Artificial Insemination in Smallholder Farming: An Exploration of Farmer Perspectives and Determinants in Beitbridge, Zimbabwe

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Abstract

This study investigated the perceptions of communal farmers in Beitbridge, Zimbabwe, regarding the adoption of artificial insemination (AI) technology in cattle breeding. A semi-structured questionnaire was administered to 80 cattle farmers who had participated in the Zimbabwe Resilient Building Fund Government Communal Cattle Insemination program between 2017 and 2021. The results revealed that 99% of the farmers did not regularly utilize AI services due to the absence of locally based AI service providers (97.5%), discontinuation of service between government programs, and insufficient knowledge of AI technology (72%). Uncontrolled breeding systems and poor seasonal nutrition were identified as major challenges by 100% and 80% of the farmers, respectively. The majority of farmers (77.5%) preferred using both AI and natural mating if available. The perceived low adoption of AI in communal areas was attributed to a shortage of locally based inseminators, inadequate farmer awareness of assisted reproductive technologies (ARTs), and the absence of structured communal breeding programs. The study recommends collaboration among cattle stakeholders to address the challenges in optimizing cattle productivity through ART implementation and adoption in rural areas, including enhancing the capacity of government workers and lead farmers, decentralizing service providers, and institutionalizing community-led sustainability frameworks. Alternative methods of

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technology dissemination are also needed to improve farmers' awareness of fundamental aspects of AI and synchronization protocols.

Keywords: Artificial insemination technology; Smallholder farming systems; Cattle Farmers perceptions; Adoption determinants; Beitbridge, Zimbabwe

1.0 Introduction

In Zimbabwe, the agricultural sector has been demonstrated to be the foundation of the economy, with livestock contributing significantly to the country's economic output. Cattle account for 35% to 38% of the Gross Domestic Product contributed by the agricultural sector (Food and Agriculture Organization, 2020). Cattle serve various social and economic functions in communal areas, underscoring their importance in agricultural production and livelihood systems (Mavedzenge et al., 2006). These functions include income generation, wealth storage, utilization as draught animals, meat and milk production, and manure for fuel and fertilizer (Ndebele et al., 2007). Most households in communal areas in semi-arid southern Zimbabwe depend on livestock farming for subsistence. Musemwa et al., (2012) emphasized that reliance on livestock farming is influenced by unreliable rainfall resulting in recurrent droughts and water shortages; consequently, livestock production is more feasible for communities focusing on mitigating food shortages, achieving nutritional and economic security, and improving economic growth. However, cattle productivity in these farming areas is low because of numerous factors, including poor or non-adoption of optimal farming systems and promoted technologies. This challenge may stem from human perceptions rather than a lack of technological advancement.

The poor genetic potential of indigenous breeds has contributed to low livestock productivity (Fillipo, 2015). Hence, various biotechnologies, such as artificial insemination (AI), which is defined as the introduction of semen and viable sperm into the female reproductive tract via artificial means (Schook et al., 2017), have been promoted to improve the genetic composition of communal cattle. For livestock improvement in developing countries, technologies, such as AI, must be comprehended and effectively transferred to farmers (Shehu, 2010). Consequently, the Division of Research, through Matopos Research Institute, has been promoting artificial cattle insemination in communal areas, artificially inseminating 300 animals in

Mwenezi (2018) under the CROPS project, 1197 cattle in Beitbridge (2018, 2019, 2020) under the Zimbabwe Resilience Building Fund - Program for Growth and Resilience (ZRBF-PROGRESS) project, and 460 in Matobo and Insiza districts (2021) under the Zimbabwe Agriculture Knowledge Innovation System (ZAKIS) project, which is one of the Zimbabwe Agricultural Growth Programmes (ZAGP), with a calving rate range of 40–45% from single cow insemination services. These programs aim to propagate superior genetics from improved indigenous breeds and enhance the participating farmers' understanding of AI technology.

