UNIVERSIDAD AUTÓNOMA AGRARIA ANTONIO NARRO

SUBDIRECCIÓN DE POSTGRADO

DETERMINACIÓN DEL PORCENTAJE DE PREVALENCIA DE LA ASIMETRÍA Y TORSIÓN DE EXTREMIDADES ANTERIORES, SU IMPACTO EN LA PRODUCCIÓN Y REPRODUCCIÓN EN VACAS LECHERAS

Tesis

Que presenta LUIS JESÚS BARRERA FLORES

como requisito parcial para obtener el Grado de
DOCTOR EN CIENCIAS EN PRODUCCIÓN AGROPECUARIA

Torreón, Coahuila   Julio 2025

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Dr. Rafael Rodríguez Martínez
Director UAAAN

Dr. Ulises Noél Gutiérrez Guzmán
Director externo UJED-FAZ

Torreón, Coahuila

Julio 2025

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Elaborada por LUIS JESÚS BARRERA FLORES como requisito parcial para obtener el Grado de Doctor en Ciencias en Producción Agropecuaria con la supervisión y aprobación del Comité de Asesoría

Dr. Rafel Rodríguez Martínez
Director de Tesis

Dr. Ulises Noél Gutiérrez Guzmán
Asesor

Dr. Francisco Gerardo Véliz Deras
Asesor

Dra. Leticia Romana Gaytán Alemán
Asesor

Dr. Alan Sebastián Alvarado Espino
Asesor

Dra. Dalia Ivette Carrillo Moreno
Jefe del Departamento de Postgrado

Dr. Antonio Flores Naveda
Subdirector de Postgrado

Torreón, Coahuila

Julio 2025

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RESUMEN

Determinación del porcentaje de prevalencia de la asimetría y torsión de extremidades anteriores, su impacto en la producción y reproducción en vacas lecheras

Luis Jesús Barrera Flores
Doctor en Ciencias en Producción Agropecuaria

Universidad Autónoma Agraria Antonio Narro

Dr. Rafael Rodríguez Martínez
Director de tesis

Se determinó la prevalencia de enfermedades de patas (LD), la torsión de extremidades anteriores y la asimetría distal (LTDA) en correlación con medidas zoometrícas, productivas y reproductivas de vacas lactantes en la Comarca Lagunera. En un primer estudio se observaron en corrales 4,270 vacas Holstein, asignando 1 a las vacas positivas y 0 a las negativas a LTDA, se midió el ancho, alto y distancia del borde del comedero a la trampa y la costra de estiércol adherida al muro y se obtuvieron los registros de la prevalencia de enfermedades de patas de todas las vacas. La LTDA y LD se analizaron mediante Xi^2, la correlación entre LD y los factores establo y corral se analizaron mediante componentes principales. La prevalencia de LTDA fue 27,6% y se muestra correlación positiva entre LD y el ancho muro comedero, distancia desde el borde del comedero a trampa, y la costra de estiércol adherida al muro del comedero. En el segundo estudio se seleccionaron aleatoriamente 120 vacas (60 positivas y 60 negativas a LTDA del primer estudio), se midió la altura a la cruz, la longitud del cuello y cabeza. Se consideraron los registros del número de lactancias, días en leche, promedio de producción, servicios por concepción, días abiertos y condición corporal. Se evaluó la asociación entre el LTDA y las medidas zoometrícas mediante regresión logística múltiple, y el efecto del LTDA sobre las variables productivas y reproductivas. Existe correlación positiva entre la altura a la cruz y la longitud del cuello con la LTDA. Los hallazgos indican que las variables productivas no inciden a la LTDA, pero sí las variables reproductivas como el tiempo de gestación. Las LD se relacionan a la distancia del borde del comedero a la trampa, la presencia de costras de estiércol adheridas.

Palabras clave: Torsión, asimetría, comedero, zoometrícas, LTDA

ABSTRACT

Determination of the percentage prevalence of asymmetry and torsion of forelimbs, their impact on production and reproduction in dairy cows

Luis Jesús Barrera Flores
Doctor of Science in Agricultural Production

Universidad Autónoma Agraria Antonio Narro

Dr. Rafael Rodríguez Martínez
Thesis supervisor

The prevalence of leg diseases (LD), forelimb torsion and distal asymmetry (DLDA) was determined in correlation with zoometric, productive and reproductive measurements of lactating cows in the Comarca Lagunera. In a first study, 4,270 Holstein cows were observed in pens, assigning 1 to positive cows and 0 to those negative to LTDA, the width, height and distance from the edge of the feeder to the trap and the manure crust adhered to the wall were measured and records of the prevalence of paw diseases of all cows were obtained. LTDA and LD were analyzed using *Xi2*, the correlation between LD and barn and corral factors was analyzed using principal components. The prevalence of LTDA was 27.6% and a positive correlation is shown between LD and the wide feeder wall, distance from the edge of the feeder to the trap, and the manure crust adhered to the feeder wall. In the second study, 120 cows (60 positive and 60 negative to LTDA from the first study) were randomly selected, height at withers, neck and head length were measured. Records of the number of lactations, days in milk, average production, services per conception, days open and body condition were considered. The association between LTDA and zoometric measures was evaluated by multiple logistic regression, and the effect of LTDA on productive and reproductive variables. There is a positive correlation between height at the withers and neck length with the LTDA. The findings indicate that productive variables do not affect LTDA, but reproductive variables such as gestation time do. LDs are related to the distance from the edge of the feeder to the trap, the presence of scabs of adhered manure.

Keywords: Torsion, asymmetry, feed bunk, zoometrics, LTDA

INTRODUCCIÓN

El bienestar animal depende del estado físico y mental del animal y ha sido evaluado con la medición de los recursos proporcionados a los animales, como el alojamiento o el diseño de este (Barker *et al.*, 2010). Los llamados parámetros indirectos de bienestar se pueden registrar de manera fácil en la mayoría de los casos de manera rápida y confiable. Comparativamente la provisión de determinados recursos medioambientales y procedimientos de gestión no necesariamente otorgan un alto nivel de bienestar. Por lo que el bienestar, debe ser evaluado válida centrándose en parámetros directos basados en el ganado lechero, como son la salud y el comportamiento propio de la especie, ya que reflejan mejor cómo las vacas son realmente capaces de hacer frente al conjunto determinado de condiciones de cría (Huxley *et al.,* 2004).

La ganadería lechera actualmente posee un rango muy grande en cuanto a tipos de infraestructura de establos, nivel de uso de tecnología de ordeño, acorde al tipo de sistema de producción y tamaño del hato lechero (Klaas *et al*., 2003). Los diversos modelos de producción lechera comparten ciertas preocupaciones con respecto al bienestar del ganado, siendo estas: 1) Enfermedades relacionadas con la producción, mastitis o trastornos metabólicos, 2) procedimientos dolorosos como el descorné de los terneros, y 3) enfermedades y/o problemas podales que generan restricciones de movimiento y comportamiento que afectan a la producción láctea y la eficiencia reproductiva (Klaas et al*.,* 2003).

En vacas lecheras las cojeras es un problema importante, las causas son variadas y relacionadas entre si, sobre todo en establos intensivos de alta producción, los orígenes de los problemas no son siempre los mismos. Conociendo el manejo de cada establo podremos plantear un programa preventivo, el cual será mucho más económico que dar tratamientos a las vacas. (Thomsen *et al.,* 2023).

Dentro de las causas con mayor relevancia que pueden causar cojera en las vacas es la Torsión de extremidades delanteras y la simetría de la falange distal (LTDA) (Muggli *et al*., 2011). No obstante, en la mayoría de los estudios de investigación, la asimetría de las extremidades anteriores ha sido el enfoque principal, mientras que la torsión solo se ha investigado en un número limitado de casos (Muggli *et al.,* 2011, Gundemir *et al.,* 2020, Parés-Casanova *et al.,* 2020a, Parés-Casanova *et al.,* 2020b). El objetivo es identificar en este estudio las variables de infraestructura y manejo, causales de torsión de extremidades anteriores y asimetría distal (LTDA).

Y la correlación de LTDA con las variables zoométricos, producción y reproducción en vacas de dos granjas intensivas de alta tecnología.

REVISIÓN DE LITERATURA

Origen y domesticación de los bovinos

Los bovinos son los mamíferos que se convierten en los animales domésticos de mayor importancia y, a nivel mundial, son del grupo de los grandes herbívoros. Existe controversia acerca de su domesticación; se ha propuesto que esta se produjo en Babilonia, antes de las invasiones de los indoeuropeos y semitas hacia Europa y oeste de Asia. Pero algunos arqueólogos, antropólogos y veterinarios de la India consideran que los bovinos nativos de la India fueron los primeros en ser domesticados. Evidencias arqueológicas muestran que la vaca sagrada de la India fue domesticada en el valle del Indo antes del 4000 a.C. y eran de una o de dos jorobas, al igual que sus antepasados salvajes (Pouran 2023).

En el proceso de domesticación los animales han desarrollado un cambio en comportamiento, forma y producción en los últimos tiempos. Las vacas lecheras, de doble propósito y las criadas para producción de carne, representan la especie doméstica más numerosa y, en aspectos económicos la más relevante a nivel mundial por su gran capacidad de adaptación (Pouran, 2023). El género *Bos* lo conforman varias especies, enfocándonos en el ganado taurino (*Bos taurus*) y el ganado cebú (*Bos indicus*) (Grison, 1978).

Bos Taurus y *Bos indicus* morfológicamente son diferentes entre sí; el ganado cebú se diferencia por la presencia de una giba prepondernte, la cabeza alargada en forma de semilla de uva y una cornamenta con crecimiento a los lados o verticalmente, orientados mayormente hacia atrás; también poseen características fisiológicas diferentes como: una menor tasa metabólica y menores requerimientos nutritivos, lo anterior es una adaptación ante la presencia de periodos de sequías y escasez de alimentos. Además, los cebuinos poseen una gran resistencia a temperaturas altas contrariamente a el ganado *Bos taurus*. Aparte, *Bos indicus* también presenta mayor resistencia a ectoparásitos y a parásitos internos. A pesar de estas diferencias tanto el ganado Cebuino como el tipo Europeo tienen el mismo número de cromosómas (2n=60) por lo que pueden cruzarse entre sí (Grison,1978).

La diferenciación entre *el ganado taurino y el cebú*

La diferenciación entre el ganado taurino (*Bos taurus) y el cebú (Bos indicus)* fue realizada a través de estudios mitocondriales que se realizaron mucho tiempo antes de su domesticación (Troy *et al.*, 2001). Troy *et al.* (2001), utilizaron 392 muestras obtenidas principalmente de de Europa y África, de las cuales 383 eran de ganado taurino y las nueve restantes de ganado cebú. A través de los estudios mitocondriales se pudo observar una gran diferencia entre ambas especies, estimándose que ocurrio hace más de 100,000 años. De la misma manera se observó que *Bos primigenius* tieme una relación muy estrecha con *Bos taurus*, pese a que claramente forman un clúster aislado.

