—Full Paper—

Occurrence of equine metabolic syndrome, clinical manifestations, and associated risk factors in Nigeria

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Insulin dysregulation (ID) is central to the pathophysiology of equine metabolic syndrome (EMS), putting the horse at risk of laminitis. There is a paucity of information on the status of EMS in Nigeria. This study aimed to determine the occurrence of EMS, clinical manifestations, and associated risk factors in Nigeria. A cross-sectional study was carried out. Selected horses underwent an insulin 2-step response test to ascertain insulin dysregulation; a physical examination was carried out to diagnose laminitis and obesity. Risk factors were assessed using a questionnaire. The overall prevalence of EMS was 43.10%. Breed and sex were significantly associated with EMS, but age was not. Horses diagnosed with laminitis showed two signs of laminitis, namely, divergent hoof rings and widened white lines. Risk factors significantly associated with the prevalence of EMS were as follows: being a West African Barb horse (60.00%), being a stallion (67.86%), being a leisure horse (67.86%), only walking horses during exercise (68.00%), exercising horses once every 5 months (82.76%), tethering horses to a stake in the ground (67.86%), obesity (92.86%), and abnormal neck crest (83.33%). The risk of ID remains higher in obese horses. However, some of the horses with ID were not obese, indicating that there are other possible underlying causes of EMS.

Key words: *equine metabolic syndrome, insulin dysregulation, laminitis, obesity*

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Horses have contributed to the cultural heritage of the Nigerian people, particularly relation to racing, recreational activities, companionship, royalty, polo, and agricultural purposes [29]. The term "equine metabolic syndrome" (EMS) was first mentioned in veterinary medicine by Professor Philip Johnson [21]. It is a clinical syndrome associated with obesity or other metabolic alterations, insulin dysregulation (ID), and an increased risk of laminitis [13, 19]. Obese horses and ponies (regional adiposity or general obesity) often have evidence of insulin dysregulation [3].

The challenge associated with EMS is diagnosing it before the onset of laminitis. Hyperinsulinaemia-associated laminitis is a highly recurrent condition that disturbs the functional abilities and welfare of the horse [10]. While the treatment concepts for laminitis have not altered in decades, there have been some significant paradigm shifts in the understanding of the condition [32]. Above all, laminitis must be regarded as a clinical syndrome rather than a separate condition [32]. As a result of this paradigm shift, one needs to understand the diseases that underlie the development of laminitis. According to recent reports, more than 70% of horses with laminitis as their primary clinical sign developed it as a result of EMS [10, 23]. It is important to identify and diagnose EMS early because the development of laminitis may be prevented by effective management strategies.

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Several studies have investigated the incidence of and risk factors for laminitis [26, 34, 40], and obesity [17, 18, 35]. Researchers have started paying attention to laminitis and obesity in association with insulin dysregulation (the EMS hallmark) [6, 7, 28, 36, 37]

The present study aimed to assess the occurrence of equine metabolic syndrome, clinical manifestations, and associated risk factors in Nigeria, which, to the best of the authors' knowledge, has never been done in Nigeria.

Materials and Methods

Study area

The study was carried out in the Zaria and Igabi Local Government Areas (LGAs) of Kaduna State, Nigeria. The Zaria Local Government Area is known to have a high number of local horses due to the presence of an emirate council in the ancient city of Zaria. Zaria LGA is situated at 11°3′ north latitude and 7°42′ east longitude of the Greenwich meridian. Igabi LGA is located at 10°47′0″N latitude and 7°46′0″E longitude. Igabi LGA is noted for having one of the largest populations of Argentine polo ponies in the country, and it annually organises international polo events.

Ethical clearance

Ethical approval for the research was obtained from the Ahmadu Bello University Committee on Animal Use and Care (ABUCAUC); approval number ABUCAUC/2022/042.

Study design and sample size

A cross-sectional study was carried out. A total of 116 horses were selected and sampled (50 from Zaria LGA and 66 from Igabi LGA).

Data and sample collection

All horses selected went through a clinical examination to ascertain their health statuses. The criteria used to select horses for sampling in this study were as follows: vital parameters within the normal range, and baseline blood glucose ≥80 mg/d*l*. Estimation of body weight (kg) was done with the formula of Wagner andTyler [39].