In areas where AI has been implemented, there has been an improvement in calving rates, with–25-30% (Institute of Rural Technology, 2010) improvement observed among smallholder farmers in semi-arid areas and 65-70% in commercial farms (Washaya et al., 2019), as well as a reduction in the calving period and an increase in calf weight (Mushonga et al., 2009). With improved herd performance and productivity that can be realized in communal areas due to rapid genetic gain from AI, the rural economy would be sustained by high cattle off-take rates, thereby reducing poverty and improving household food security (Mugwabana 2018). Communal cattle farmers in rural areas can adopt and utilize these technologies to address the shortage of bulls, reduce the transmission of venereal diseases, minimize the costs associated with acquiring and managing high-quality bulls, and improve calving rates (Kubkuhoma, 2018).

Despite these well-documented advantages, there is generally a low rate of AI technology adoption in rural communities, with an AI coverage of 3.25% recorded in Zimbabwe (Mlemba, 2011). The rate at which a particular technology is adopted in a community depends on how the technology is perceived (Ntshangase et al., 2018), the socio-economic attributes of the intended beneficiaries, their level of education, and linkage with extension structures (Adesina and Baidu-Forson, 1995). According to Tatlidil et al. (2009), technologies that are perceived negatively will have a low-to-zero adoption level. Ntshangase et al. (2018) highlighted that farmers have numerous reasons for adopting new farming technologies; some may be rational in their behaviour, and their perceptions may be influenced by the information available to them, community demographics, farm enterprises, cultural practices, and alternatives to the technology available to them. Therefore, there is a need to conduct studies to generate empirical data and insights on how communal farmers and stakeholders

perceive potential challenges and benefits that could be derived from adopting AI in communal cattle production systems as a cost-effective method of breed improvement. This information is critical for designing improved models and implementing methods for such technologies for better acceptance by farmers. This study was conducted to determine farmers' perceptions and demographic dynamics of cattle artificial insemination technology under communal farming systems in Zimbabwe.

2.0 Materials and Methods

2.1 Data Collection Site

The study was conducted in LIPS-ZIM participating wards in the Beitbridge district, located in Matabeleland, South province of Zimbabwe. The district was selected primarily because of the availability of farmers whose cattle were artificially inseminated by the Matopos Research Institute under the Zimbabwe Resilience Building Fund Program for Growth and Resilience (ZRBF-PROGRESS) project, the abundance of cattle produced under communal systems, and the representation of many rural parts of semi-arid Zimbabwe. Beitbridge is characterized by communal livestock production, where 1197 animals were inseminated between 2018, 2019, and 2020 in the communal areas. Mean annual temperatures in Matabeleland South Province range between 25 °C in summer months and 27.5°C during winter months. Rainfall in the province ranges from 300 to 600 mm per annum, with an average of 332 mm per annum (Matsa and Dzawanda, 2019). Vegetation varies from savannah in deep fertile soils to shrub savannah in shallower soils.

2.2 Data Collection Sampling Procedure

Farmers who participated in the ZRBF-PROGRESS funded cattle artificial inseminations conducted by Matopos Research Institute were selected as lead AI farmers for the survey. Lead AI farmers and farmers who were trained as community-based inseminators were selected with the assistance of agricultural extension and veterinary personnel involved in the ZRBF-PROGRESS AI program, as well as project implementation coordinators in the respective wards. The lead farmers in this study represent the farmers described by Kundhlande et al. (2014) as experienced model farmers who are utilized in demonstrating improved farming systems. Only three

targeted wards were employed because it has been observed that when in-depth interviews are to be conducted with a targeted group of respondents, the sample size will have a minimal impact on the outcome of the studies (Crouch & McKenzie, 2006; Marshall et al., 2013; Small, 2009)

2.3 Data Acquisition Strategy

A semi-structured questionnaire comprising closed- and open-ended questions was developed and validated prior to its administration to the targeted group of farmers who had previously participated in cattle insemination activities under ZRBF-PROGRESS, encompassing 80 households. Data collection was conducted by co-investigators and ward-based government extension officers (Agricultural and Rural Development Advisory Services) in wards 3, 5, and 11, utilizing digital means through an application called KOBO (see Appendix 1 for the questionnaire).

2.4 Inferential Analysis Approach

The data generated from the questionnaire were analysed using the Statistical Package for Social Sciences version 22 (Armonk, NY, USA). Descriptive statistics were used to determine frequencies, means, and ranges. The reliability of the data was assessed using Cronbach's α based on standardized items (0.952). A chi-squared (X2) test with a 95% level of significance was used to measure the statistical association between the demographic characteristics of the participants and their perceptions of cattle artificial insemination.