Importancia del ganado lechero a nivel mundial

El incremento de la población, así como, el aumento de los ingresos, los cambios en el estilo de vida y forma de alimentarse, se refleja en el aumento exponencial de la demanda de productos cárnicos y lácteos. A la par, los sistemas de producción de ganado han impactado de manera significativa en la calidad del aire, el suelo, el agua y en la diversidad de especies. La ganadería lechera a nivel mundial coadyuva en aspectos de seguridad alimentaria, la leche es una fuente de alimentación y nutrición en todos los sectores sociales, se considera que contribuye al alivio de la pobreza y el crecimiento económico (Gerber, 2010).

La producción mundial anual de leche de bovino en 2022 fue de 753,320,578 miles de toneladas de leche fluida. México es el 14º país productor de leche de bovino, con el 2 % del total producida a nivel mundial (FAO, 2025).

Cuadro 1. Principales paises productores de leche de bovino en el año 2023 (Miles de toneladas de leche fluida)

País	Producción
India	127,105,140
Estados unidos	102,677,105
China	41,966.500
Brasil	36,436,492
Alemania	34,012,620
Rusia	33,559.230
Pakistán	23,893,450
Francia	23,882,000
Nueva Zelanda	21,245,000
Turquía	19,961,908
Reino Unido	15,759,500
Polonia	15,482,240
Países Bajos	14,685,300
México	13,735,386

Italia	13,058,970
Bangladesh	12,661,200
Uzbekistan	11,943,952
Argentina	11,665,405
Irlanda	8,730.710
Austria	8,467,000
Bielarosia	7,811,266
Irán	7,654,331
España	7,564,500
Colombia	7,309,000
Japón	7,297,614
Ucrania	7,267,100

Fuente: Información obtenida de FAO (2025).

Importancia de la producción lechera bovina a nivel nacional

A nivel nacional, dentro de los productos pecuarios producidos, la leche del bovino ocupa el 3er lugar con el 17 % (SIAP, 2023).

Cuadro 2. Valor de la producción pecuaria (miles de pesos) a nivel nacional en el año 2023.

Producto	Valor
Carne de bovino	171,506,595
Carne de ave	147,966,233
Leche de Bovino	112,820,105
Carne de porcino	91,682,067
Huevo para plato	87,969,090
Carne de ovino	6,086,170
Carne de caprino	3,102547
Miel	2,522524
Carne de guajolote	1,219,719
Leche de caprino	1,336,869

Fuente: Información obtenida de (SIAP, 2025)

La producción de leche de bovino representa el 3er lugar a nivel nacional en el valor de la producción pecuaria y representa el 17 %.

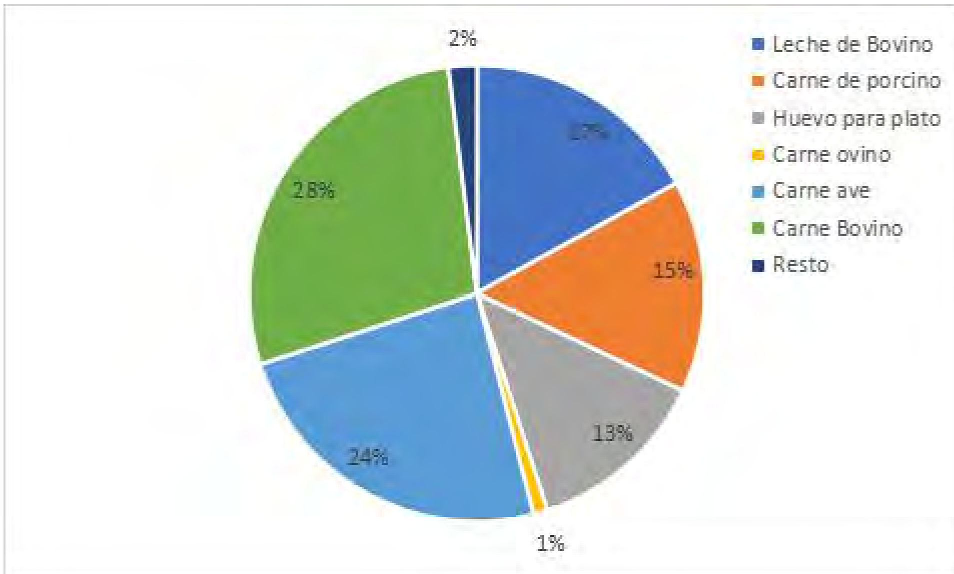

Figura 1. Producción pecuaria de México 2023 por porcentaje de abasto. (Elaboración propia, con datos de SIAP, 2025).

En el cuadro 3 se muestran los principales estados productores de leche de bovino, los cuales producen más dl 50% de la producción a nivel nacional.

Cuadro 3. Principales estado productores de leche de bovino (mies de litros) en el año 2023.

Estado	**Producción**
Jalisco	2´799,040
Coahuila	1´537,747
Durango	1,515,249
Chihuahua	1,262,218
Guanajuato	912,848
Veracruz	807,075
Puebla	462,639
Edo Mex	434,103
Hidalgo	429,856
Michoacán	382,988
Baja California	212,041

Cuadro 3. Principales estados productores de leche de bovino, información obtenida de (SIAP, 2025)

La Laguna, se considera una de las regiones más importantes para la producción de leche en México, la región abarca municipios del Estado de Coahuila (5) y municipios del Estado de Durango (10); la producción anual en la Comarca Lagunera de Coahuila es de 1,537,748,000 lt, y en la Comarca Lagunera de Durango es de 1,515,250,000 lt; existe en esta región un inventario de 547, 240 vacas en producción (SIAP, 2023).

En esta región existen cerca de 380 explotaciones de bovino lechero, 251 de tipo empresarial altamente tecnificados y 129 de familiar o de traspatio con tecnología media a básica para el ordeño, con hatos ganaderos de diversos tamaños y grado tecnológico, siendo los establos con alta tecnología propiedad de los socios de las empresas LALA, Alpura, Chilchota, Loneg y algunos proveedores de las empresas Danone, Nestle, Sigma, Pomas,Coca-Cola/Santa Clara, y los establos con tecnología de ordeño básica y traspatio son proveedores de las empresas Liconsa,Cremeria América, La Valenciana (Arellano *et al.,* 2020).

Las empresas altamente tecnificadas cuentan con salas rotativas (carruseles) en versiones paralelo ordeño exterior, espina de pescado ordeño interior, salas tipo paralelo, salas tipo parada y dos salas en auto tándem, sistemas de pulsación electrónica, retiradores automáticos, pesadores electrónicos con registro de conductividad eléctrica, células somáticas, temperatura, sistemas de identificación del ganado y detectores de celos, rumia y pH ruminal. En los que respecta a los corrales en estas grandes empresas todos son tipo open corral, con comedero de concreto con diferenciación de altura en el interior y trampas automáticas en pesebre. Cuentan con sistemas de enfriamiento de leche a paso con tanques enfriadores y los grandes emplean sistemas de enfriamiento instantáneo vía placas intercambiadoras y bancos de hielo o chillers (Rivas Sada, 2011).

Importancia de la ganadería lechera en La Comarca Lagunera

Las lactancias en la región lagunera van desde los 8,500 l hasta los 12,200 l por vacas por año (28 a 40 l/día/vaca) con estándares de calidad internacional (SIAP,2023).

De acuerdo con Loera, J. y Banda, J. (2017), los sistemas de producción bovino leche en México están relacionados con el nivel de productividad y competitividad, situación que impacta directamente en la eficiencia: la utilidad mayor se observa en las ganaderias con poca infraestructura en pastoreo; a diferencia, de la producciónpromedio en l/día esta por debajo al contrastarla con la producción de la ganaderia tecnificada. Para los dueños del ganado lechero cuidar del manejo y de la administración de sus unidades de producción es una regla de oro, aprovechando en lo posible la tecnología actual disponible, atendiendo la sanidad de los animales y capacitarse en temas orientados a lograr unidades más eficientes, como la integración a cadenas de valor, el acceso a esquemas de financiamiento disponibles y el manejo de la administración de riesgos.

En la Comarca Lagunera predominan los establos con gran nivel tecnológico, con sistemas de ordeño, enfriamiento de leche, manejo y gestión de los hatos; con infraestructura altamente especializada, establos desde un tamaño pequeño pero con un número de vacas en promedio de 200 vacas en producción, hasta los grandes con promedio de 25,000 vacas en producción; emplean el concepto de diseño de corrales abiertos rectangulares con la variación en el número de animales y el estilo de sombra, ya sea sombras independientes ubicadas al centro de los corrales o los grandes tejabanes que cubre hasta el 40 a 45 % del interior del corral y el área de alimentación y el mismo pasillo de maniobras. Con pisos de concreto y comederos del mismo material equipados con trampas automáticas metálicas galvanizadas, para el entrampe automático de las vacas para su revisión, pasillos de conducción, área de apretadero y sala de ordeño revestidos de concreto (Barrera-Flores *et al.,* 2024).

Sistemas de producción de leche bovina en México

En México los sistemas de producción de leche se diferencian considerando los aspectos tales como la raza o cruzas de ganado que utilizan, la tecnificación del ordeño y el sistema de enfriamiento o conservación de la leche, uso de toros o inseminación artificial, la ubicación geográfica y la alimentación del ganado (Ingredientes y forma de distribución en pesebre), y el proposito, es decir, si es fundamentalmente para producción de leche o también para la engorda de las crías para comercializar la carne (Martínez-Alba *et al.,* 2021). Deacuerdo con lo anterior Robledo-Padilla (2018), diferenció los siguientes sistemas de producción de leche:

1. **Sistema especializado.** Cuenta con ganado con alta genética y producción con razas Holstein, Suizo y Jersey, utilizan tecnología moderna o actualizada para el ordeño y el enfriamiento de la leche, así como para la administración y manejo de los establos, el sistema es de estabulación total principalmente y algunos en pastoreo controlado, el 50.0% de la producción en el país se obtiene bajo este sistema productivo,. (Figura 1).

Figura 1. Sistema especializado, comedero con trampas head lock en establo altamente tecnificado.

2. **Sistema semi-especializado.** El 20.0 % de la producción láctea total del país se desarrolla en este sistema, con razas F1 Holstein y Suizo, en instalaciones pequeñas se efectúa la ordeña, regularmente de manera manual y no se cuenta con equipo para enfriar la leche, el manejo del ganado es semiestabulado , con un nivel intermedio en cuanto a la producción y tecnología (figura 2).

Figura 2. Sistema semi-especializado, ordeña manual, /Ganadería en el Estado de Veracruz, México.

3. **Sistema familiar.** Generalmente se localiza en poblaciones rurales, se utilizan razas como la Holstein y Suizo con cruzas de estas destinadas a la producción con pastoreo para el autoconsumo, se realiza la ordeña manual en instalaciones con poca o nada infraestructura, con poco uso de tecnología, la producción representa el 21.0% a la producción nacional (figura 3).

Figura 3. Sistema familiar, ordeña manual en corral/ Ganadería de traspatio en el Estado de Michoacán, México.

4. **Sistema de doble propósito.** Es aquel donde el ganado se utiliza tanto para la producción de leche como para la producción de carne con razas de ganado cebú y cruzas con Suizo, Holstein y Simmental, alojadas en corrales rusticos y básicos, con ordeña manual; su aportación a la producción total nacional es del 9% y generalmente se desarrolla al sur y sureste de México, así como las zonas costeras del Golfo de México y el Océano pacifico (figura 5).