General obesity was assessed using the body condition score (BCS; 1–9) as described by Henneke *et al.* [20] and modified by Kohnke [24]. The horses were classified as under-condition (<4.5), moderate condition (4.5–5.5), over-condition (6–6.5), and obese (≥7) based on their BCS scores [12].

Regional obesity was assessed using the cresty neck score (CNS; 0–5) as described by Carter *et al.* [7]. CNS >2 was regarded as indicating an abnormal neck crest, while CNS ≤2 was regarded as indicating a normal neck crest.

Laminitis was diagnosed based on history, clinical signs, and a thorough physical examination. The severity of the laminitis was determined using a five-grade Obel System (0 to 4) [27, 31]. The Obel grades were grouped into three subgroups of lameness, which were sound (grade 0), mild (grades 1 and 2), and severe (grades 3 and 4) [27].

Age, breed, and sex were recorded. A structured questionnaire was used to collect information on use, housing, exercise, exercise intensity, exercise frequency, body condition score, and cresty neck score.

Insulin 2-step response test

A disposable sterile 2 m*l* syringe with a 23G needle attached was used to collect 0.5 m*l* of blood via jugular venepuncture to be used in determining the baseline glucose concentration with a hand-held glucometer (Accu-Answer, Guilin Royalyze Medical, Guangxi Zhuang Autonomous Region). Thereafter, a regular human recombinant insulin (Actrapid insulin 0.1 IU/kg, Novo Laboratories, Basingstoke, UK) was injected intravenously. After 30 min, another 0.5 m*l* of blood was collected using a disposable sterile 2 m*l* syringe attached to a 23G needle via the same jugular venepuncture to determine the final glucose concentration with the same hand-held glucometer.

As described by Bertin and Sojka-Kritchevsky [5] and Durham *et al.* [13], horses were considered positive for insulin dysregulation if their final blood glucose concentration did not fall below 50% of their baseline glucose concentration, while those with a concentration of less than 50% of their baseline glucose concentration were considered negative for insulin dysregulation. At the end of the procedure, 100 g of oral glucose was given to the horses to replace the lost glucose due to the insulin administration.

Data analyses

The collected data were summarised and presented in tables using descriptive statistics to calculate prevalence. A χ^2 test was used to test for associations between the prevalence of equine metabolic syndrome and the categorical variables. Using logistic regression, odds ratios were used to estimate the strength of the risk factors. Confidence intervals of 95% (95% CIs) were calculated, and values of $P \leq 0.05$ were considered significant. IBM SPSS Statistics (version 26; IBM Corp., Armonk, NY, USA) was used for the analysis.

Results

A total of 116 horses were sampled in this study, 56 from Zaria LGA and 60 from Igabi LGA. The result showed the prevalence of EMS to be 67.86% (38/56) in Zaria LGA and 20.00% (12/60) in Igabi LGA. The overall prevalence of EMS in the two study areas was 43.10% (50/116; Table 1).

In terms of sex, the overall prevalence of EMS was 67.86% (38/56) in stallions and 20.00% (12/60) in mares. The association between EMS and sex was significant (χ^2 (1)=27.051, P<0.05).

By horse breed, the overall prevalence of EMS was 60.00% (42/70) in West African Barb horses and 17.39% (8/46) in Argentine polo ponies. The association between EMS and breed was significant (χ^2 (1)=20.549, P<0.05).

In terms of age, the overall prevalence of EMS was 50.00% (21/42) in horses aged 3 to 8, 41.79% (28/67) in horses aged 9 to 14, and 14.29% (1/7) in horses aged 15 to 20 years. However, there was no significant association between EMS and age (χ^2 (2)=3.232, P>0.05).

The overall prevalence of laminitis in horses sampled was 31.03% (36/116). Out of these horses, 61.29% (31/50) were EMS positive and 7.58% (5/66) were EMS negative. There was a significant association between EMS and laminitis (χ^2 (1)=39.370, P<0.05; Table 2).

In terms of the clinical signs associated with laminitis in this study, the horses examined showed two forms of laminitic changes to the hoof, namely divergent hoof rings (Fig. 1) and widened white lines (Fig. 2).

Of the horses diagnosed with laminitis in this study, 72.22% (26/36) had sound laminitis (grade 0), 27.78% (10/36) had mild laminitis (grades 1 and 2), and 0% (0/36) had severe laminitis (grades 3 and 4).