3.0 Results and Discussions

Table 1 presents the demographic characteristics of the cattle farmers and their association with their knowledge of artificial insemination. This study assessed 80 farmers in Beitbridge regarding their understanding and perception of cattle artificial insemination. The majority of the respondents (78.85%) were male, with females comprising 21.25% of the sample. The household head gender distribution consisted of 67.5% males and 32.5% females. All participants reported awareness of the government-led ZRBF-PROGRESS implementing an artificial insemination program in their district. The predominant breeding method was uncontrolled natural bull mating, with artificial insemination considered in government-sponsored programs.

Gororo et al. (2017) and Nyamushamba et al. (2017) reported that the primary hindrance to breed improvement in the communal areas of Zimbabwe was uncontrolled breeding, which resulted in high levels of inbreeding depression and poor cattle reproductive performance (Tada et al., 2013). Isolating breeding cows may present a challenge, as 80% of the respondents indicated insufficient grazing in their communities (Figure 1). The majority of farmers indicated greater familiarity with natural mating than artificial insemination, having been exposed to AI for the first time between 2017 and 2020 (64%), despite varying years of farming experience (Table 3).

Table 1. Participant farmers' demographic profile, farming enterprise and experience and association with AI related activities

		Frequency (%) N=80	breeding method preference if AI is available		Did you have any say in AI semen selection		Do you prepare cows for AI		Do you keep Farm Breeding Records	
			Bulls	AI & Bulls	Yes	No	Yes	No	Yes	No
Gender of respondent	Male	63(78.8)	23(36.5)	40(63.5)	44(69.8)	19(30.2)	23(36.5)	40(63.5)	61(96.8)	2(3.2)
	female	17(21.3)	5(29.4)	12(70.6)	14(82.4)	3(17.7)	4(23.5)	13(76.5)	16(94.1)	1(5.9)
	P Value		0.771		0.374		0.395		0.517	
Age of the household head	<25 years	4(5)	3(75)	1(25)	4(100)	0(0)	1(25)	3(75)	3(75)	1(25)
	26-35 years	1(1.3)	1(100)	0(0)	1(100)	0(0)	0(0)	1(100)	1(100)	0(0)
	36-45years	12(15)	5(41.7)	7(58.3)	10(83.3)	2(16.7)	7(58.3)	5(41.7)	12(100)	0(0)
	46-65 years	42(52.5)	12(28.6)	30(71.4)	28(66.7)	14(33.3)	28(66.7)	14(33.3)	40(95.2)	2(4.8)
	> 66years	21(26.3)	7(33.3)	14(66.7)	15(71.4)	6(28.6)	17(81.0)	4(19.1)	21(100)	0(0)
	P Value		0.227		0.504		0.117		0.168	

Education Levels of household head	Primary/No Education	61(76.3)	19(31.2)	42(68.9)	43(70.5)	18(29.5)	21(34.4)	40(65.6)	2(3.3)	59(96.7)
	Secondary	13(16.3)	5(38.5)	8(61.5)	9(69.2)	4(30.8)	1(7.7)	12(92.3)	0 (0)	13(100)
	Tertiary	6 (7.5)	4(66.7)	2(33.3)	6(100)	0(0)	5(83.3)	1(16.7)	1(16.7)	5(83.3)
	P Value		0.211		0.291		0.005		0.190	
Occupation of the household head:	Off-farm self-employment	12 (15)	4(33.3)	8(66.7)	8(66.7)	4(33.3)	2(16.7)	10(83.3)	11(91.7)	1(8.3)
	Formal employment	10(12.5)	4(40)	6(60)	7(70)	3(30)	5(50)	5(50)	10(100)	0(0)
	Farming	58 (72.5)	20(34.5)	38(65.5)	43(74.1)	15(25.9)	20(34.5)	38(65.5)	56(96.6)	2(3.5)
	P Value		0.936		0.855		0.251		0.576	
Which farming enterprises do you have on your farm	Livestock only	5(6.3)	0 (0)	5 (100)	5(100)	0(0)	3(60)	2(40)	5(100)	0(0)
	Crop-livestock	75(93.8)	28(37.3)	47(62.7)	53(70.7)	22(29.3)	24(32)	51(68)	72(96)	3(4)
	P Value		0.094		0.155		0.200		0.649	

