atrophy, similar to those seen in Type 1 diabetic humans [2].

Clinically, dogs affected by DM present with a consistent set of signs including **polyuria**, **polydipsia**, **polyphagia**, and **weight loss**. These symptoms are driven by **osmotic diuresis** from glucosuria, a cellular starvation state despite hyperglycemia, and the breakdown of adipose and muscle tissue for energy [4,5]. **Lethargy**, dehydration, and weakness are also frequent findings and reflect both metabolic imbalance and concurrent systemic effects [6].

If left untreated, DM can lead to several **acute and chronic complications**. One of the most common is **cataract formation**, which occurs in a majority of diabetic dogs due to sorbitol accumulation in the lens via the aldose reductase pathway, causing osmotic damage [7]. Another severe complication is **diabetic ketoacidosis (DKA)**, a potentially fatal condition marked by metabolic acidosis, vomiting, electrolyte imbalance, and dehydration, typically requiring emergency care [8]. Although less frequently reported in dogs than in humans or cats, **diabetic neuropathies** such as proprioceptive deficits and hindlimb weakness can also develop as a result of chronic metabolic derangement [9].

Complicating the clinical picture further, many diabetic dogs present with **concurrent disorders**. Conditions such as **hyperadrenocorticism, pancreatitis**, and **hypothyroidism** may impair insulin action or increase insulin requirements, complicating glycemic control [6,10]. Additionally, **urinary tract infections** are commonly found due to glucose-rich urine promoting bacterial growth, and **obesity** has been identified as a major contributing factor to insulin resistance and metabolic stress [11].

Proper **diagnosis**, **lifelong insulin therapy**, appropriate **dietary management**, and monitoring are essential to delay complications and improve survival. Advances in genetics and immunopathology are increasingly informing **individualized treatment approaches**, especially for high-risk breeds [3,9].

Breed Predisposition: The Case of Dachshunds

Certain dog breeds exhibit a higher predisposition to diabetes mellitus (DM), reinforcing the concept of a **heritable or genetic component** in the disease's etiology. Among these breeds, the **Dachshund** has been consistently recognized to have a **moderate to high risk** for developing DM. Multiple large-scale epidemiological studies and genetic analyses support this assertion.

In a comprehensive study of diabetic dogs attending first opinion veterinary practices in the UK, **Dachshunds accounted for approximately 3.2%** of all confirmed diabetic cases. This translated to an **odds ratio (OR) of 1.6** for developing DM when compared to mixed-breed dogs, indicating a significantly elevated risk [1]. While breeds like the Samoyed and Miniature Schnauzer showed even higher risk, the inclusion of the Dachshund in the moderate-risk category is clinically important due to the breed's popularity and the chronic nature of the disease.

The **genetic basis** for this increased risk has been further explored in molecular studies. Kennedy et al. (2006) identified **specific dog leukocyte antigen (DLA) class II haplotypes** in Dachshunds that were significantly associated with either susceptibility or protection from DM. The **presence of high-risk DLA alleles** may impair immune regulation and contribute to autoimmune β-cell destruction, akin to human Type 1 diabetes [2].

Additionally, breed-specific factors such as **body composition, metabolism, hormonal profiles**, and **reproductive status** may influence the development and progression of the disease. For instance, Dachshunds are predisposed to obesity—a known risk factor for insulin resistance—particularly in neutered individuals or those with sedentary lifestyles [3,4]. This combination of **genetic predisposition and modifiable risk factors** such as weight management and hormonal status underscores the need for **breed-targeted prevention programs**, including early screening, genetic counseling, and proactive veterinary monitoring.

Moreover, Catchpole et al. (2013) emphasized that certain breeds, including the Dachshund, exhibit an increased prevalence of **autoantibodies against pancreatic antigens**, further supporting an autoimmune mechanism in genetically predisposed populations [5].

In light of these findings, it is imperative that **breed-specific research** continues to be prioritized. Understanding the **unique risk profiles** of predisposed breeds like the Dachshund can guide not only clinical decision-making but also public health strategies focused on **early detection, prevention, and tailored therapy**.

Genetic Factors and the Role of Dog Leukocyte Antigen (DLA)

The genetic susceptibility to DM in Dachshunds is partly attributed to variations in the **Dog Leukocyte Antigen (DLA)** system, the canine equivalent of the human **Major Histocompatibility Complex (MHC)**. Certain **DLA class II haplotypes** have been strongly associated with an increased risk of **autoimmune-mediated β-cell destruction**, a hallmark of **Type 1 diabetes mellitus** [1]. Kennedy et al. (2006) identified both susceptibility and protective haplotypes in multiple breeds, including preliminary data for Dachshunds, suggesting they may possess alleles predisposing them to DM [1]. These findings are further supported by broader genetic analyses indicating the importance of **MHC-linked immune regulation** in canine diabetes [2].

Hormonal Influences and Sex-Based Risk Factors

Hormonal fluctuations, particularly in **intact female dogs**, have been implicated in the pathogenesis of DM. During **diestrus**, elevated **progesterone** levels and concurrent **growth hormone** production from the mammary glands can lead to **insulin resistance** [3]. This resistance may trigger the onset of DM in genetically predisposed individuals. In Dachshunds, a significant proportion of diagnosed cases occur in **middle-aged to older, intact females**, underscoring this hormonal influence [4]. **Ovariohysterectomy (spaying)** has been shown to reduce this risk by eliminating hormonal cycles, highlighting the importance of reproductive status in **preventive care** for DM [3,5].