Figura 5. Sistema doble propósito, con razas Gyr y f1 suizo en Sureste de México.

La intensificación de la producción de lechera de bovinos ha requerido un cambio significativo en la modificación de los sistemas de producción, en aspectos tales como la selección, el manejo y la alimentación del ganado. Estos cambios hacen que los animales se sometan a situaciones de estrés continuo, lo que los hace más susceptibles a a presentar problemas en la salud, dentro de estos las patologías podales (Chuisaca Flores, 2011).

Problemas podales en vacas lecheras

Pérez López (2021), plantean que la problematica de las cojeras en el ganado bovino lechero es multifactorial, y se deben a multiples factores que interactuan entre sí, y estan relacionados fuertemente con las instalaciones y las condiciones donde se aloja el ganado, de tal manera que el origen o causas de los problemas no son los mismos en todas. Conocer oportunamente los factores predisponentes de estos problemas de cogeras para poder establecer planes de prevención, en prioritario, siempre será más beneficioso la prevención que aplicar tratamientos curativos.

En numerosos sistemas de alojamiento de establos lecheros contemporáneos, las vacas solo tienen un acceso limitado a suelos blandos, lo que representa una deficiencia notable en su cuidado general. A pesar del recorte regular y funcional de los cascos, que sirve para reducir la discrepancia de longitud entre los cascos y para mitigar la sobrecarga de los laterales delanteros y traseros, la prevalencia de úlceras en las plantas de las pezuñas y otros trastornos del patas sigue siendo considerable.

Por lo tanto, parece prudente proporcionar a las vacas lecheras corrales con suelo blando y pastos, especialmente durante el periparto, cuando las pezuñas son particularmente susceptibles a la enfermedad (Knott *et al.,* 2007). Esto sugiere que el ganado lechero no se ha adaptado con éxito a los sistemas de alojamiento intensivos fabricados, donde se emplea el concreto como material de piso de la instalación.

Uno de los principales factores predisponentes para la cojera de las vacas es la LTDA (Muggli *et al*., 2011).(figura 6 y7). Sin embargo, en varios estudios de investigación, la asimetría de las extremidades anteriores ha sido el enfoque principal, mientras que la torsión solo se ha investigado en un número limitado de casos (Muggli *et al.,* 2011, Gundemir *et al.,* 2020, Parés-Casanova *et al.,* 2020a, Parés-Casanova *et al.,* 2020b).

A **B**

Figura 6. A) Vaca positiva a LTDA en corral B) Vaca negativa a LTDA en corral.

C D

Figura 7. C) Asimetría distal extremidad anterior izquierda D) Asimetría distal extremidad anterior derecha

La prevalencia de cojera es mayor en las explotaciones ganaderas intensivas (Schlageter-Tello *et al.,* 2015, Smits *et al.,* 1992). La cojera en los hatos lecheros representando un grave problema, que tiene perjudiciales efectos sobre el bienestar animal, la producción láctea y la economía de pequeños a grandes productores nivel mundial. Cojera se denomina a cualquier afección de la pezuña o de las extremidades del bovino de origen infeccioso o no infeccioso que limita parcial o total la movilidad dependiendo del grado de afectación, la postura y la actividad de la vaca (Archer *et al.,* 2010). (figura 8).

Figura 8 Vaca con lesión de pezuña, tratada y se colocó con tacón de plástico, para ayuda en el proceso de recuperación.

Van Nuffel *et al. (*2015), indican que, en vacas lecheras, la principal causa de cojera son las lesiones en la pezuña, que pueden ser de origen no infecciosas (enfermedad de la línea blanca, úlcera en la sepia, hemorragia en la suela, hiperplasia interdigital) o de origen infecciosas, como la dermatitis digital (DD), la dermatitis interdigital, la erosión del talón y el flemón interdigital (pudrición de la pata).

ESTUDIO 1

Primer artículo : Impact of Feed Bunk Space on the Prevalence of Torsion and Foreleg Distal Asymmetry in Holstein Cows

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Article

Impact of Feed Bunk Space on the Prevalence of Torsion and Foreleg Distal Asymmetry in Holstein Cows

Luis Jesús Barrera-Flores [1,2], Rafael Rodríguez-Martínez [3,*], Francisco Gerardo Véliz-Deras [3], Guadalupe Calderón-Leyva [3], Viridiana Contreras-Villarreal [3], Ulises Noel Gutiérrez-Guzmán [2], Jorge Arturo Bustamante-Andrade [2], Amaury Esquivel-Romo [2], Robert Hagevoort [4] and Martín Alfredo Legarreta-González [5,6]

1 Programa de Doctorado en Producción Agropecuaria, Universidad Autónoma Agraria Antonio Narro Unidad Laguna, Torreón 27054, Mexico; luis.barrera@uaaan.mx
2 Facultad de Agricultura y Zootecnia, Universidad Juárez del Estado de Durango, Venecia 35000, Mexico; ulisesnoelg@yahoo.com.mx (U.N.G.-G.); jorge.bustamante@ujed.mx (J.A.B.-A.); amauryer@ujed.mx (A.E.-R.)
3 Departamento de Ciencias Médico Veterinarias, Universidad Autónoma Agraria Antonio Narro, Torreón 27054, Mexico; velizderas@gmail.com (F.G.V.-D.); gpecalderon09@gmail.com (G.C.-L.); dra.viridiana.c@gmail.com (V.C.-V.)
4 Agricultural Science Center at Clovis, New Mexico State University, Clovis, NM 88101, USA; dairydoc@nmsu.edu
5 Universidad Tecnológica de la Tarahumara, Chihuahua 33180, Mexico; mlegarreta@utarahumara.edu.mx
6 Postgraduate Department, Fatima Campus, University of Makeni (UniMak), Makeni City 00232, Sierra Leone
* Correspondence: rafael.rdz.mtz@gmail.com; Tel.: +52-871-189-3372

Simple Summary: The prevalence of foreleg distal asymmetry and its relationship with the size of the feed bunk were studied in two farms (G60 and G100) in northern Mexico. The prevalence was 27.6% (G60: 31.4%, G100: 22.4%); principal component analysis revealed that the weight variables associated with leg diseases were the farm (G60) and three out of twelve pens in G100. Furthermore, the analysis indicated that the weight variables for leg diseases were the farm (G60) and three out of twelve pens in G100. The prevalence was related to the width of the feed bunks and the width of the manure crust on them. The proper cleaning of feed bunks and their adequate design and construction are strategies that can reduce lameness and premature culling of cows.

Abstract: Leg torsion and distal asymmetry (LTDA) among cows reared on intensive farms in the Comarca Lagunera region of northern Mexico may be indicative of underlying health concerns. To ascertain whether the incidence of LTDA is associated with trough measurements and with productive, reproductive, and disease variables, the prevalence of LTDA was determined in lactating dairy cows. The data were derived from two intensive dairy farms in northern Mexico (G60: 2043 cows in 13 pens with 142.0 m of linear feed bunk space and 65.0 m of pen depth; G100: 2227 cows in 12 pens with 213.0 m of linear feed bunk space and 49.0 m of pen depth). The cows were observed over the course of a week to identify any macroscopic lesions indicative of LTDA. Cows exhibiting lesions were assigned a value of "1", while those without lesions were assigned a value of "0". Furthermore, data regarding other limb diseases (LDs) were collected and subjected to analysis. A comparison was conducted to ascertain the impact of reproductive, productive, and feed bunk size variables on the prevalence of LTDA and other LDs. To ascertain the prevalence of LTDA and LDs, a chi-squared test was employed. The prevalence of LTDA was found to be 27.6% (G60: 31.4%, G100: 22.4%). No association was identified between LTDA and the variables included in the study. However, a correlation was identified between LDs and the following variables: total width, distance from the edge, width from the feed bunk to the tramp, and the presence of a manure crust on the walls. Principal component analysis (PCA) was conducted to examine the correlation between LDs and various factors at the farm and pen levels. The findings indicated that the distance from the feed bunk to the trough, the presence of manure crusts on the walls, and the breeding time were associated with LDs in G100, as well as in three of the twelve pens (302, 306, and 308) within G100. The findings suggest that the prevalence of LDs is associated with an increase in the width of the feed bunk and

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the width of the manure crust on the walls, particularly in pregnant cows. The results permit the conclusion that LTDA and LDs are associated with the measurements of the feed bunks, the absence of manure cleaning of the feed bunks, and gestation. This association gives rise to significant health issues for Holstein cows on these farms, with more than one in four cows affected. To reduce the prevalence of LTDA in lactating dairy cows, it is recommended that the standard measurements for feed bunk design be adhered to. This will reduce the prevalence of LTDA and LDs, promote the cleaning protocols to avoid the accumulation of manure crusts, and facilitate close monitoring of pregnant cows, thereby alleviating the impacts of these foot pathologies on animal welfare.

Keywords: animal welfare; cow locomotion; foreleg torsion; distal asymmetry; feed bunk design; principal component analysis

1. Introduction

Lameness in dairy cows has a significant adverse effect on both animal welfare and production [1]. Furthermore, lameness can have a deleterious impact on cow welfare by impeding their ability to move without discomfort [2]. The prevalence of lameness in cattle in modern dairy production systems is high [3,4]. Cows have been observed to exhibit a preference for walking on soft surfaces [5,6]. Moreover, the prevalence of injuries to cows' feet decrease when cows walk on grass or sandy soil [5,7]. One of the primary predisposing factors for lameness in cows is leg torsion and distal asymmetry (LTDA) [8]; this can be defined as the presence of a macroscopic lesion that manifests as torsion and growth of the hoof wall in the internal frontal phalanx, which is far from the fetlock joint, which causes inflammation and locomotion problems in dairy cattle (Figure 1). Similarly, the phenotype of the high-producing Holstein Friesian breed, with its large animals where adult females can weigh up to 680 kg, is regarded as a contributory factor in the appearance of lameness in intensive production systems [9–11].

Figure 1. (**A**) Positive cow exhibiting limb torsion and distal asymmetry (LTDA), and (**B**) negative cow. In the positive cow, the position of the open anterior legs and the larger size of the internal toes of both extremities are observed, which are absent in the negative cow.

In numerous contemporary dairy farm housing systems, cows are afforded only limited access to soft soil, which represents a notable deficiency in their overall care. Notwithstanding the regular functional hoof trimming, which serves to reduce the length discrepancy between the hooves and to mitigate the overload of the front and rear lateral hooves, the prevalence of sole ulcers and other foot disorders remains considerable. It seems prudent, therefore, to provide dairy cows with pens with soft soil and pastures, especially during peripartum, when the hooves are particularly susceptible to the disease [12]. This suggests that dairy cattle have not successfully adapted to manufactured intensive housing systems, where concrete is employed as the facility's floor material. One of the primary predisposing factors for cow lameness is LTDA [4]. However, in the majority of research studies, forelimb asymmetry has been the primary focus, while torsion has only been investigated in a limited number of cases [8,13–15].