Number of years practicing farming	10 years	9(11.3)	4(44.4)	5(55.6)	8(88.9)	1(11.1)	4(44.4)	5(55.6)	8(88.9)	1(11.1)
	11-20 years	27 (33.8)	8(29.6)	19(70.4)	20(74.1)	7(25.9)	6(22.2)	21(77.8)	27(100)	0(0)
	21-30 yes	20 (25)	6(30)	14(70)	13(65)	7(35)	9(45)	11(55)	18(90)	2(10)
	+30 years	24(30)	10(41.7)	14(58.3)	17(70.8)	7(29.2)	8(33.3)	16(6.7)	24(100)	0(0)
	P Value		0.709		0.894		0.605		0.138	

Nevertheless, most households expressed a preference for both breeding methods if available. No significant association (P > 0.05) was observed between sex and breeding method preference across all age groups. Cattle farmers aged 46–65 years constituted the majority of participants (52.5%), followed by those aged 66 years and above (26.3%). Notably, the economically active age group of 26-35 years demonstrated lower involvement in farming (1.3%) within the sample size. However, knowledge of cattle artificial insemination technology was not significantly associated (P > 0.05) with participant age across all parameters measured.

The educational level of most participants (76%) was at the primary level or below, with 16% and 8% of participants having reached the secondary and tertiary educational levels, respectively (Table 2). Educational level was positively correlated with the perceived level of satisfaction with AI, as 50% of respondents with tertiary education expressed satisfaction with AI, compared to 46% and 45% of farmers who had secondary and primary education, respectively. However, the differences were not statistically significant.

Significant differences were observed between the level of education and farmer cow preparation for AI (P <0.05). Similar observations have been noted in other regions where it has been reported that the educational status of households is directly related to the perception of farmers in estrus synchronization, with illiterate farmers not preparing cows for artificial insemination in Ethiopia compared to educated farmers (Destalem et al., 2015). There was also no statistically significant association (p>0.05)

between years of farming experience and knowledge of cattle artificial insemination. This may have been influenced by the fact that most participants (64%) indicated that they had no exposure to AI before 2017, when the ZRBF program was introduced in the district, regardless of years of experience (Table 3). This observation aligns with reports from earlier work by Gororo et al. (2017), who revealed that 40% of farmers in communal areas have never heard of the term assisted reproduction technologies (ART), with only 1% awareness of estrus synchronization for AI. Therefore, it is critical to continuously provide extension services to smallholder cattle farmers on the advantages of artificial insemination, detection of estrus, estrus synchronization for timed artificial insemination, potential problems associated with breeding, and good animal management practices. The findings corroborate the recommendations by Abebe and Alemayehu 2021, who suggested that knowledge and skill-based training should be provided regularly to both smallholder cattle producers and AI technicians, as it may enhance the technology's effectiveness and the attitudes of communal farmers towards cattle artificial insemination technology.

Table 2: Farmer education level in relation to satisfaction on AI

		Educational level of the household head			Total
		Primary	Secondary	Tertiary	
Are you satisfied with the overall AI service *P*=0.982	Yes	28 (45)	6 (46)	3 (50)	37 (46)
	No	33 (55)	7(52)	3 (50)	43 (54)
Total		61 (76)	13 (16)	6 (8)	80 (100)

Table 3: Relationship between years practicing farming versus when farm first heard about AI

		When did you first hear about artificial insemination			Total
		2017-2020	2010-2016	<2010	
Number of years practicing farming P =0.491	10 years	6	2	1	9 (11)
	11-20 years	15	5	7	27(34)
	21-30 yes	13	1	6	20 (25)
	+30 years	17	1	6	24 (30)
Total		51(64)	9(11)	20 (25)	80 (100)