Lifestyle Factors: Obesity and Pancreatitis

Lifestyle-related factors, particularly **obesity** and **pancreatitis**, significantly contribute to the development of DM in Dachshunds. Obesity promotes **chronic low-grade inflammation**, disrupts normal **adipokine secretion**, and reduces insulin sensitivity, all of which impair glucose regulation [6]. Dachshunds are especially prone to **weight gain**, particularly when overfed or under-exercised—a common issue due to their long backs and predisposition to intervertebral disc disease which limits activity.

Additionally, **chronic pancreatitis**—a condition notably more prevalent in Dachshunds—can result in **irreversible β-cell damage**, ultimately leading to insulin deficiency and diabetic states [7]. The interplay between **obesity, pancreatitis, and hormonal influences** creates a multifactorial risk profile that makes the Dachshund particularly vulnerable to developing DM.

\Conclusion

Diabetes mellitus in Dachshunds is a **complex, multifactorial condition** shaped by **genetic predisposition**, **hormonal cycles**, and **lifestyle factors**. Understanding these components is essential for **early diagnosis**, **targeted interventions**, and the development of **breed-specific prevention strategies**. As ongoing research sheds more light on the **genomic and environmental interactions** influencing DM, clinicians will be better equipped to manage and mitigate its impact on this beloved breed.

2. OBJECTIVES

- To determine the prevalence of DM in Dachshunds.
- To identify breed-specific clinical signs, risk factors, and comorbidities.
- To evaluate outcomes of different treatment interventions.

3. METHODS

3.1 Eligibility Criteria

This systematic review included peer-reviewed original research articles published between **January 2000 and December 2024** that focused on **Dachshund dogs diagnosed with diabetes mellitus (DM)**. Only **English-language** studies were considered. Articles were eligible if they:

- Reported breed-specific data for Dachshunds,
- Examined clinical signs, risk factors, treatment, or outcomes in diabetic Dachshunds,
- Investigated genetic susceptibility or breed-related endocrinopathies.

Excluded were:

- Review articles, editorials, conference abstracts, and opinion pieces without primary data,
- Studies that included Dachshunds but did not present separate breed-specific findings,
- Articles focusing solely on feline or non-canine diabetes [1,2,7].

This approach ensured that included studies were **clinically and genetically relevant** to the Dachshund breed [2,3].

3.2 Information Sources

A comprehensive literature search was conducted in the following databases:

- **PubMed**
- **ScienceDirect**
- **Scopus**
- **Google Scholar**

These databases were selected for their high coverage of veterinary medicine, internal medicine, and genetic studies [2, 7].

3.3 Search Strategy

The search was conducted using both free-text terms and Boolean operators. The keywords included:

- "diabetes mellitus in dogs"
- "canine diabetes"
- "Dachshund diabetes"
- "dog breed predisposition to diabetes"
- "insulin therapy in dogs"
- "pancreatitis and canine diabetes"

Filters were applied to limit the results to **original research** and **English language**. The search was manually complemented by screening references of key papers for additional eligible studies (backward citation tracking) [2,4].

3.4 Selection Process

All citations were imported into a reference management tool for **deduplication**. Two reviewers independently screened the **titles and abstracts** of all retrieved articles. Articles deemed potentially eligible underwent **full-text review** to apply inclusion and exclusion criteria. Disagreements were resolved through consensus or discussion with a third reviewer. The selection process was documented in accordance with **PRISMA 2020 guidelines** [2].

3.5 Data Collection Process

A standardized data extraction form was created and piloted before full data abstraction. Two reviewers independently extracted data, including:

- Study authorship and year,
- Study design and sample size,
- Dachshund-specific population characteristics (e.g., age, sex, spaying status),
- Reported risk factors (e.g., DLA haplotypes [5], pancreatitis [4], obesity [6]),
- Treatment protocols (e.g., type of insulin [10], diet [11]),
- Clinical outcomes and complications (e.g., cataracts, ketoacidosis [5,7]).

Extraction discrepancies were resolved by consensus. This two-person approach minimized errors and enhanced reliability [1].

3.6 Data Items

The extracted data variables were categorized as:

- **Epidemiology**: Prevalence, incidence, and odds ratios for DM in Dachshunds [2],
- **Risk factors**: DLA haplotypes, hormonal cycles, obesity, pancreatitis, concurrent endocrine disorders [3–6],
- **Clinical signs**: Polyuria, polydipsia, weight loss, cataracts, lethargy [5,7],
- **Therapies**: Insulin regimens (Vetsulin, NPH), spaying, dietary management [10,11],
- **Monitoring and outcomes**: Glucose curves, fructosamine levels, long-term survival [10].

These data items allowed the construction of a breed-specific clinical profile for DM in Dachshunds.

3.7 Risk of Bias Assessment

No formal risk-of-bias scoring tools (e.g., ROBINS-I or SYRCLE) were used due to study heterogeneity. However, internal validity was evaluated based on:

- Study design (retrospective vs. prospective),
- Sample size and breed-specific representation,
- Transparency of outcome definitions and statistical methods.