Table 1. Prevalence of equine metabolic syndrome in the Zaria and Igabi local government area (LGA) of Kaduna State, Nigeria

LGA	No. of sampled horses	No. of EMS-positive horses	Prevalence of EMS (%)
Zaria	56	38	67.86
Igabi	60	12	20.00
Overall	116	50	43.10

EMS, equine metabolic syndrome.

Table 2. Summary of laminitis and equine metabolic syndrome in horses sampled in the Zaria and Igabi local government area (LGA) of Kaduna State, Nigeria

LGA	Laminitis in the horses sampled (n=116)			Laminitis in EMS-positive horses (n=50)			Laminitis in EMS-negative horses (n=66)			*P*-value
	Total no. sampled	No. positive	Prevalence (%)	Total no. sampled	No. positive	Prevalence (%)	Total no. sampled	No. Positive	Prevalence (%)	
Zaria	56	34	60.71	38	29	76.32	18	5	27.78	
Igabi	60	2	3.33	12	2	16.67	48	0	0	
Overall	116	36	31.03	50	31	61.29	66	5	7.58	<0.001*

EMS, equine metabolic syndrome; *, significant.

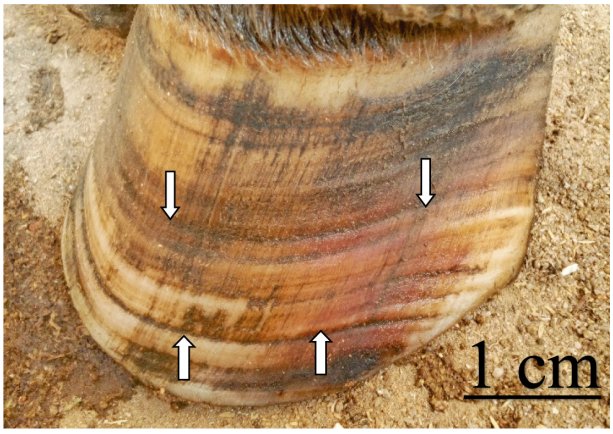

Fig. 1. White arrows indicate divergent rings on the outer hoof wall of a West African Barb horse with laminitis (the distance between the rings is wider at the heel).

Fig. 2. White arrows indicate a widened white line on the ventral aspect of the hoof in a West African Barb horse with laminitis.

Table 3. Overall occurrence of equine metabolic syndrome according to risk factor categories (breed, sex, age, use, housing, exercise, and exercise intensity) in the Zaria and Igabi local government areas (LGAs) of Kaduna State, Nigeria

Risk factors	No. of sampled horses	No. of EMS-positive horses	Prevalence (%)	OR (95% CI)	*P*-value
Breed (n=116)					
• WAB	70	42	60.00	7.13 (2.90, 17.52)	<0.001*
• APP	46	8	17.39	Reference	
Sex (n=116)					
• Stallion	56	38	67.86	8.44 (3.63, 19.67)	<0.001*
• Mare	60	12	20.00	Reference	
Age (n=116)					
• 3–8 years	42	21	50.00	6.00 (0.66, 54.24)	0.111
• 9–14 years	67	28	41.79	4.31 (0.49, 37.80)	0.188
• 15–20 years	7	1	14.29	Reference	
Use (n=116)					
• Leisure	56	38	67.86	8.44 (3.63, 19.67)	<0.001*
• Polo	60	12	20.00	Reference	
Housing (n=116)					
• Tethered	56	38	67.86	8.44 (3.63, 19.67)	<0.001*
• Stabled	60	12	20.00	Reference	
Exercise (n=116)					
• No	5	4	80.00	5.65 (0.61, 52.23)	0.127
• Yes	111	46	41.44	Reference	
Exercise intensity (n=111)					
• Walk	51	34	66.67	8.00 (3.39, 18.90)	<0.001*
• Walk and trot	60	12	20.00	Reference	

WAB, West African Barb; APP, Argentine polo pony; *, significant.

In terms of breed, West African Barb horses (60.00%; 42/70) were 7.13 times more likely to have EMS than Argentine polo ponies (17.39%; 8/46), and the relationship was significant (OR 7.13, 95% CI [2.90, 17.52], $P<0.05$; Table 3).

In terms of sex, stallions (67.86%; 38/56) were 8.44 times more likely to have EMS than mares (20.00%; 12/60), and the relationship was significant (OR 8.44, 95% CI [3.63, 19.67], $P<0.05$; Table 3).