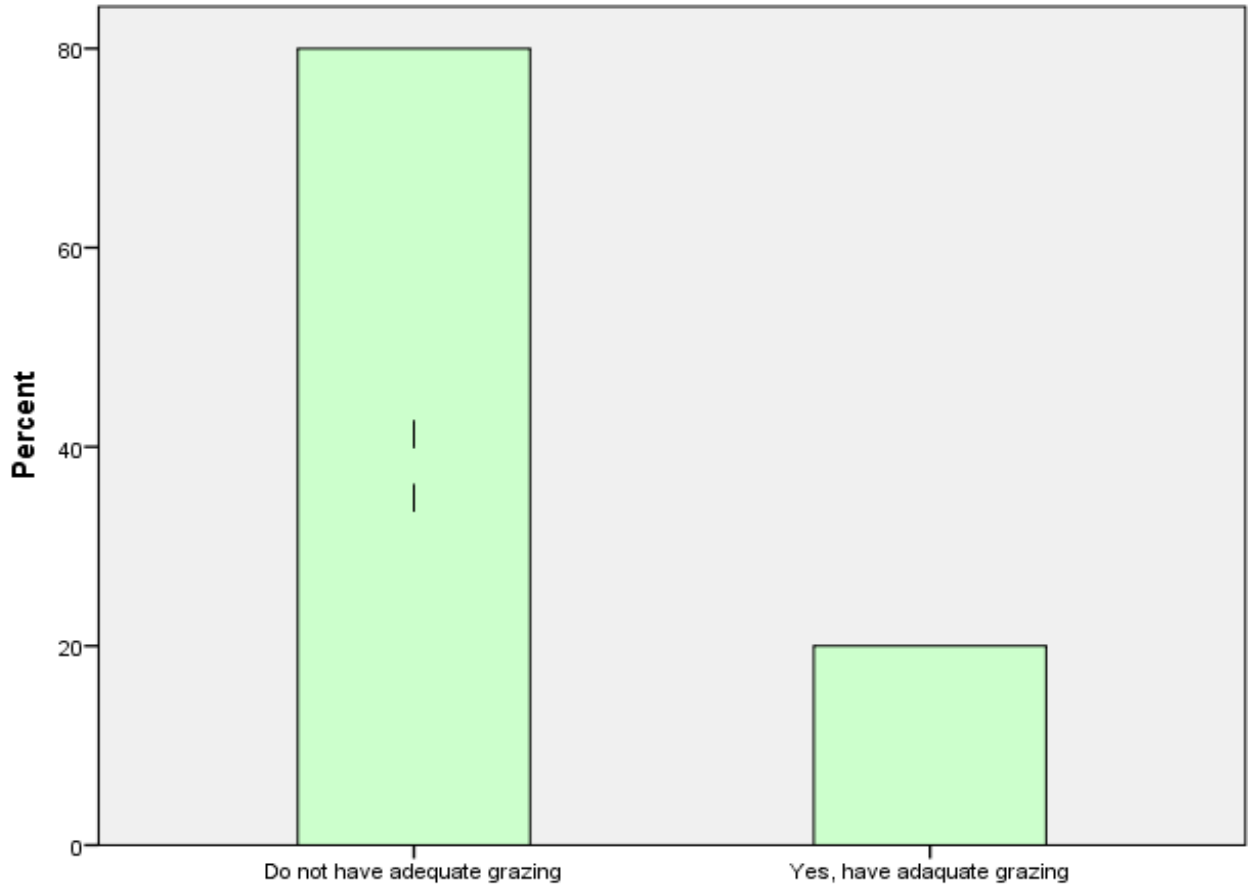

Figure 1: Availability of adequate grazing

Table 4: Farmer perception of AI technician's cooperation, access to AI service, satisfaction with AI service

		Ward 3	Ward 5	Ward 11	Total
AI technician cooperation *P* =0.991	Cooperative	22(27.4)	23(28.8)	34 (42.5)	79 (98.7)
	Non-cooperative	0 (0)	0 (0)	1 (1.3)	1 (1.3)
	Total	22 (27.4)	23 (28.8)	35 (43.8)	80 (100)
Access to AI service post ZRBF *P* = 0.611	Have Access	1 (1.3)	0 (0)	1 (1.3)	2 (2.5)
	Do not Have Access	21 (26.3)	23 (28.8)	34 (42.5)	78 (97.5)
	Total	22 (27.4)	23 (28.8)	35 (28.8)	80 (100)
Satisfaction *P* = 0.128	Satisfied	11 (13.8)	14 (17.5)	11 (13.8)	37 (46.3)
	Not Satisfied	11 (13.8)	9 (11.3)	23 (28.8)	43 (53.7)
	Total	22 (27.4)	23 (28.8)	35 (28.8)	80 (100)
Do you have all the information you need on AI *P* = 0.609	Yes	6 (7.5)	8 (10)	8(10)	22 (27.5)
	No	16 (20)	15 (18.7)	27 (33.7)	58 (72.5)
	Total	22	23	35	80