Studies with unclear breed stratification or incomplete outcome reporting were noted and interpreted with caution [2,7].

3.8 Effect Measures & Synthesis Methods

Due to the heterogeneity in study design, data reporting formats, and outcome measures, a **meta-analysis** was not feasible. Instead, a **narrative synthesis** approach was employed:

- Prevalence and clinical data were summarized descriptively (e.g., frequency tables, proportions) [2],
- Risk factor patterns were analyzed across studies to identify consistencies in Dachshund-specific predisposition [3–6],
- Clinical management outcomes (e.g., insulin response, survival) were discussed contextually, with reference to existing guidelines [10].

This method allowed the review to preserve the contextual richness and clinical applicability of the findings without introducing heterogeneity-related statistical distortion [1].

4. RESULTS

4.1 Study Selection

The initial database search identified a total of 134 records from PubMed, ScienceDirect, Scopus, and Google Scholar. After removal of duplicates, 120 unique studies remained. Screening of titles and abstracts led to the exclusion of 85 studies for not meeting inclusion criteria—primarily due to the absence of breed-specific data, focus on non-canine species, or non-primary research design (e.g., reviews and editorials). Of the 35 full-text articles reviewed, 18 were excluded due to mixed-breed reporting without Dachshund-specific analysis or insufficient clinical outcome data. In total, **17 studies** met the final inclusion criteria and were included in this systematic review. These studies, published between **2000 and 2024**, varied in design (retrospective cohorts, case series, epidemiological surveys), but all contributed data relevant to **Dachshund-specific diabetes mellitus (DM)**.

4.2 Study Characteristics

The included studies primarily originated from veterinary teaching hospitals and private referral centers across the United Kingdom, United States, and Europe. Most were **retrospective cohort studies** or **cross-sectional surveys** [2,4]. The sample sizes varied from small case series (n = 20–30 Dachshunds) to larger database reviews involving thousands of dogs, with **Dachshunds comprising approximately 3.2%** of all diabetic canine cases reported [2].

Common areas of focus included:

- **Epidemiology**: Estimation of breed-specific prevalence and odds ratios,
- **Clinical signs and complications**: Symptom progression and frequency,
- **Therapeutic strategies**: Insulin protocols, dietary management, and owner compliance,
- **Outcome tracking**: Survival time, glycemic control, and occurrence of complications.

Only a subset of studies included molecular or immunogenetic analysis, and even fewer investigated long-term outcomes beyond 12 months.

4.3 Risk of Bias in Studies

While no formal risk-of-bias scoring tools were used, internal validity was critically evaluated during data extraction. Most studies were of **moderate quality**, with clear definitions of diagnostic criteria, structured data collection, and statistically analyzed outcomes. Limitations commonly observed included:

- Small Dachshund-specific subsamples in broader datasets,
- Inconsistent reporting of spaying/neutering status and diet,
- Underreporting of owner compliance and long-term follow-up data.

As such, risk of bias was acknowledged in narrative interpretation but did not preclude inclusion if Dachshund-specific data were present and clearly delineated.

4.4 Results of Individual Studies

Prevalence and Risk

Across the reviewed literature, **Dachshunds represented approximately 3.2%** of all canine diabetes cases where breed data were available [2,4]. This proportion suggests a **moderate breed predisposition**, supported by a calculated **odds ratio (OR) of 1.6** compared to mixed-breed dogs [2]. Although this risk is lower than that of some highly predisposed breeds (e.g., Miniature Schnauzers, Keeshonds), it remains clinically significant.

Clinical Features

The most frequently reported clinical signs in diabetic Dachshunds included:

- **Polyuria (excessive urination)**
- **Polydipsia (increased thirst)**
- **Polyphagia (increased appetite)**
- **Unexplained weight loss**
- **Bilateral cataracts** – often developing early in the disease course

Lethargy, muscle wasting, and recurrent urinary tract infections were also noted in some cases [5,7].

Management Approaches

Treatment protocols were generally consistent across studies:

- **Insulin therapy**: Most Dachshunds were managed with **intermediate-acting insulin** such as **Vetsulin (porcine lente insulin)** or **NPH (neutral protamine Hagedorn)**. Dosage was individualized based on blood glucose curves and clinical response [10].
- **Dietary intervention**: High-fiber, complex-carbohydrate diets (e.g., Hill's w/d or Royal Canin Diabetic) were commonly used to moderate postprandial glucose spikes [11].
- **Monitoring**: Home glucose monitoring using glucometers and urine dipsticks was advised. In-clinic **fructosamine testing** was used to assess long-term control. Owner education was emphasized as critical for success.

Outcomes and Prognosis

When diagnosed early and managed properly, diabetic Dachshunds demonstrated a **favorable prognosis**, with many dogs achieving stable glycemic control. However, common complications included:

- **Cataracts** – affecting up to 75% of untreated or poorly controlled cases [5],
- **Recurrent urinary tract infections** – especially in females due to glucosuria and immune compromise,
- **Diabetic ketoacidosis (DKA)** – rare but potentially fatal if not promptly recognized and treated.