The prevalence of lameness is higher in intensive livestock farms [16,17], as is the case on farms in the Comarca Lagunera area in north-central Mexico. The region is home to a dairy cow population of 506,217, representing 20.33% of the national herd and producing 2,730,752 thousand liters of milk per year, which constitutes 21.75% of the country's total [18]. The objective of the study was to evaluate the prevalence of lameness in dairy cows on large dairy farms in the Comarca Lagunera area and to analyze the variables that cause this pathology and their association with productive, reproductive, and disease variables in this important dairy area. This study assessed a greater number of animals than in previous studies, with the objective of identifying the primary cause of LTDA and thus preventing its adverse effects on animal welfare [19].

2. Materials and Methods

2.1. Overview

All experimental and animal handling procedures were conducted following the guidelines for the ethical use, care, and welfare of research animals at the international [20] and national levels [21] and with institutional approval (UAAAN-UL-18-3059).

2.2. Location, Weather Conditions

The study was conducted on two large dairy farms in north-central Mexico (25°52′39″ LN, 103°23′39″ LO), a region characterized by a dry climate with an average annual temperature of 21 °C, ranging from 0 °C (winter) to 37 °C (summer), with rainfall occurring from June to September with an annual average of 266 mm [22].

2.3. Description of the Experimental Area

The pens utilized in the study were constructed with concrete cow alleys measuring 15 cm in thickness. The alleys were reinforced with a 20 × 20 cm electro-welded rebar mesh exhibiting a concrete strength of 400 kg/cm^2 with 1.27 cm aggregate. The alleys were 3.5 m in width and sloped laterally at a rate of 0.7%, a design feature that facilitates mechanical cleaning. The surface of the pen was composed of a mixture of clay-rich soil and fine sand. The sidewalk floors in corrals were equipped with eight channels, each measuring 2.5 cm in width and depth, and designed to provide a non-slip surface. The head gates were constructed from galvanized stanchions, measuring 3.05 m in length, which were mounted on schedule 80 steel support posts. The aforementioned gates were inserted into the feed curb and were of similar concrete strength to that of the walkways. The gates were equipped with a self-locking mechanism and five holes. All soil surfaces, all the sidewalk floors in corrals, and all the head gates were similar in all the pens.

The first farm (G60) was home to 2043 lactating Holstein cows, which were evaluated in 13 pens. The pens were 142 m in length (along the feed lane) and 65 m in depth, with a slope of 1.5%. The height of the inner wall of the feed bunker exhibited a range of 27.5–46 cm, while the width of the trap support wall at the troughs varied from 19.5 to 21 cm. Furthermore, the distance from the inner edge of the trap support wall to the inner base of the traps exhibited variability, with measurements ranging from 13 to 16 cm (Figure 2A). A total of 2227 lactating Holstein cows in 12 pens were evaluated on the second farm (G100). The pens on this farm were 215 m in length (along the feed lane) and 49 m in depth, with a slope of 1.5%. The height of the inner wall of the feed bunker exhibited a range of 28 to 38 cm, while the width of the trap support wall at the feeders demonstrated a fluctuation of 28.5–37 cm. Furthermore, the distance from the inner edge of the trap support wall to the inner base of the traps varied between 20 and 22 cm (Figure 2B).

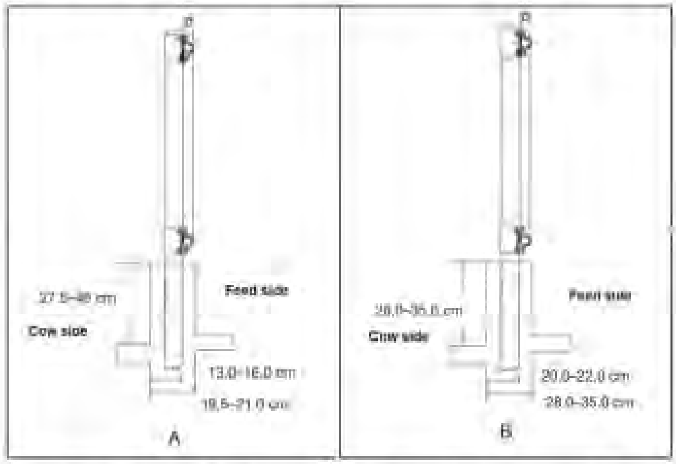

Figure 2. Section of feeder wall of the pens of farm G-60 (**A**) and the pens of farm G100 (**B**).

2.4. Characteristics of the Animals

A total of 4270 lactating Holstein Friesian cows were evaluated on both farms. Cows in G60 were from one to six lactations, while in G100 they were from two to five lactations. The cows in both dairies were milked three times per day and had been in milk for less than 120 days. A fourth milking was conducted at the peak of the lactation period. The cows in both dairies had unlimited access to drinking water. The diet provided to the cows was based on their nutritional requirements [23] and consisted of the following components: corn silage, alfalfa hay, whole cottonseed, soybean meal, canola meal, rolled corn, molasses, a mineral package, a mycotoxin binder, and sodium bicarbonate.

2.5. Determining the Prevalence of LTDA

To determine the prevalence of LTDA, the front legs of all cows were observed for a seven-day period between the hours of 5:00 a.m. and 3:00 p.m. while they were either ingesting feed or resting, without disturbing their rest. Cows exhibiting twisting and growth of the hoof wall at the anterior distal internal phalanx were classified as positive for LTDA and assigned a value of "1". Cows that did not exhibit any lesions were considered negative for LTDA and assigned a value of "0". Moreover, photographic documentation of the cows in question was obtained. Photographs were taken with a cell phone camera (iPhone 11, Apple Inc., Zhengzhou, China; 12-pixel resolution) at a distance of 1.0 m, at an approximate height of 1.20 m, and at an angle of 30–40°. This approach permitted a more comprehensive examination of the lesions. Furthermore, data from additional LDs were documented.

2.6. Analysis of the Effect of Variables on the LTDA and LD Presence

The objective was to relate the presence of LTDA and LDs with the physical characteristics of the feed bunk on both farms and with productive, reproductive, and disease variables. To this end, the dimensions of the feed areas were measured: the width of the feeder walls (WF), the distance from the edge of the wall to the trap (WTD), and the height of the feed bunk walls (HF). Furthermore, the width (SWF) and height (SHF) of the manure crust adhering to the wall were also measured. All these measurements are expressed in cm. The resistance of the manure crust to manual pressure was also evaluated, with scores of 1, 2, and 3 assigned to indicate the crust's softness (1), medium softness (2), and hardness (3), respectively. Following standard practice, the measurements were taken with a 6 m retractable measuring tape (Truper FCG-6M). The productive variables of interest include dairy farm (DF), corral number (CN), lactation (LC), days in milk (DIM), last production 24 h (PLD), body condition score (BCS), ruminant movement average 24 h (RA; Cow Watch, NEDAP Agri, Netherlands), and activity average 24 h (AA; Cow Watch, NEDAP Agri, Netherlands). The reproductive variables were as follows: the breeding number (IA); the status (ST, calving = 1, abort = 2, empty = 3, heat = 4, inseminated = 5; pregnant test I = 6, pregnant test II = 7, dry = 8); the pregnancy time (BT); the open days (OD); the calving interval (CI). The data presented herein were obtained from farm systems (DP21, Westfalia Surge, Oelde, Westfalia, Germany). The variables designated as "diseases" were limb torsion and distal asymmetry (LTDA) and leg diseases (LDs: crooked, foot rot, and lameness).

2.7. Statistical Analysis

The distribution of LTDA and LD cases was evaluated using the chi-square test and a principal component analysis (PCA) was employed to ascertain the variables associated with the prevalence of both of them. The X^2 and PCA analyses were conducted using the R programming language [23]. Only those differences that reached a level of statistical significance ($p \leq 0.05$) were accepted for further consideration.

3. Results

The present study considered cows belonging to the G60 and G100 groups, with a minimum of one and maximum of six lactations. In order to analyze the level of interaction between variables of production, reproduction, as well as variables of pen infrastructure and cleaning, and their level of causality for LTDA and LDs, several variables were considered.

3.1. Statistical Descriptive of Numerical Variables of Study

The statistical descriptive of the variables analyzed in this study is presented in Table 1, where mean, standard deviation, minimum, and maximum values for each one the variables can be observed.

Table 1. Descriptive statistics of variables in relationship with limbs torsion distal asymmetry in cows from two farms in northern Mexico. Mean, standard deviation, minimum, and maximum.

Variable	Mean	SD	Min	Max
Lactation number	3.32	1.52	1.00	9.00
Days in milk	130.14	82.58	2.00	571.00
Last production in 24 h	40.38	9.90	0.00	100.65
Breeding services	2.58	1.70	1.00	10.00
Open days	91.34	51.53	2.00	324.00
Calving interval	385.83	71.67	0.00	916.00
Body condition score	3.74	8.71	2.75	325.00
Pregnancy time	61.05	49.22	0.00	215.00
Ruminant movements in last 24 h	275.21	62.83	1.00	598.00
Activity average in last 24 h	247.39	58.04	24.00	833.00
Width of feed bank	0.24	0.05	0.19	0.37
Distance from the edge of the wall to the top	0.18	0.05	0.13	0.22
Height of the feed bunk	0.32	0.05	0.28	0.48
Width of manure crust adhered to the wall	10.70	4.22	5.00	17.00
Height of manure crust adhered to the wall	21.34	9.05	8.00	40.00
Total width of the feed bunk	10.74	4.15	5.20	16.29

3.2. *Principal Component Analysis*

3.2.1. Asymmetry/Torsion Prevalence (LTDA, LDs)

The 14 selected variables were subjected to an analysis grouped by LTDA and LDs using the principal component analysis (PCA) method. The results indicated that a total inertia was explained by the first two components, amounting to 43.5%. Nevertheless, no distinction could be made between the positive and negative groups of cows. Table 2 presents the results from the X^2 analyses from the variables related with LTDA, which highlights the differences between negative and positive groups ($p < 0.05$) with a percentage of 72.4 for negative and 27.6 for positive cows. In relation to the status of cows, we also found differences ($p < 0.05$ for this variable, with the biggest value for inseminated cows (41.8%) and the lowest value for aborted cows (0.00)). Finally, leg disease variables showed differences ($p < 0.05$), with lameness being the most important associated variable (94%).

Table 2. Categoric variables in relationship with foreleg torsion distal asymmetry in cows from two farms in northern Mexico: n, percentage, χ^2, and significance.

	n	Percentage	χ^2	Significance
Foreleg torsion and distal asymmetry				
Negative	3090	72.4	854.36	***
Positive	1180	27.6		
Status				
Abort	2.0	0.0	6091.34	***
Colostrum	354	8.8		
Fresh	324	7.6		
Inseminated	1788	41.8		
Another	101	2.4		
Pregnancy test 1	1162	27.2		
Pregnancy test 2	341	8.0		
Cull	124	2.9		
Empty	78	1.8		
Leg diseases				
Crooked	15	3.2	803.62	***
Foot rot	9	1.9		
Lameness	447	94.0		

Significance level $p > 0.05$, NS; $p < 0.001$ ***.