In terms of age, horses aged 3 to 8 years (50.00%; 21/42) were 6 times more likely to have EMS than horses aged 15 to 20 years (14.29%; 1/7); however, the relationship was not significant (OR 6.00, 95% CI [0.66, 54.24], $P>0.05$; Table 3).

In terms of horse uses, leisure horses (67.86%; 38/56) were 8.44 times more likely to have EMS than polo horses (20.00%; 12/60), and the relationship was significant (OR 8.44, 95% CI [3.63, 19.67], $P<0.05$; Table 3).

On the issue of the housing of the horses, tethered horses (67.86%; 38/56) were 8.44 times more likely to have EMS than stabled horses (20.00%; 12/60), and the relationship was significant (OR 8.44, 95% CI [3.63, 19.67], $P<0.05$; Table 3).

In terms of exercise, horses that were not exercised (80.00%; 4/5) were 5.65 times more likely to have EMS than horses that were exercised (41.44%; 46/111); however, the relationship was not significant (OR 5.65, 95% CI [0.61, 52.23], $P>0.05$; Table 3).

In terms of exercise intensity, horses that only walked (66.67%; 34/51) were 8 times more likely to have EMS than horses that walked and trotted (20.00%; 12/60), and the relationship was significant (OR 8.00, 95% CI [3.39, 18.90], $P<0.05$; Table 3).

Concerning exercise frequency, horses exercised once every 5 months (82.76%; 24/29) were 19.20 times more likely to have EMS than horses exercised daily (20.00%; 12/60), and the relationship was significant (OR 19.20, 95% CI [6.06, 60.80], $P<0.05$; Table 4).

In terms of the BCS, obese horses (92.86%; 13/14) were 10.11 times more likely to have EMS than under-condition horses (56.25%; 9/16), and the relationship was significant (OR 10.11, 95% CI [1.05, 97.00], $P<0.05$; Table 4).

Regarding the CNS in the horses sampled, horses with an abnormal neck crest (83.33%; 15/18) were 9 times more likely to have EMS than horses with a normal neck crest (35.71%; 35/98), and the relationship was significant (OR 9.00, 95% CI [2.44, 33.24], $P<0.05$; Table 4).

Table 4. Overall occurrence of equine metabolic syndrome according to risk factor categories (exercise frequency, body condition score (BCS), and cresty neck score (CNS)) in the Zaria and Igabi local government areas (LGAs) of Kaduna State, Nigeria

Risk factors	No. of sampled horses	No. of EMS-positive horses	Prevalence (%)	OR (95% CI)	*P*-value
Exercise frequency (n=111)					
• Daily	60	12	20.00	Reference	
• Once a week	22	10	45.45	3.33 (1.17, 5.93)	0.025*
• Once every 5 months	29	24	82.76	19.20 (6.06, 60.80)	<0.001*
BCS (n=116)					
• UC (<4.5)	16	9	56.25	Reference	
• MC (4.5–5.5)	61	18	29.51	0.33 (0.11, 1.01)	0.052
• OC (6–6.5)	25	10	40.00	0.52 (0.15, 1.85)	0.311
• Ob (≥7)	14	13	92.86	10.11 (1.05, 97.00)	0.045*
CNS (n=116)					
• Normal (≤ 2)	98	35	35.71	Reference	
• Abnormal (>2)	18	15	83.33	9.00 (2.44, 33.24)	0.001*

UC, under condition; MC, moderate condition; OC, over condition; Ob, obese; *, significant.

Discussion

To the best of the authors' knowledge, this is the first study to report on EMS prevalence in Nigeria and the first robust prevalence estimate of EMS in horses using the insulin 2-step response test.

Our data showed the overall prevalence of EMS in horses in the Zaria and Igabi LGAs, Kaduna State, Nigeria, to be 43.10%. Previous studies have reported the prevalence of EMS as determined using basal insulin: Muno [30] reported a prevalence of 22% in the US, and Morgan *et al*. [28] reported a prevalence of 27% in ponies (Australian, Welsh Mountain, Connemara, and Shetland Ponies) in Australia. Pleasant *et al.* [33] estimated the prevalence of EMS in the US to be 18% in mature light breed horses, whereas Tavanaeimanesh *et al.* [36] reported a low prevalence (2.5%) in Turkman, Thoroughbred, and warm-blood horses in Iran. Using an oral glucose test, a prevalence of 23.3% was reported in UK native ponies [6]. In horses diagnosed with laminitis, Karikoski *et al.* [23] and de Laat *et al.* [10] reported that EMS played a role in 97% and 82.4% of the cases, respectively. The varied prevalence may be due to bias in sampling only horses with laminitis and differences in diagnostic methods, breeds, and study locations. The findings of our study, however, fall within the range of the other studies across the globe.