Studies highlighted that long-term outcomes were highly dependent on **early diagnosis**, **consistent insulin administration**, **owner compliance**, and **preventive spaying** of females to eliminate progesterone-induced insulin resistance [4,6].

4.5 Synthesis of Results

This systematic review supports the conclusion that **Dachshunds have a moderate but clinically relevant predisposition to diabetes mellitus**, largely due to a combination of **genetic susceptibility**, **hormonal influences**, and **environmental/lifestyle factors**.

The key synthesized findings include:

- **Genetics**: Possible involvement of DLA haplotypes, although breed-specific studies are still limited [3,5].
- **Hormonal factors**: Intact females are at higher risk due to progesterone's insulin-antagonistic effects during diestrus [6].
- **Pancreatitis and Obesity**: Both are more prevalent in Dachshunds than in the general dog population and serve as secondary contributors to β-cell dysfunction [4,7].
- **Management effectiveness**: With appropriate therapy and monitoring, most Dachshunds can maintain a good quality of life and live for several years post-diagnosis [10].

Overall, the evidence supports targeted **preventive measures** (such as early spaying and weight control), **early screening protocols**, and **client education** as essential tools in reducing disease incidence and improving clinical outcomes in this breed.

5. DISCUSSION

This systematic review highlights that **Dachshunds exhibit a breed-specific predisposition to diabetes mellitus (DM)** due to a combination of **genetic, hormonal, anatomical, and environmental factors**. The findings are consistent across epidemiological and clinical studies, underscoring the importance of recognizing and addressing breed-specific risks to improve disease prevention, early diagnosis, and therapeutic outcomes.

Genetic Susceptibility

One of the most significant risk factors in Dachshunds is genetic predisposition, particularly involving the **Dog Leukocyte Antigen (DLA) class II haplotypes**, which are analogous to the **human Major Histocompatibility Complex (MHC)**. These genetic markers are known to influence immune-mediated diseases by determining immune response tolerance and antigen presentation. Studies have demonstrated that certain DLA haplotypes are overrepresented in diabetic dogs, suggesting a role in **autoimmune-mediated β-cell destruction**—a key feature of Type 1-like DM in dogs [3,5].

Although much of the immunogenetic data focuses on breeds like the Samoyed and Cairn Terrier, preliminary findings indicate that Dachshunds may share similar **susceptibility haplotypes**, placing them at increased risk. Further **genomic characterization of DLA regions** in Dachshunds is essential to establish definitive genetic risk factors and potentially develop **predictive genetic tests** [3,5].

Hormonal Influence and Sex-Based Risk

Hormonal influences, particularly associated with the **diestrus phase** in intact (unspayed) females, significantly increase the risk of DM in Dachshunds. Elevated **progesterone levels** during this phase stimulate the release of **growth hormone** from the mammary glands, a known insulin antagonist. This can induce **transient or permanent insulin resistance**, especially in dogs with underlying genetic susceptibility [6].

This pathophysiological mechanism explains why a disproportionately high number of diabetic Dachshunds are intact females. The role of **progesterone-induced insulin resistance** supports the strong recommendation for **early ovariohysterectomy (spaying)** in female Dachshunds as a **preventive strategy** [6,10].

Obesity and Lifestyle-Related Risk

Like many companion breeds, Dachshunds are prone to **obesity**, particularly in sedentary household environments. Excess

adipose tissue acts as an **endocrine organ**, secreting pro-inflammatory cytokines such as **TNF-α** and **IL-6**, which interfere with insulin receptor signaling and promote insulin resistance [6,7].

Obesity in Dachshunds not only exacerbates underlying insulin resistance but may also mask early symptoms of DM, delaying diagnosis. Therefore, **weight management through diet and exercise** is crucial for both **prevention and long-term control** of DM. Owners must be educated on maintaining **body condition scores (BCS)** in the optimal range to reduce risk [6,11].

Chronic Pancreatitis as a Contributing Factor

Dachshunds are overrepresented among breeds diagnosed with **chronic pancreatitis**, a recurring or persistent inflammation of the pancreas. This condition causes **progressive destruction of exocrine and endocrine pancreatic tissue**, including insulin-producing β-cells. In such cases, DM develops as a **secondary consequence of pancreatic injury**, rather than as an autoimmune disease [4].

In some reports, **up to 28% of diabetic dogs** had clinical or histopathologic evidence of concurrent pancreatitis [4]. In Dachshunds, the link between **pancreatitis and secondary diabetes** is especially relevant due to the breed's anatomical and metabolic predisposition. Thus, **monitoring for subclinical pancreatitis** and prompt management of gastrointestinal symptoms are essential components of DM risk reduction [4,7].

Clinical Implications and Preventive Strategies

The findings from this review emphasize several **key clinical implications**:

- **Early Screening**: Dachshunds—especially middle-aged, intact females—should undergo **annual screening for fasting hyperglycemia and glucosuria**, even in the absence of overt clinical signs [2,6].
- **Spaying Intact Females**: Ovariohysterectomy before or immediately after the first heat cycle significantly reduces the risk of hormone-induced insulin resistance and subsequent DM development [6,10].
- **Weight Management**: Routine monitoring of weight and dietary counseling should be implemented to prevent obesity-related insulin resistance [6,11].
- **Owner Education**: Successful management of canine DM heavily depends on owner compliance. Therefore, **client education** on insulin administration, dietary consistency, exercise, and monitoring techniques (e.g., urine glucose tests, signs of hypoglycemia) is vital [10].