With regard to the prevalence of LTDA and LDs (Table 3) in each of the study barns, both were observed to be higher ($p < 0.05$) in G60 than in G100 (LTDA, G60 = 31.4% vs. G100 = 22.4%; LDs, G60 = 17.6% vs. G100 = 1.7%). Significant differences were observed between the two farms for LTDA and LDs in the proportion of positive cows (LTDA: G60 (0.31), G100 (0.22) [χ^2 (1, 41.196), $p < 0.001$]; LDs: G60 (0.18), G 100 (0.02) [χ^2 (1, 268.01), $p < 0.001$].

Table 3. Prevalence of limb torsion and distal asymmetry (LTDA) and leg diseases (LDs) in two intensive dairy farms in northern Mexico.

	n	G60	G100	χ^2	Significance
LTDA					
Negative	3090	1706 (68.6)	1384 (77.6)	41.64	***
Positive	1180	780 (31.4)	400 (22.4)		
LDs					
Negative	3799	2046 (82.30)	1753 (98.26)	269.64	***
Positive	471	440 (17.60)	31 (1.74)		

Significance level $p > 0.05$, NS; $p < 0.001$ ***.

3.2.2. Principal Component Analysis: LTDA

To analyze LTDA with the variables of the study, these were grouped according to their association resulting in a total of 43.5% variation explained by the first two components (PC1, 22.6% and PC2, 20.9%); Table 4.

Table 4. Principal component analysis for foreleg torsion and distal asymmetry (LTDA) in cows from two farms in northern Mexico.

	PC1	PC2
Lactation	−0.2621	0.0584
Days in milk	0.3400	−0.4081
Last production to last 24 h	−0.0898	0.3188
Breeding services	0.1135	−0.4949
Open days	−0.0106	−0.5165
Calving interval	0.0231	0.0947
Body condition score	0.0969	−0.1176
Pregnancy time (BT)	0.4601	0.0166
Ruminant movement average last 24 h	0.2474	0.1162
Activity average 24 h	0.2988	0.0746
Width of the feed bunk wall (WF)	0.4755	0.1555
Distance from the edge of the wall to the trap (WTD)	−0.0865	−0.3400
Width of the manure crust adhered to the wall (SWF)	0.3373	0.1582
Total width (TW) [WTD + SWF]	0.2743	0.0989

PC1 = Principal component 1; PC2 = Principal component 2.

PCA found no association between the variables included in the study and LTDA (Figure 3), although it is observed that the variables SW, SWF, and BT are grouped in the same direction.

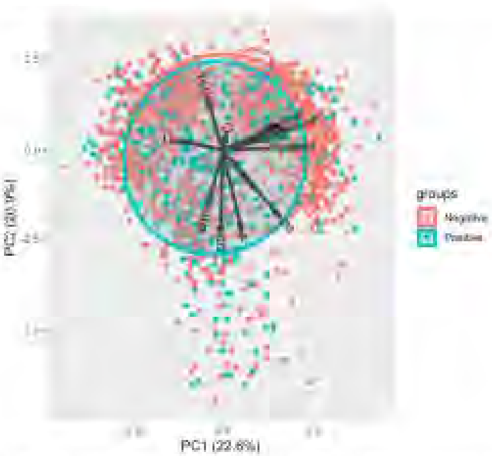

Figure 3. Principal component analysis for foreleg torsion and distal asymmetry (LTDA) in cows from two farms in northern Mexico. PC1 = Principal component 1, PC2 = Principal component 2, DM = Days in milk, PLD = Last production in 24 h, IA = Breeding days, OD = Open days CI = Calving interval, BCS = Body condition score, BT = Pregnancy time, RA = Ruminant movement average last 24 h, AA = Activity Average in last 24 h, WF = Distance from the edge of the wall to the trap, WTD = Height of the feed crust, and SWF = Height of manure crust adhered to the wall.

3.2.3. Principal Component Analysis: LDs

To analyze LDs with the variables of the study, these were grouped according to their association resulting in a total of 32.8% variation explained by the first two components (PC1, 26.0% and PC2, 16.8%); Table 5.

Table 5. Principal component analysis for leg diseases (LDs) in cows from two farms in northern Mexico.

	PC1	PC2
Lactation	0.1859	0.3025
Days in milk	−0.4942	−0.1635
Last production to last 24 h	0.3396	0.0115
Breeding services	−0.4499	0.0543
Open days	−0.4323	0.0898
Calving interval	0.0472	0.0263
Body condition score	−0.1450	−0.0479
Pregnancy time (BT)	−0.2745	−0.2219
Ruminant movement average last 24 h	0.0431	−0.2680
Activity average 24 h	−0.0317	−0.0483
Width of the feed bunk wall (WF)	−0.0069	−0.5728
Distance from the edge of the wall to the trap (WTD)	−0.3110	−0.0637
Width of the manure crust adhered to the wall (SWF)	0.1292	−0.4663
Total width (TW) [WTD + SWF]	0.0405	−0.5491

PC1 = Principal component 1; PC2 = Principal component 2.

The distinction between LDs and the variables with the highest values associated with this group is shown in Figure 4. Results for WF, SWF, and TW were found to be 0.579718, 0.3371, and 0.50856, respectively.

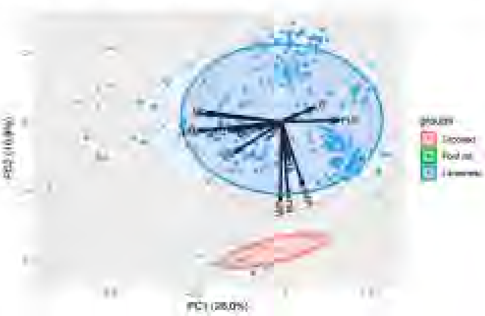

Figure 4. Principal component analysis for legs diseases (LDs) in cows from two farms in northern Mexico. PC1 = Principal component 1; PC2 = Principal component 2, DM = Days in milk, PLD = Last production in 24 h, IA = Breeding days, OD = Open days CI = Calving interval, BCS = Body condition score, BT = Pregnancy time, RA = Ruminant movement average last 24 h, AA = Activity Average in last 24 h, WF = Distance from the edge of the wall to the trap, WTD = Height of the feed crust, and SWF = Height of manure crust adhered to the wall.

3.2.4. Principal Component Analysis for Dairy Farms

Following the identification of variables associated with the LTDA, another principal component analysis was conducted to ascertain whether the variables exhibiting this association are related to the dairy farms, since the study was conducted on two dairy farms (G60 and G100). The sum of the principal components (PC1 + PC2) is equal to 43.5% (PC1 22.6%, and PC2 20.9%) (Table 4).

The results demonstrated that the variables associated with the occurrence of crooked cows are related to dairy farm G100 (Figure 5). The analysis demonstrates that the variables with the greatest weight are those pertaining to the total width of the feed bunk. These variables are the manure crust adhering to the feeder wall (WF) and the distance from the edge of the wall to the feeder trap (SWF), which exhibited the following values: WF (0.631) and SWF (0.4955). Another significant associated variable was breeding time (BT), which exhibited a value of 0.4767.

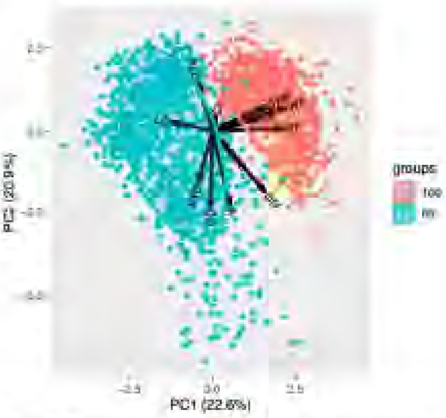

Figure 5. Principal component analysis for dairy farm in cows from two farms in northern Mexico. PC1 = Principal component 1; PC2 = Principal component 2. DM = Days in milk, PLD = Last production in 24 h, IA = Breeding days, OD = Open days CI = Calving interval, BCS = Body condition score, BT = Pregnancy time, RA = Ruminant movement average last 24 h, AA = Activity Average in last 24 h, WF = Distance from the edge of the wall to the trap, WTD = Height of the feed crust, and SWF = Height of manure crust adhered to the wall.

3.2.5. Principal Component Analysis for Pens

Another analysis was developed to investigate whether there is a relationship between these variables and specific pens. The results of the principal component analysis (PCA) indicated that pens 308, 302, and 306 are associated with these specific variables. Principal component analysis was performed on the data set derived from the G100 barn. The sum of the principal components (PC1 + PC2) yielded a value of 43.5%, with PC1 accounting for 22.6% and PC2 for 20.9% (Table 4).

The analysis shows that the variables with the highest weight were SWF and WF which interacts mainly in pens 308, 302, and 306 (Figure 6). In all barns, the measurements of the wall show a WF value of 0.20 m. The only noticeable difference between these three barns is the presence and height of the manure crust adhering to the wall. The manure crust height for corrals 308, 302, and 306 was 0.24 m, 0.40 m, and 0.30 m, respectively. Furthermore, BT is identified as a significant variable in the analysis. The variable values are as follows: The WF variable has a value of 0.631, the SWF variable has a value of 0.495, and the BT variable has a value of 0.4767.

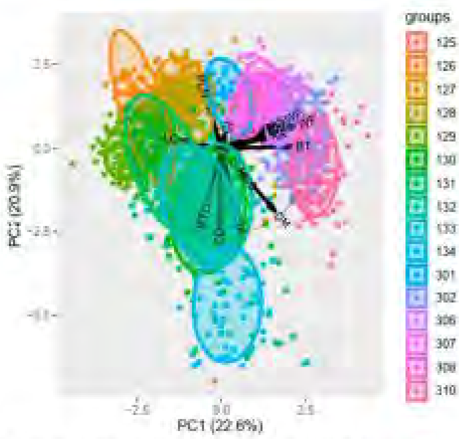

Figure 6. Principal component analysis for corrals/pens of G100 in cows from northern Mexico. PC1 = Principal component 1; PC2 = Principal component 2, DM = Days in milk, PLD = Last production in 24 h, IA = Breeding days, OD = Open days CI = Calving interval, BCS = Body condition score, BT = Pregnancy time, RA = Ruminant movement average last 24 h, AA = Activity Average in last 24 h, WF = Distance from the edge of the wall to the trap, WTD = Height of the feed crust, and SWF = Height of manure crust adhered to the wall.

Figures 7–9 illustrate the realistic physical conditions of the G60 and G100 feeder bunks, as well as the manure crusts attached to them and the behavior of the cows in accessing the feed. Figure 7A depicts a G100 feeder bunk, which has been designed in a manner that is more conducive to promoting feed consumption by cows. This is due to the fact that the feeder bunk does not induce the cows to twist their forelimbs, which can predispose them to LTDA. Figure 7B depicts a G100 trough that has accumulated crust, resulting in an increase in width. This impedes the cattle's ability to access the feed adequately.

Figure 7. Feeder bunk without crust (**A**) and barn feeder with crust (**B**) of the G100 dairy farm in north-central Mexico.

Figure 8. Non-crusted feeder bunk (**A**) and crusted feeder bunk (**B**) of the G60 dairy farm in north-central Mexico.