The survey revealed that 79 (98.7%) farmers perceived the AI service technicians as cooperative across all three wards, with no significant association (P ≥0.05) observed between ward and perception of farmer AI technicians (Table 4). However, almost all respondents did not practice AI outside government-sponsored initiatives, with 97.5%

of the farmers indicating that there are no cattle artificial insemination practitioners in the district, and 53.7% of the farmers reported dissatisfaction with the service due to lack of access to critical information on AI (72.5%). This sentiment was consistent across all wards, with no significant differences observed ($P > 0.05$). The results of the current study corroborate the findings of Juneyid et al. (2017), who reported that the majority of communal farmers in Ethiopia have a negative perception of using AI services because of a lack of locally based artificial insemination technicians and limited inputs. These findings indicate that farmers in the Beitbridge communal area are unable to access AI services when needed, particularly during the optimal insemination window for animals in estrus, to improve their animals' genetic potential and productivity. Only 22 of the 80 farmers indicated that they possessed comprehensive knowledge of AI across all wards, with 75.5% lacking full understanding of AI. These observations align with the findings of Gororo et al. (2017), who noted that only 1% of farmers had knowledge of synchronization, although some (59%) were aware of artificial insemination technology.

4.0 Conclusions and Recommendations

This study examined farmers' perceptions and determinants of artificial insemination (AI) technology in communal farming systems in Beitbridge, Zimbabwe. Factors such as demographic profiles, farming experience, education, and satisfaction with AI services were investigated. Findings indicate that education levels may influence satisfaction with AI services and that farming experience correlates with awareness of AI technology. The study also examined the availability of grazing, perceptions of AI technician cooperation, access to AI services, and overall satisfaction. Communal farmers in Beitbridge primarily use natural mating, with AI and estrus synchronization only during government or NGO-sponsored programs. Low AI adoption is due to insufficient awareness and lack of structured breeding programs, leading to uncontrolled mating in communal grazing lands.

Respondents noted challenges in implementing ARTs like estrous synchronization and AI due to the lack of local inseminators, relying on government programs, and insufficient information on insemination services. This inaccessibility to reproductive technology practitioners has limited AI and synchronization use in communal areas. The study recommends collaboration among cattle stakeholders to address

challenges in optimizing cattle productivity through ART. The ART project should ensure continuity beyond government/NGO periods by training government workers and lead farmers as inseminators and decentralizing service providers. Community-led sustainability frameworks should support government efforts in rural cattle farming.

Alternative methods for technology dissemination are needed as many communal farmers lack awareness of AI fundamentals, such as breeding equations and synchronization protocols. These results highlight the complex interplay of factors affecting AI adoption and perception in communal farming. The outcomes may improve AI implementation and acceptance in similar contexts. Further research is recommended to explore additional factors influencing AI adoption and develop strategies for enhancing AI program effectiveness in communal farming systems. The findings can guide policymakers and agricultural extension services in better supporting farmers in adopting and benefiting from AI.

STUDY HIGHLIGHTS

- Farmers in communal areas overwhelmingly prefer natural mating over artificial insemination for cattle breeding.
- Government and NGO-sponsored programs are the primary contexts for artificial insemination usage.
- Artificial Insemination adoption is constrained by the scarcity of locally-based insemination services.
- Limited knowledge of assisted reproductive technologies (ARTs) among farmers poses a significant challenge.
- In communal grazing lands, unmanaged breeding practices are prevalent, with cows frequently mating with unknown bulls.
- The shortage of structured breeding initiatives in communal areas impedes the adoption and effectiveness of Artificial Insemination.
- ARTs require a collaborative stakeholder approach to boost cattle productivity in smallholder farming sector.

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All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by SS; SW; XZ; AC; and ICJ. The first draft of the manuscript was written by BT; GT; TDM; and GS and all authors commented on subsequent versions of the manuscript. Review & editing to the manuscript were guided by NA. All authors read and approved the final paper.

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