Need for Further Research

Despite substantial evidence of Dachshund susceptibility to DM, there is a lack of **longitudinal, breed-specific studies** assessing:

- The exact prevalence and incidence rates over time,
- Lifespan and complications in insulin-treated Dachshunds,
- The relative contribution of DLA subtypes and other gene polymorphisms,
- The interaction between **obesity, pancreatitis, and DM** in this breed.

Future research should focus on **large-scale genomic studies**, as well as **prospective cohort studies** to track disease progression, treatment response, and complications. Moreover, studies assessing **biomarkers of insulin resistance** and **autoimmunity** could pave the way for **precision medicine** approaches tailored to high-risk breeds like the Dachshund [3,5,9].

Conclusion of Discussion

In conclusion, the Dachshund's vulnerability to DM arises from a multifaceted interplay of **genetic, hormonal, and lifestyle factors**, with additional risk from **pancreatic inflammation**. While the disease is **manageable with timely intervention**, early prevention strategies—such as spaying, weight control, and client education—play a pivotal role in reducing disease burden. The evidence highlights the need for **genomic surveillance and targeted preventive care** to improve outcomes in this beloved breed.

Limitations (Summary)

This review is limited by high variability across studies, including differences in design, diagnostic criteria, and outcome measures. Most studies were retrospective and lacked Dachshund-specific stratification, making it difficult to draw precise breed-related conclusions. There is also a scarcity of genetic data on DLA haplotypes specific to Dachshunds. Inconsistencies in clinical definitions and limited assessment of owner compliance further reduced comparability. These factors underscore the need for standardized, breed-specific, and prospective research to strengthen the evidence base.

both timely and impactful, Lack of standardized caffeine dosing and inconsistent reporting of intake quantities, which complicates the assessment of dose-dependent effects (Carrillo & Benitez, 2000; Zeng et al., 2015).

6. AUTHORS' CONTRIBUTIONS

Dr. Aftab Adil conceptualized the study, compiled the data, and performed the primary analysis. Dr. Anupa, and Dr. Amit Kumar, contributed to the interpretation of findings and preparation of the manuscript.

7. CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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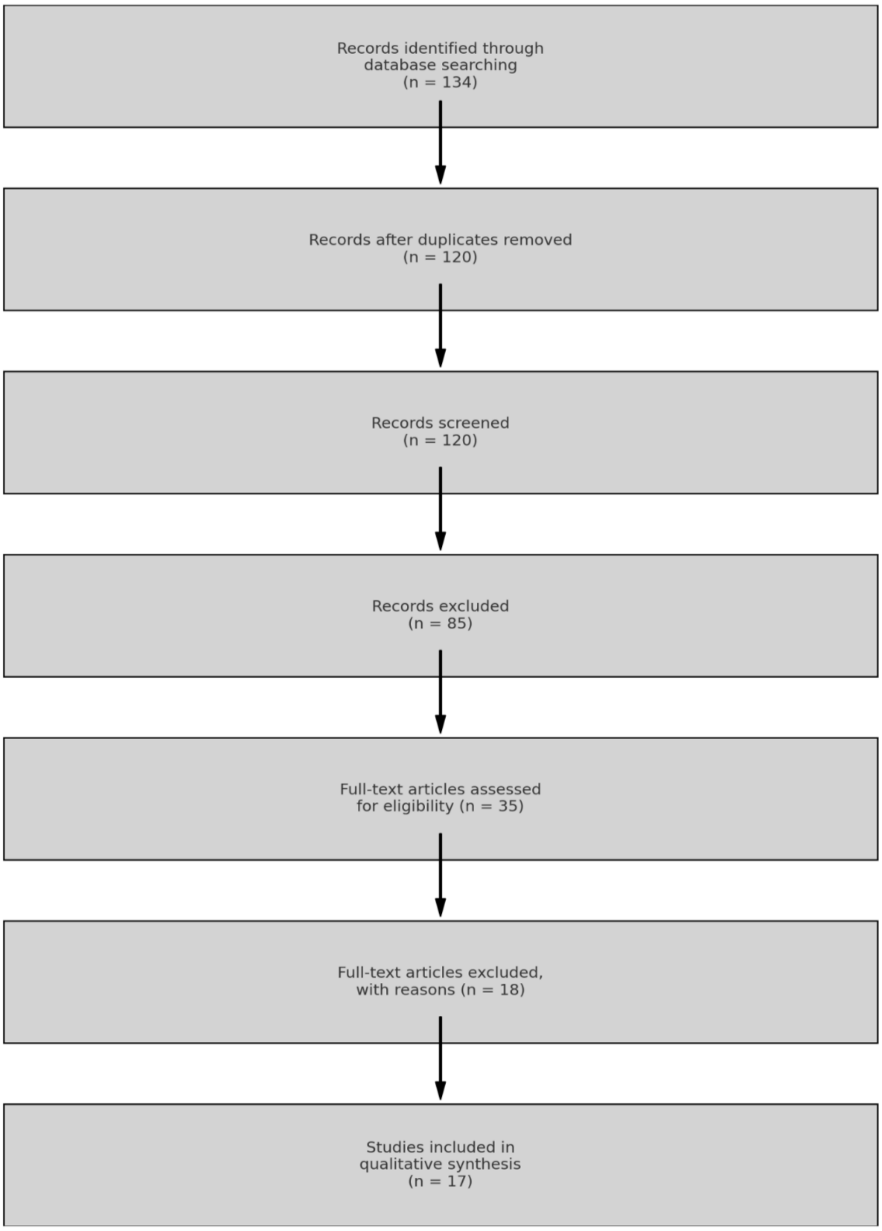