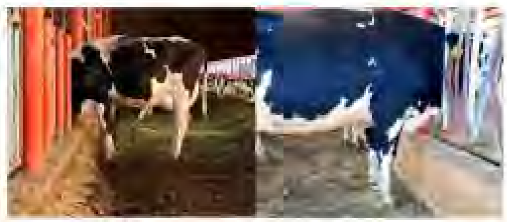

Figure 9. Non-crusted feeder bunk (**A**) and crusted feeder bunk (**B**) of the G60 dairy farm in north-central Mexico.

Figure 8 illustrates the configuration of feeder bunks on the G60 farm. The initial image (A) depicts a feeder devoid of a crust, whereas the subsequent image (B) illustrates a feeder with a crust. As can be observed, there is a notable difference in the accumulation of crust between the G100 and G60 samples.

Figure 9 illustrates the behavior of cows consuming feed in a G100 pen (A) and in a G60 pen (B). The first cow displays an opening of the limbs, while the second cow does not exhibit this additional effort.

4. Discussion

Our results show that the design of the feed bunk on dairy farms, and more specifically the height of the feed curb, affect the health of the front legs, increasing the prevalence of leg torsion and distal asymmetry (LTDA) and leg diseases (LDs) according to feed bunk weight augments. The overall prevalence of LTDA found in this study was 27.6%, with 31.4% in G60 and 22.4% in G100. Solano-López et al. [10] reported a prevalence of limb torsion of 35% in cows with five lactations and 36.2% for cows with six lactations. The bigger prevalence reported by Solano-López et al. could be explained because their study was conducted in Canada, where the cows under investigation remained on slippery floors, in contrast to dairy cows from the Comarca Lagunera region of north-central Mexico, which spent a significant portion of the day directly on soft pen surfaces.

The PCA results indicate that there is no statistically significant association between the variables included in the study and LTDA. Nevertheless, a statistically significant correlation was identified between the variables and LDs. In this case, the variables with the highest weights were WF, SWF, and TW, with values of 0.579718, 0.3371, and 0.50856, respectively. It is likely that the lack of an association in LTDA is a consequence of the failure to include other variables with explanatory capacity, particularly the physical conformation of the cows, given that the cows in the barns included in the study originate from disparate genetic lines. It is widely accepted that the limbs of cattle are symmetrical, however, the available data on this subject are limited [8,25] and few studies have investigated geometric morphometry [14,15], which is inheritable.

The elevated prevalence of LTDA in G60 can be attributed to the augmented dimensions of the feed bunk in this farm (high and wide) in comparison to those in G100, as substantiated by the findings. In this regard, Gündemir et al. [13] conducted an analysis of the phalanges of the hind and forelimbs of Holstein cows obtained from slaughterhouses in the Istanbul region. Morphometric measurements were taken from 144 digital bones, and the researchers concluded that forelimb asymmetry may be related to the fact that the cows were raised and kept on concrete floors. Furthermore, the disparate distribution of stress on the cattle's legs has been linked to the anatomical positioning of the hooves during feeding in the pen [26]. This is also related to the dimensions of the feed bunk, which restrict the quantity of food that cows can consume at one time during feeding. It seems reasonable to suggest that the higher prevalence in G60 is attributable to the variation in feed bunk height and width across pens. When cows transition between pens based on days in milk, they must adapt to the disparate feed bunk dimensions. In contrast, in G100, all feed bunk dimensions are consistent across pens. In contrast, the feed fences in G60 are taller and wider, which may contribute to increased postural stress for cows on this farm. Moreover, the change of pens is associated with the reproductive condition of the cows (pregnant or not), which may also predispose to the presence of LTDA and LDs. This is because the PCA asserts that breeding time predisposes to these diseases, particularly in pregnant cows [10].

A number of factors have been identified as affecting hoof health, including genetics, diet, infectious agents, hygiene, housing systems, animal behavior, and management practices [27]. In this regard, painful conditions affecting the musculoskeletal system of the cow prompt the animal to alter its gait and posture in order to reduce discomfort. Such changes are evidenced by alterations in movement, gait, or posture [28]. Furthermore, foreleg and hind leg disorders resulting in lameness are more prevalent in higher-yielding management system [29,30]. Furthermore, the ongoing process of selecting and crossbreeding dairy cattle for production and reproductive traits has resulted in the unintended consequence of the neglect of other essential characteristics, such as the structure of the limbs [31]. Consequently, further research is required to ascertain the mechanisms by which the prevalence of distal asymmetry and foreleg rotation can be reduced, thus extending the productive life of cows and improving animal welfare [29].

Lameness represents a significant concern within the dairy industry, given its associated costs and implications for animal welfare [32]. The estimated cost of clinical lameness in dairy cattle is approximately $500 per case [33], which translates into significant economic losses in intensive production systems and concerns regarding animal welfare. In this context, the term "costs" is understood to encompass not only financial losses but also losses pertaining to animal health and welfare [29].

Visual locomotion scoring has been a commonly utilized method for assessing the quality of cow movement. However, it has been demonstrated to be an unreliable and relatively subjective method of locomotion assessment when compared to automated alternatives [25]. The application of kinematic, kinetic, and accelerometric technologies enables the acquisition of more detailed outcome measurements than those obtained through visual scoring [34], which must be evaluated to qualify the possibility of their use in the farms with LTDA problems.

Another issue pertaining to the locomotion of cattle, which is prevalent in highly technical systems and intensive conditions, is directional asymmetry. This phenomenon is evidenced by a significant divergence in direction [35]. This can be attributed to lateralized behavior and biomechanical pressures exerted on a single side of the bovine body [36]. It seems reasonable to suggest that deficiencies in the design of feed bunk structures and their subsequent impact on hoof health (LTDA and LDs) may result in impaired feeding behavior in cows, which in turn could affect the Five Freedoms of Animals as outlined by the Farm Animal Welfare Council [2]. This is because cows experiencing discomfort are unable to express normal behavior, which may manifest as fear and distress. It is evident that foot diseases have a significant impact on the welfare of cattle, leading to alterations in their behavioral patterns. These include changes in their grazing and rumination habits, resting patterns, recumbency, and water intake [37,38]. In this regard, foot health has been identified as the most significant welfare issue in dairy cows, and its monitoring represents the most reliable indicator of welfare in dairy cattle [39].

The presence of LTDA and LDs has the potential to result in the experience of pain, which has the capacity to significantly impair animal welfare. This is due to the aversive nature of pain, the distress associated with the inability to avoid such sensations, and the adverse effects that can negatively impact the animal's overall quality of life. Furthermore, pain can affect a number of additional functions, including appetite, sleeping patterns, and intestinal function. Consequently, cows afflicted with LTDA or LDs are deprived of the fundamental right to freedom from pain, which is a crucial aspect of animal welfare. The aforementioned conditions have a detrimental impact on a number of factors, including chronic pain, body condition, reproductive capacity, productive potential, and destructiveness [40]. For this reason, stress has been employed as an indicator of diminished well-being, given its capacity to disrupt internal homeostasis through the induction of alterations in autonomic nervous system activity and the hypothalamic–pituitary–adrenocortical axis [41]. The presence of an unevenly sized feeder bunk with a manure crust adhering to it may result in difficulties in accessing feed and gestation, which could potentially lead to stress in the animals [41]. As a result, the presence of LTDA exerts an influence on a number of aspects pertaining to an animal's well-being, including its capacity to feed and drink without restriction, its ability to engage in species-specific behaviors, its experience of pain or stress, and its overall health status. This can be attributed to the clinical effects of LTDA.

The present study is limited by a number of factors. Firstly, the exclusion of zoometric variables pertaining to the cattle represents a notable shortcoming in the study. Secondly, the relatively limited number of farms included in the study represents a limitation of the study. Thirdly, the lack of progeny data that could contribute to an understanding of genetic effects represents a further limitation. Additionally, the absence of measurements of chemical indicators of stress, such as cortisol and heat shock proteins, represents a further limitation. Moreover, the absence of progeny data, which could provide insight into genetic effects, represents a significant limitation. The findings of our study suggest a correlation between the configuration of the feed bunk (specifically the dimensions of the feed curb), the cleaning and maintenance of pens, and the prevalence of LTDA in lactating Holstein cows. The dimensions of the feeder bunks in G100 were excessive, which may have contributed to lameness in the legs. This discrepancy between the original concrete dimensions and the accumulation of manure may have been a contributing factor. It is therefore recommended that the G60 pen design, illustrated in Figure 7A, be employed and that there be no variation in pen construction. Moreover, it would be prudent to consider the body size of the dairy animals to be housed when designing feeder bunks. Further research on facility design is recommended, as it can impact both animal welfare and productive life.

5. Conclusions

The dimensions of dairy cattle feeder bunks require the cow to expend additional effort to reach the feed when the feeders are of a larger size, due to the increased distance the cow must traverse to access the feed. This results in the limbs being rotated outwards, which can lead to the development of deformed and asymmetrical toes (LTDA).

Moreover, the width of the crust is a contributing factor to the presence of LTDA and LDs. It is thus recommended that dairy farm managers implement enhanced supervision of feed bunks and wall cleaning in order to prevent the accumulation of manure crusts.

The breeding time is associated with the presence of LTDA and LDs, particularly in pregnant cows. It is therefore recommended that greater attention be paid to cows exhibiting this condition, given their heightened predisposition to limb lesions.

If the prevalence of LTDA observed in this study is indicative of the broader population of dairy farms within the complex, it would be prudent to assess the design standards and cleaning procedures of corrals/pens for new dairy facilities. Such an approach would assist in reducing the prevalence of this pathology while simultaneously promoting cow comfort.

Author Contributions: Conceptualization, R.R.-M. and L.J.B.-F.; methodology, R.R-M. and L.J.B.-F.; software, M.A.L.-G.; validation, R.R.-M. and L.J.B.-F.; formal analysis, F.G.V.-D., A.B.-R. and M.A.L.-G.; investigation, R.R.-M., L.J.B.-F., U.N.G.-G. and G.C.-L. resources, R.R.-M., L.J.B.-F. and G.C.-L.; data curation, M.A.L.-G.; writing—original draft preparation, F.G.V.-D., R.R.-M. and L.J.B.-F.; writing—review and editing, R.R-M., L.J.B.-F., V.C.-V. and M.A.L.-G.; visualization, U.N.G.-G. and J.A.B.-A.; supervision, R.R.-M., F.G.V.-D. and R.H.; project administration, R.R.-M., L.J.B.-F. and G.C.-L.; funding acquisition, G.C.-L. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used along with this research could be available from the corresponding author on reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

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ESTUDIO 2

Segundo artículo: Limb torsion and distal asymmetry in Holstein cows: their relationship with zoometric variables and effects on productive and reproductive variables.