Equine metabolic syndrome has been shown to increase the risk of laminitis in field studies [7, 38] and to directly induce laminitis in experimental studies [1, 11]. The overall prevalence of laminitis in the horses sampled was 31.03%. Similar findings were obtained by Treiber *et al.* [38], who reported a prevalence of 34%. However, Carslake *et al.* [6] reported a lower prevalence of 9.7%. The overall prevalence of laminitis in EMS-positive horses in this study was 61.29%. This supports a previous report by Karikoski *et al.* [23], in which laminitis was found to be prevalent (89%) in EMS-positive horses and also supports the reports of Treiber *et al.* [38] and Carter *et al.* [7]. The overall prevalence of laminitis in EMS-negative horses (7.58%) could be attributed to other forms of laminitis (supporting limb laminitis, sepsis-associated laminitis, traumatic/mechanical laminitis) [4, 14], which were not observed in this study. This suggests that not all horses with laminitis have EMS.

Divergent hoof rings and widened white lines were the laminitic changes to the hoof observed in the present study. These changes were also reported by Morgan *et al*. [28] and Carslake *et al*. [6]. In addition, the widened white line is also known as a part of the lamellar wedge resulting in excess production of an ectopic white line [8]. In other words, the widened white line was evidence of past severe damage to the lamellar layer of the foot [25].

In terms of sex, the horses sampled in Zaria LGA were all stallions, while those in Igabi LGA were all mares. The stallions (67.86%) had significantly greater odds of having EMS than the mares (20.00%). However, Carslake *et al.* [6] reported in a similar study that mares had significantly greater odds of having EMS than geldings and stallions. The difference may be due to high levels of obesity and physical inactivity, which were more common among the stallions than mares in this study.

An association between age and the prevalence of EMS has been recognised in horses and humans [22, 28]. In this study, there was no significant association between age and the prevalence of EMS, indicating that horses within the three age groups kept under similar conditions were equally predisposed to EMS. This agrees with similar findings by

Tavanaeimanesh *et al.* [36].

Regarding the horse uses, leisure horses (67.86%) were significantly more likely to have EMS than polo horses (20.00%). Similar observations were made by Carslake *et al.* [6], who reported that sedentary and companion cob horses and ponies had greater odds of being positive for EMS than those driven or ridden.

This study observed that horses that walked during exercise (66.67%) had significantly greater odds of developing EMS than horses that walked and trotted (20.00%). Furthermore, horses that exercised once every 5 months (82.76%) had significantly greater odds of developing EMS ($P<0.05$) than horses that exercised daily (20.00%). Hence, exercise might not effectively prevent the prevalence of EMS if exercise intensity and frequency are not taken into consideration. Similar findings have been reported by Carslake *et al.* [6]. However, previous reports have been conflicting as to the level of exercise required to improve EMS, with moderate-intensity exercise being recommended by Durham *et al.* [13].

The prevalence of EMS in horses classified as obese was 92.86% in this study. However, Tavanaeimanesh *et al.* [36] reported a prevalence of 16%. The prevalence of EMS in horses with an abnormal neck crest (regional adiposity) was 83.33%, and these horses had significantly greater odds of developing EMS than in horses with normal neck crest. Similar observations were made by Fitzgerald *et al.* [15], who established regional adiposity as a strong risk factor for EMS.

The observed presence of EMS in non-obese horses in this study may be due to the presence of internal fats. Alternatively, it might be due to genetic predispositions and the sustained carbohydrate absorption from concentrates fed to the horses sampled. Therefore, obesity might not be a primary cause of EMS. In other reports, obesity (regional and general) has been associated with EMS in horses and ponies [7, 16, 38]. However, obesity has not been a consistent finding across studies [2, 3, 9].

The present study indicates that EMS occurs in Nigeria with an overall prevalence of 43.10%. The observation of obesity (general and regional) in horses in the study, indicates that the risk of insulin dysregulation remains higher in obese horses. However, some of the horses with insulin dysregulation were not obese, indicating that other underlying causes of metabolic syndrome exist in these horses.

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