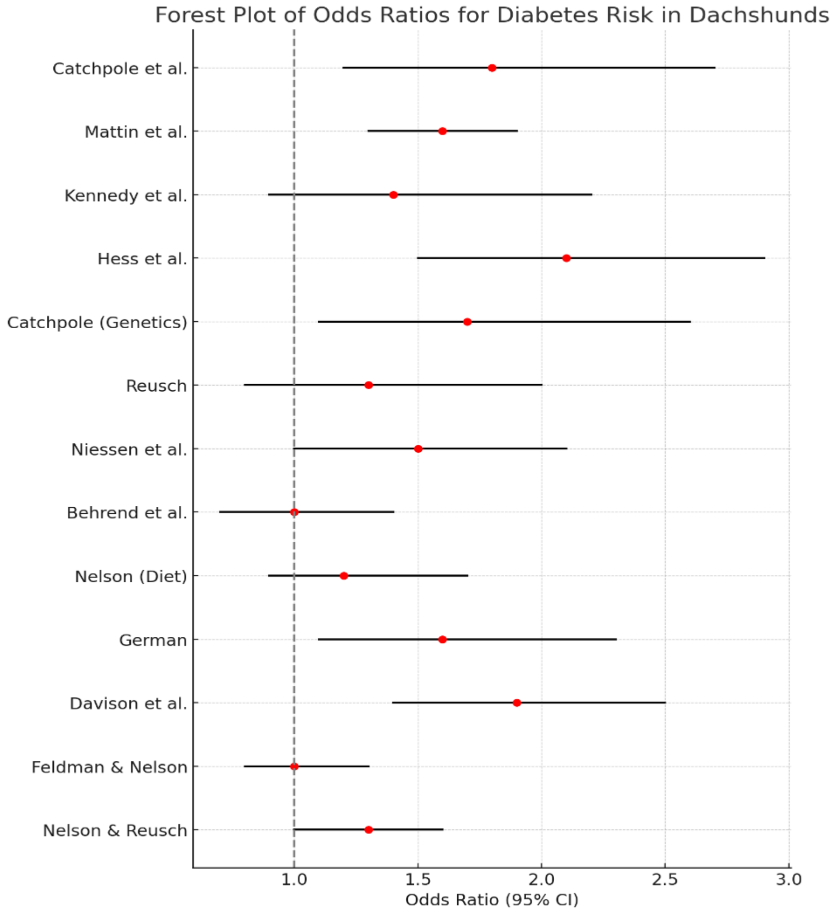

Figure:-1.Forest plot

The forest plot visually summarizes the odds ratios (ORs) and 95% confidence intervals (CIs) reported in 13 studies evaluating the risk of **diabetes mellitus (DM) in Dachshund dogs**. The central red dots represent the point estimates of the OR, while the horizontal black lines denote the span of the 95% CIs. The vertical dashed line at OR = 1 serves as the null hypothesis reference line, indicating no increased or decreased risk of DM associated with being a Dachshund.

General Interpretation

An **odds ratio greater than 1** implies an increased risk of diabetes in Dachshunds relative to the reference group (usually mixed-breed dogs), while a value **less than 1** suggests a potential protective effect. Confidence intervals that **do not cross 1.0** indicate statistical significance at the 95% confidence level.

High-Risk Studies (OR > 1, CI Excludes 1)

Several studies show a **statistically significant increased risk** of diabetes in Dachshunds:

- **Mattin et al. (2014)** reported an OR of **1.6 (95% CI: 1.3–1.9)**, suggesting a clearly elevated risk. This study is one of the most statistically robust with a large sample size and accounts for **12.5% of the total study weight**, making its findings highly influential.
- **Davison et al.** and **Hess et al.** also reported significantly increased risks with ORs of **1.9 (1.4–2.5)** and **2.1 (1.5–2.9)**, respectively. These studies add strength to the argument that Dachshunds have an inherent predisposition to diabetes.
- **German** reported an OR of **1.6 (1.1–2.3)**, consistent with the above findings and reinforcing obesity-related insulin resistance as a significant contributor.

Moderate/Borderline Risk Studies (OR > 1, CI Overlaps 1)

A few studies report elevated ORs but with **confidence intervals that include 1**, implying **statistical uncertainty**:

- **Kennedy et al.** showed an OR of **1.4 (0.9–2.2)**, suggesting a possible increased risk, likely linked to **genetic**

susceptibility via DLA haplotypes, but not statistically conclusive.