(Enviado MDPI AGRICULTURE)

agriculture

MDPI

Type of the Paper (Article)

LIMB TORSION AND DISTAL ASYMMETRY IN HOLSTEIN COWS: THEIR RELATIONSHIP WITH ZOOMETRIC VARIABLES AND EFFECTS ON PRODUCTIVE AND REPRODUCTIVE VARIABLES

Luis J. Barrera-Flores [1,4], Francisco G. Veliz-Deras [2], Viridiana Contreras-Villarreal [2], Pedro Antonio Robles Trillo [3], Ulises N. Gutiérrez-Guzman [4], Amaury Esquivel-Romo [4], Ma. Esther Rios-Vega [4], Apolinar Gonzalez-Mancilla [4], Martin Alfredo Legarreta-González [1,5,6*], Rafael Rodriguez-Martinez [2*]

[1] Programa de Doctorado en Producción Agropecuaria, Universidad Autónoma Agraria Antonio, Narro, Torreón, Coahuila, 27054, Mexico; luis.barrera@ujed.mx (L.J.B-F).
[2] Departamento de Ciencias Médico Veterinarias, Universidad Autónoma Agraria Antonio Narro, Torreón, Coahuila, Mexico, 27054; velizderas@gmail.com (F.G.V.-D.); dra.viridianac@gmail.com (V.C.-V.); rafael.rdz.mtz@gmail.com (R.R.-M.).
[3] Departamento de Producción Animal, Universidad Autónoma Agraria Antonio Narro, Torreón, Coahuila, Mexico, 27054, Pedro Antonio Robles Trillo <parobles58@gmail.com> (P.R.-T.).
[4] Facultad de Agricultura y Zootecnia, Universidad Juárez del Estado de Durango, Vereda 35100, Mexico; Ulises.gutierrez@ujed.mx (U.N.G.-G.); esther.rios@ujed.mx (M.E.R.-V.); amauryer@ujed.mx (A.E.-R.); apolinar.gonzalez@ujed.mx (A.G-M.)
[5] Universidad Tecnológica de la Tarahumara, Chihuahua 33180, Mexico; mlegarre@uttarahumara.edu.mx
[6] Posgraduate Department, Fatima Campus, University of Makeni (UniMak), Makeni City 00232, Sierra Leone
* Correspondence: rafael.rdz.mtz@gmail.com (R.R.-M.) Tel.: +52-871-189-3372; mlegarre@uttarahumara.edu.mx (M.A.L-G.)

Abstract: The present study evaluated the correlation of limb torsion and distal asymmetry (LTDA) with respect to zoometric, productive, and reproductive variables in Holstein cows. A total of 120 cows diagnosed with LTDA in a previous experiment (60 positive and 60 negative) with one or more lactations were randomly selected for measurement. The height at withers (cm), neck length (cm), and head length (cm) of all cows were measured. Records were obtained for the year of the study regarding lactation number, days in milk, mean of milk production in 24 h (kg), number of inseminations by conception, open days, and body condition (scale 1-5). The association between LTDA and zoometric measures was evaluated by multiple logistic regression, and the effect of LTDA on productive and reproductive variables. A statistically significant correlation ($p < 0.05$) was identified between the zoometric variable's height at withers and neck length, while no association was found between LTDA and head length ($p > 0.05$). The study revealed no effect of LTDA on productive variables ($p = 0.38$), but an effect of LTDA on reproductive variables ($p = 0.01$), primarily on body condition. The present findings indicate that body condition exerts an influence on the occurrence of LTDA in stabled and intensive systems Holstein cows and that LTDA can impact certain variables, particularly reproductive ones. Consequently, it is recommended to formulate strategies to identify LTDA issues in cows and to assess the factors that render cows susceptible to its development. This approach is intended to avert consequences on the productivity and reproduction of Holstein cows and to promote animal welfare.

Keywords: Limb torsion and distal asymmetry, reproduction, production, zoometric measurements, animal welfare.

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1. Introduction

The zoometric traits of Holstein cows are characterized by well-defined phenotypic traits, including height at withers, rib cage, and head size, which surpass those of other breeds specialized in milk production [1, 2]. Consequently, these animals support weights greater than 600 kilograms when moving to feeders, milking parlors, and handling aisles, which has favored the appearance of locomotion problems, limb twisting, and lameness [3]. These problems are also associated with the intensive production with which dairy cattle are managed on some farms.

Espejo et al. [3] have indicated that lameness represents the primary issue for animal welfare in intensive dairy farming. In such systems, cows open the compass of their forelimbs to tilt their heads and eat pasture. In contrast, under natural conditions, the height at the withers of cows has no effect on grazing [4]. However, in the context of intensive housing and feed provision in troughs, a different scenario emerges [5]. Animals with low height encounter limitations in accessing feed located near the trough wall, and their hooves contact the base of the trough wall. This hinders their ability to access feed located near the trough wall, prompting them to turn their limbs outwards to approach and reach the feed [6]. In some cases, animals have been observed to adopt an abnormal posture, characterized by spreading their limbs apart, to reach feed located near the trough wall [2]. These observations are consistent with the prevalence of limb twisting and distal asymmetry (LTDA) in dairy cattle in intensive production systems.

In the Comarca Lagunera, an arid northern area of Mexico where cattle milk production is intensive, cases of lameness, asymmetry, and torsion of the forelimbs have been reported [7]. Consequently, there has been a decrease in animal comfort and welfare [8]. In light of these observations, a study was conducted to test the working hypothesis that there is a correlation of the zoometric traits of lactating Holstein cows on LTDA, as well as that this lesion affects productive and reproductive variables of the cattle.

2. Materials and Methods

2.1. General.

The present study was observational, cross-sectional, and comparative in nature. Data were obtained from the records of a dairy farm, and body measurements were taken from the cows in the study on 2024. It is important to note that these measurements did not affect the cows' welfare. The animals utilized in this study adhered to the guidelines for the ethical use, care, and welfare of research animals at the international [9], national [10], and institutional (UAAAN-UL-18-3059) levels.

2.2. Location and description of the experimental area.

The study was conducted in a dairy complex, which is located at 25°52'39" N 103°23'39" W longitude in Tlahualilo, Durango, Mexico. The region is distinguished by a rainy season that extends from June to September, with an annual mean of 266 mm (range 163 to 440 mm), and a dry climate with an average annual temperature of 21 °C, ranging from 0 °C in winter to 37 °C (May-August) [11].

2.3. Methodology.

In a preliminary LTDA prevalence study conducted in the Comarca Lagunera dairy complex [12], 30 LTDA-positive and 30 LTDA-negative cows were randomly for the study (Figure 1. A) LTDA-positive cow in feed bunk, B) LTDA positive cow, C) LTDA-negative cow.

Figure 2. LTDA-positive cow in feed bunk (A), LTDA positive cow in pen B) and LTDA-negative cow in pen (C).

2.4. Animal management.

The feed ration for the study animals in both barns consisted of corn silage, alfalfa hay, cottonseed, soybean meal, canola, rolled corn, molasses, mineral salts, mycotoxin binder, sodium bicarbonate, and free water. The ration offered was balanced according to the nutritional needs based on what is established by the NRC [13]. Feed was offered four times a day. The quantity of feed offered was adjusted based on consumption, with additional feed being provided as needed. The cows were milked three times a day, and during the initial 120 days in milk, an additional milking was performed during peak lactation.

2.5. Zoometrics variables

The selected bovines were measured for the following zoometric variables: height at the withers (CH; stainless steel ruler), neck length (NM), measuring from the shoulder blades to the base of the ear, and head length (HM), measuring from the base of the ear to the tip of the nose. All measurements were made in centimeters (cm). The latter measurement was made with a flexometer (Trupper FCG-3M retractable, Jilotepec, Edo Mexico, Mexico) (Figure 2).

Figure 2. Zoometric variables. A: height at withers (CH), B: neck length (NM), C: head length (HM). All the measurements are in cm.

2.6. Productive variables

The following productive variables were measured: 24-hour milk production (PLD, with electronic meters [Metatron Demas, Westfalia-Surge GmbH, Oelde, Germany]), number of lactations (LC), and days in milk (DIM). All these variables were obtained from Herd Management Software Records [Dairy Plan DP21, Westfalia-Surge GmbH, Oelde, Germany]).

2.7. Reproductive variables

The reproductive variables documented encompassed the number of inseminations (AI), days open (OD), and body condition score (BCS), scale one to five (Ferguson et al., 1994). These data were derived from Herd Management Software Records (Dairy Plan DP21, Westfalia-Surge GmbH, Oelde, Germany).

2.8. Statistical analysis

A logistic regression analysis of the observed cow data was performed to examine the influence of zoometric variables on LTDA, with the data partitioned into two halves (i.e., sample and test). Likewise, a MANOVA was performed to compare cows with and without LTDA on productive and reproductive variables. A value of $p < 0.05$ was defined as statistically significant.

The statistical analyses were executed using R version 4.4.1 [14] and the following packages: *InformationValue* Version 1.3.1 [15], *pscl* version 1.5.9 [16], and *caret* [17] for Logistic Regression and *tidyverse* [18], *gridExtra* [19], *effectsize* [20], MASS [21], *rstatix* version 0.7.2 [22], *mvnormalTest* version 1.0.0, and *ggplot2* [23] for MANOVA and plots.

3. Results

3.1. Zoometric variables and LTDA

The findings indicate that the coefficients of the predictive model reflect the mean variation in the log-odds of "LTDA". For instance, an increase of one unit in the variable "Height at withers" (CH) is associated with a mean decrease of 0.2985 in the log-odds of "LTDA" presence ($p = .003$). With respect to neck length, the estimated value of the coefficient was -0.235, which is interpreted as a decrease in log odds ($p = .015$). With respect to head length, the coefficient was 0.009, however it was not statistically significant ($p = .581$) (Table 1). The McFadden pseudo R^2 of the model was .220.

Table 1. Regression coefficient estimates between forelimb torsion and the presence of forelimb torsion and distal asymmetry and zoometric variables in Holstein cows raised in an intensive dairy farm.

	Estimate	Std. Error	Z value	Pr(|>z|)
Intercept	53.060	17.540	3.026	.002
Height at withers	-0.298	0.102	-2.931	.003
Neck length	-0.235	0.096	2.441	.015
Head length	0.092	0.166	0.552	.581

3.2. Productive variables

Descriptive statistics for Productive variables are shown on Table 2. A One-way MANOVA was conducted to determine whether there is a difference between positive and negative cows to LTDA on productive variables (Number of lactations, Days in milk, and Average daily milk production per cow [kg]) (Figure 3). There was non-significant difference in Productive variables based on LTDA, $F(1, 118) = 0.819$, $p = 0.486$; partial eta squared = 0.02.

We fail to reject the null hypothesis and conclude that there is no difference between positive and negative cows to LTDA on productive variables (Number of lactations, Days in milk, and Average daily milk production per cow [kg]).

Table 2. Mean and standard deviation of productive variables in Holstein cows positive or negative forelimb torsion and distal asymmetry (LTDA) reared in an intensive dairy farm.

Variable	LTDA	n	mean	sd
Number of lactations	Negatives	60	3.870	0.724
	Positives	60	3.620	1.121
Days in milk	Negatives	60	127.570	34.780
	Positives	60	129.100	46.005
Average daily milk production per cow (Kg)	Negatives	60	42.280	7.127
	Positives	60	41.240	9.821

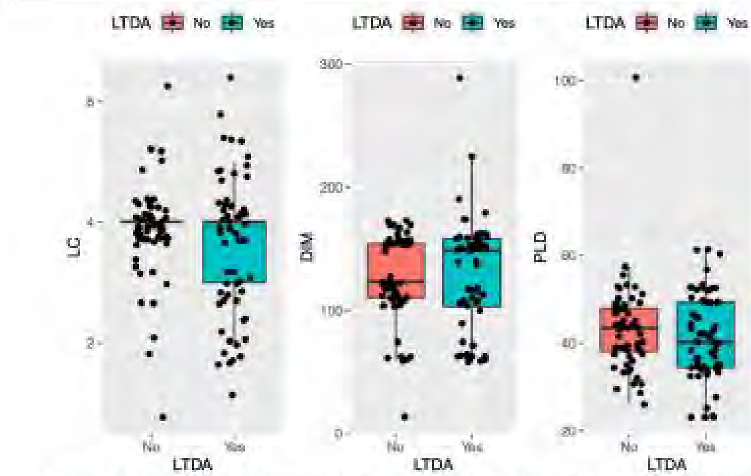


Figure 3. Productive variables: number of lactations (LC), days in milk (DIM) and average daily milk production per cow (PLD), in cows positive (Yes) and negative (No) to forelimb torsion and distal asymmetry (LTDA) raised an intensive dairy farm.

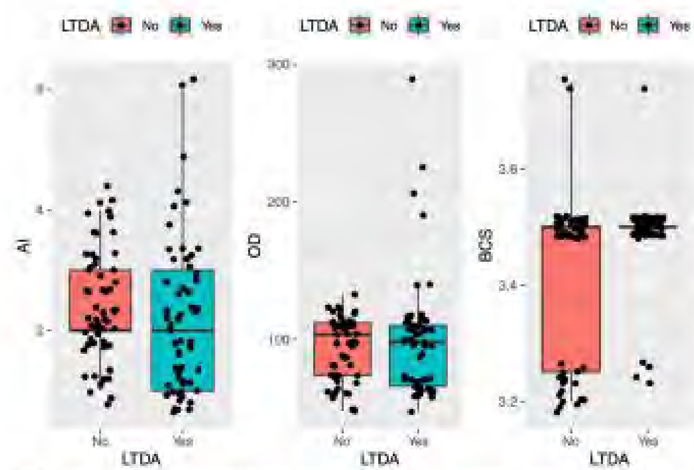
3.3. Reproductive variables

Descriptive statistics for the reproductive variables are shown on Table 3. One-way MANOVA was conducted to determine whether there is a difference between positives and negatives cows to LTDA on Reproductive variables (Number of inseminations, Open days, and Body condition score) (Figure 4). There was significant difference in Reproductive variables based on LTDA, $F(1, 118) = 5.55$, $p = 0.001$; partial eta squared = 0.013.

Table 3. Mean and standard deviation of reproductive variables in Holstein cows positive and negative forelimb torsion and distal asymmetry (LTDA) reared in two intensive dairy farms.

Variable	LTDA	n	mean	sd

Number of inseminations	Negatives	60	2.290	1.095
	Positives	60	2.290	1.095
Open days	Negatives	60	94.520	22.717
	Positives	60	99.080	42.409
Body condition score	Negatives	60	3.420	0.142
	Positives	60	3.490	0.072



FigFigure 4. Reproductive variables: number of artificial inseminations (AI), days open (OD) and body condition (BCS) in cows positive (Yes) and negative (No) to forelimb torsion and distal asymmetry (LTDA) raised in two intensive dairy farms.

We reject the null hypothesis and conclude that there is difference between positive and negative cows to LTDA on Reproductive variables.

4. Discussion

This study postulated two hypotheses. The first postulated that there exists an association between the zoometric traits of Holstein cows (HC, NM, HM) and LTDA, and that this lesion of the anterior train exerts an influence on the productive and reproductive variables of the cattle. The second postulated that the presence of LTDA impacts both productive (LC, DIM and PLD) and reproductive variables (AI, OD and BCS).

The findings of this study provide evidence to support the initial hypothesis, as demonstrated by the observation that two of the zoometric variables (HC and NM) exhibited an impact on the presence of LTDA. However, no such effect was detected for HM on LTDA. In this context, the zoometric variables of height at withers and neck length have been found to demonstrate a significant negative association with LTDA.

That is, as the height of the cow at the withers increases, and its neck length increases, the prevalence of LTDA decreases. The design of the automatic traps' support wall and the presence of a crust of manure adhering to it due to inadequate cleaning of the inner sidewalk area of the pen did not appear to affect the height and neck length of cows [12, 24]. Conversely, cows with a conformation characterized by low height and short neck encounter difficulties in accessing the feed trough. To address this challenge, cows are forced to approach the trough at an angle, resulting in their hooves making contact with the trough's wall. This leads to the stiffening of their forelimbs, which serves as the primary support for their body weight [4].

With regard to the second hypothesis, an association between LTDA and productive variables was not observed ($p > 0.5$), indicating that foot lesions in dairy cattle do not affect milk production. However, other studies have reported a negative association between milk production and limb diseases. Consequently, in regions where intensive cattle milk production is the norm, a negative impact of locomotion problems on milk production has been observed in response to the demand for high productivity. This phenomenon has been demonstrated to culminate in an augmented risk of hoof disorders [25, 26]. Conversely, it has been documented that approximately one-third of Holstein dairy cows in Spain encounter a minimum of one hoof disorder annually [1, 27]. Comparable trends have been observed in the United Kingdom, with estimates ranging from 21% [28] to 36% [26]. In the Netherlands, more than 70% of dairy cows are affected by at least one hoof disorder [29, 30]. However, these studies have not examined the potential role of body conformation and trough design as a contributing factor to the observed hoof problems.

A study of dairy cattle was conducted to evaluate the impact of lameness on milk production [31]. The study concluded that cows with high milk yields in a herd may experience a reduction in their potential if they become lame. The authors of the study report that a decline in milk production was observed from four months before to five months after a cow was diagnosed as clinically lame, resulting in a milk loss of up to 360 kilograms (range 160 to 550 kilograms) during a lactation period. This finding aligns with the conclusions reported by Huxley et al. [32], who examined the repercussions of lameness on the health, animal welfare [33], and productivity of dairy cows. The aforementioned findings underscore the necessity of formulating strategies for the timely detection of locomotion problems in cows [27], whether due to torsion, asymmetry, or lameness, in order to mitigate losses in milk production [32, 34–36]. In contrast, lame cows appear to be more prone to postpartum uterine infections, experience higher levels of negative energy balance, resume ovarian cyclicity at a lower rate during the puerperium, and exhibit lower potential to conceive and higher pregnancy losses [37]. In the context of LTDA and reproductive variables ($p<0.01$), an association was observed, primarily in BCS. A high BCS value (>4.0) is indicative of higher body weight, which, when added to advanced gestation, prevents the cow from a comfortable approach to the trough, and thus, to an increased occurrence of LTDA [24, 38–40]. Furthermore, cows with short stature, high body condition, and advanced gestation, whether uniparous or multiparous, that inhabit pens with very wide walls and poor cleanliness, and manure crust accumulation, are more prone to LTDA [41, 42]. To mitigate the consequences of trough size on LTDA, dairy farms with crossbred populations (Holstein + Jersey), (Holstein + Ashire), [30, 43] should consider adjusting the trough floor areas by elevating the trough with an over floor [29, 44]. Additionally, increasing the frequency and meticulousness of the approach of the ration to the trough wall plays a pivotal role in the prevention of LTDA in housed dairy cattle [41].

The findings of this study could be enhanced by increasing the sample size, incorporating age-related variations in LTDA lesions, and including the severity of the lesions (mild, moderate, or severe) as a variable. Additionally, measuring the effects on production and reproduction as the animal ages would contribute to a more comprehensive understanding.

5. Conclusions

LTDA in cows in production is associated with the zoometric variables height at withers and neck length, indicating that cows with lower height and shorter neck length are more prone to present LTDA.

Although the productive variables showed no effect of the presence of LTDA, the reproductive variables are affected, especially body condition, since the heavier cow will have more difficulty accessing the feeder to feed comfortably.

Consequently, it is recommended that the study of the presence of LTDA, its causes, and its negative effects on animal welfare and variables of interest to livestock be extended, with the aim of establishing preventive measures to reduce or eliminate its presence in dairy farms.

Author Contributions: Conceptualization, L.J.B.-F and R.R.-M.; methodology, R.R-M. and L.J.B.-F.; software, M.A.L.-G. and L.J.B.F.; validation, R.R.-M, and L.J.B.-F., M.E.R-V.; formal analysis, F.G.V.-D., A.E.-R. and M.A.L.-G.; investigation, L.J.B-F., R.R.-M., U.N.G.-G. and M.E.R-V.; resources, R.R.-M., L.J.B.-F. and A.G-M.; data curation, M.A.L.-G.; writing—original draft preparation, F.G.V.-D., R.R.-M. and L.J.B.-F.; writing—review and editing, R.R-M., L.J.B.-F., V.C.-V. and M.A.L.-G.; visualization, U.N.G.-G. and P.A.R-T.; supervision, R.R.-M., F.G.V.-D. and R.H.; project administration, R.R.-M., L.J.B.-F. and P.A.R-T; funding acquisition, P.A.R-T. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: All experimental and animal handling procedures were carried out following the guidelines for the ethical use, care and welfare of research animals in the FASS International Guide for the Care and Use of Farm Animals in Agricultural Research and Teaching and at the national level NOM Norma Oficial Mexicana, Especificaciones Técnicas Para La Producción, Cuidado y Uso de Los Animales de Laboratorio and with institutional approval (UAAAN-UL-18-3059).

Data Availability Statement: Data sets used in conjunction with this research could be made available from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare that they have no conflicts of interest.

Abbreviations

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CONCLUSIÓN GENERAL

Los comederos fuera de norma en los corrales de establos, provocan que la vaca haga un esfuerzo adicional para alcanzar el alimento debido a la mayor dimensión del muro, sumado a esto el grosor de la costra de estiércol adherida a la base del muro del comedero, dan como resultado que las pezuñas de las extremidades anteriores al topar con la base del muro del comedero se roten hacia afuera, lo que puede conducir al desarrollo de dedos deformes y asimétricos incrementando la prevalencia de LTDA y LD.

La LTDA en vacas en producción se asocia con las variables zoométricos altura a la cruz y longitud del cuello, lo que indica que las vacas con menor altura y menor longitud del cuello son más propensas a presentar LTDA. A pesar de que las variables productivas no mostraron efecto de la presencia de LTDA, las variables reproductivas se ven afectadas, especialmente días de gestación y la condición corporal, ya que la vaca más pesada tendrá más dificultad para acceder al comedero para alimentarse cómodamente.

Si la prevalencia de LTDA observada en este estudio es indicativa de la población más amplia de establos lecheros, sería prudente evaluar los estándares de diseño/construcción y los procedimientos de limpieza de los corrales para las nuevas instalaciones lecheras, y en las ya existentes que presentan similar infraestructura, eficientar el programa de limpieza de baquetas-muros de comederos en corrales e incrementar la rutina de acercamiento de alimento en pesebre, estas acciones reducirán la prevalencia de esta patología y, al mismo tiempo, promovería la comodidad de las vacas y reducirían sus efectos negativos sobre el bienestar animal.

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