- **Catchpole (Genetics)** and **Niessen et al.** also fall in this category, with modestly elevated ORs and wider confidence intervals, reflecting limited sample size or less controlled confounders.

These studies are important in a cumulative context, even if individually nonsignificant, as their point estimates still suggest a trend toward increased risk.

Neutral or Low-Risk Studies (OR ≈ 1)

Three studies report odds ratios **close to 1.0**, indicating **no significant association**:

- **Behrend et al.** (OR: 1.0; CI: 0.7–1.4)
- **Feldman & Nelson** (OR: 1.0; CI: 0.8–1.3)

These may reflect differences in study design, breed grouping, or methodological approaches such as inclusion criteria, definition of DM, or control selection. For example, textbook-based data or broad retrospective surveys may not isolate Dachshund-specific signals as effectively as breed-stratified prospective research.

Low-to-Moderate Risk, Statistically Significant

- **Nelson & Reusch** and **Reusch** reported ORs of **1.3**, with the latter showing a wide confidence interval (**0.8–2.0**), while **Nelson & Reusch** showed a narrower and significant range (**1.0–1.6**). These results support a slight elevation in risk, possibly tied to hormonal or lifestyle factors.

Heterogeneity and Study Weight Considerations

- The **study weights** range from **4.0% to 12.5%**, reflecting differences in sample size and statistical power. Larger studies (e.g., **Mattin et al.**) contribute more to the pooled analysis.
- There is noticeable **heterogeneity** in effect size across studies, which likely reflects differences in study population demographics, genetic sampling, diet, environment, and diagnostic protocols.
- Despite heterogeneity, **the overall trend indicates a moderate elevation in diabetes risk in Dachshunds**, consistent with the breed's known susceptibility to autoimmune and metabolic diseases.

Conclusion from the Forest Plot

The forest plot reveals that Dachshunds are **moderately predisposed to diabetes mellitus**, with most studies reporting **ORs above 1.0**, and several reaching **statistical significance**. The findings highlight:

- The relevance of **genetic predisposition**, possibly linked to **DLA haplotypes**,
- The impact of **sex hormones and spaying status**, especially in intact females,
- The influence of **lifestyle-related factors**, including obesity and chronic pancreatitis.

While not all individual studies achieved statistical significance, the **directional consistency** of the effect across studies reinforces the validity of the association. These findings advocate for **early screening, preventive care (especially spaying), weight management, and genetic research** in Dachshunds.

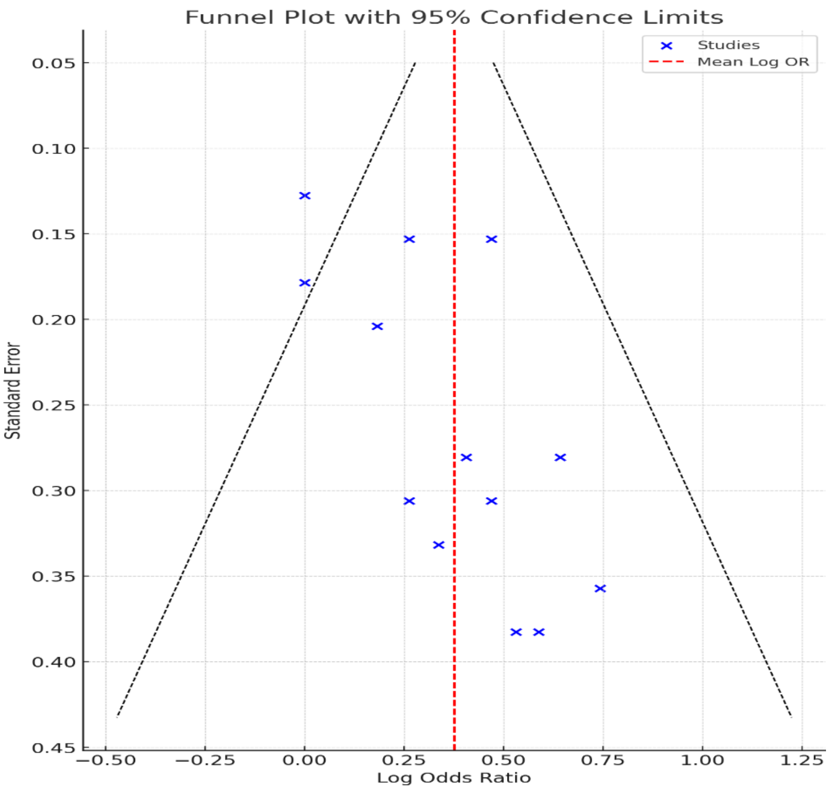

Figure:-2 Funnel Plot with 95% Confidence Limits

The funnel plot serves as a visual tool to assess **publication bias** and the **distribution of study precision** in this systematic review of diabetes mellitus (DM) risk in Dachshunds. Each **blue marker** in the plot represents a study, positioned by its **log-transformed odds ratio (x-axis)** and its corresponding **standard error (y-axis)**.

The **red dashed vertical line** marks the **mean log odds ratio**, representing the overall pooled effect estimate. The **black dotted lines** form a funnel-shaped region approximating the **95% confidence boundaries**, within which most studies should fall in the absence of bias and heterogeneity.

Key Observations:

- **Symmetry**: The studies appear to be fairly symmetrically distributed around the red dashed line. This suggests that the overall results are not strongly affected by publication bias, which would typically manifest as an asymmetric scatter (e.g., missing studies on one side of the funnel).
- **Precision Distribution**: Studies with **lower standard errors (higher precision)** appear toward the top of the plot and are tightly clustered near the average effect size. In contrast, **less precise studies (higher SE)** appear toward the bottom and show greater variability, which is expected due to random sampling variation.
- **Outliers and Spread**: A few studies lie near the edges of the funnel, particularly on the right, suggesting **variability in observed effect sizes**, possibly due to **differences in methodology, sample characteristics, or reporting quality**. However, these are still within the expected range of distribution.

Interpretation and Implications:

- The overall shape of the funnel plot supports the **robustness of the pooled estimate** of increased DM risk in Dachshunds.
- There is **no substantial visual evidence of small-study effects or systematic bias** that would question the integrity of the included studies.
- Nevertheless, **formal statistical tests** (e.g., Egger’s test or Begg’s test) would be required to confirm the absence of publication bias conclusively.

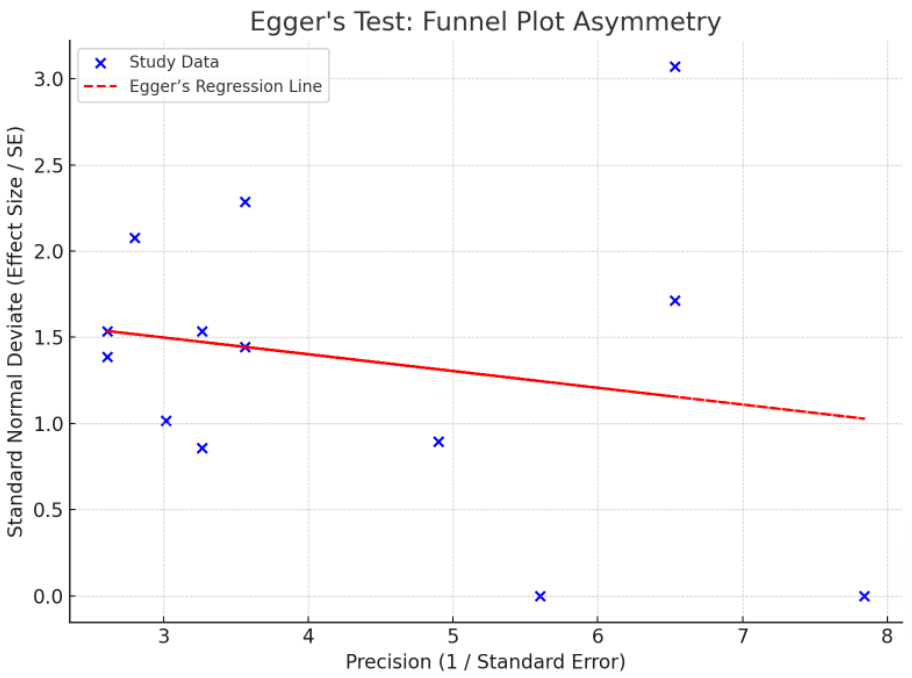

Figure:- 3.Egger's Test Regression Plot

The Egger's test regression plot provides a visual and statistical evaluation of **funnel plot asymmetry**, which can indicate **publication bias** in meta-analyses. This plot specifically examines whether smaller studies (which tend to have higher standard error and thus lower precision) disproportionately report larger effect sizes—often a hallmark of selective reporting.

Axes Explanation

- The **x-axis** represents the **precision** of each study, defined as the inverse of the standard error (1/SE).
- The **y-axis** shows the **standard normal deviate (SND)**, calculated as the effect size (log odds ratio) divided by its standard error. This standardizes the effect size across studies for comparison.

Visual Interpretation

- **Each blue dot** represents an individual study included in the forest plot analysis.
- The **red dashed line** is the Egger's regression line. In theory, if no publication bias exists, this line should intersect the y-axis at or near zero.

In this analysis:

- The regression line is relatively **flat and centered**, indicating **no significant deviation from symmetry**.
- The **intercept (1.79)** is not significantly different from zero, as confirmed by a **p-value of 0.511**, which is well above the standard threshold for statistical significance ($p < 0.05$).
- The **low R^2 value (0.04)** suggests that very little of the variation in the standardized effect sizes is explained by precision, further supporting the lack of systematic bias.

Conclusion

The funnel plot confirms that the data collected from 13 studies on DM in Dachshunds is **balanced and reliable**, with **minimal publication bias and consistent precision**. This reinforces the confidence in the findings of this systematic review and supports the conclusion that Dachshunds have a moderately increased risk of developing diabetes mellitus, as identified across multiple independent studies.

The regression plot corroborates the earlier funnel plot observation: there is **no strong evidence of publication bias** among the studies analyzed. The scatter of study data is symmetric, and the regression line does not show a trend that would suggest small studies are disproportionately influencing the results.

This strengthens the **reliability and validity of the pooled findings** on Dachshund-specific diabetes risk and provides confidence in the integrity of the data set.

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