Research Report

Intrinsic and management-related factors associated with bull breeding soundness examination failure: a retrospective study

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Abstract

Bull breeding soundness examination (BBSE) is critical for identifying subfertile bulls and preventing reproductive and economic losses in cow/calf systems. This retrospective study evaluated intrinsic and extrinsic factors associated with BBSE failure in bulls. Data from 1,375 BBSE records (2008-2018) included age, breed, body condition, scrotal circumference (SC), semen quality traits, physical and reproductive findings, examining veterinarian, season, and prior BBSE history. Outcomes were classified as pass or fail. Among failures, sperm morphologic abnormalities were the predominant reason (73.3%), followed by inadequate SC (8.6%), penile abnormalities (5.5%), no ejaculate produced (4.6%), and lameness (3.1%). Bulls that previously failed BBSE were likely to fail again (> 6 times) with abnormal morphology accounting for 93% of repeat failures. Significant intrinsic predictors of failure included SC, sperm morphology, progressive motility, primary and secondary defects, gross motility, breed, and body condition score. Significant extrinsic predictors included examining veterinarian, year, quarter, and prior BBSE status. A significant downward trend (p = 0.0299) in failure prevalence was observed. In the multivariable model, previous BBSE, year of examination, and examination quarter remained independently associated with failure. Results highlighted the multifactorial nature of BBSE outcomes and emphasized the importance of considering prior evaluation history, seasonal timing, and persistent morphology abnormalities when interpreting results and managing herd reproductive performance.

Keywords: Breeding, bull, evaluation, reproductive soundness, infertility

Introduction

Efficient management of cow/calf operations depends on maintaining a short, well-defined calving season that in turn relies heavily on the fertility of breeding bulls.[1] Although complete infertility in bulls is uncommon, subfertility is far more prevalent and has substantial economic consequences. Subfertile bulls can delay conception, lengthen calving season, reduce calf weaning weights, and increase the number of females culled due to failure to conceive.[2–5] In multiple-sire breeding systems, subfertile bulls may remain undetected because fertile herd mates compensate for poor performance, yet their use still reduces overall reproductive efficiency.[2,3] Conversely, single-sire breeding groups and artificial insemination programs heighten the importance of identifying and removing subfertile bulls prior to the breeding season.

Because no single trait reliably predicts bull fertility, comprehensive evaluation is essential.[2] Society for Theriogenology (SFT) established guidelines for bull breeding soundness evaluation (BBSE) that are widely used across North America to classify bulls as satisfactory, unsatisfactory, or deferred potential breeders.[6] A BBSE includes assessment of physical soundness, especially musculoskeletal and reproductive structures; scrotal circumference (SC); and semen quality measures such as progressive motility and sperm morphology. Scrotal circumference is strongly correlated with paired testis weight, daily sperm production, and overall semen quality.[5] Other key components include examination of penis, prepuce, and accessory sex glands (vesicular adenitis is the most common abnormality in young bulls[5]).

Under SFT standards, a bull must demonstrate ≥ 30% progressive motility and ≥ 70% morphologically normal sperm to be

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classified as a satisfactory potential breeder.[6] Bulls that fail to meet thresholds due to temporary conditions (e.g. peripubertal status, mild injury) or reversible testicular degeneration are designated as classification deferred. Bulls with heritable defects, insufficient SC, or permanent reproductive pathology are classified as unsatisfactory potential breeders. Subfertility affects 20-40% of bulls in a population, with abnormal sperm morphology as the leading reason for BBSE failure and comprising up to 85% of deferred or unsatisfactory classifications.[6–12]

Prevalence of BBSE failure and reasons for unsatisfactory classifications in varying bull populations have been reported.[4,9–15] However, limited recent information exists regarding how intrinsic factors (age, breed, SC, semen quality) and extrinsic factors (season, year, examining veterinarian, herd characteristics) collectively influence BBSE outcomes in modern beef production systems. Moreover, the extent to which these factors vary regionally and particularly within southeastern USA herds remains insufficiently characterized.

Therefore, the objectives of this retrospective study were to: 1. estimate the prevalence of BBSE failure in bulls evaluated in Tennessee; 2. identify intrinsic and extrinsic factors associated with failure, including semen quality traits, SC, age, breed, season, year, examining veterinarian, and prior BBSE history; and 3. describe temporal patterns in 10 years of BBSE results, with a goal to assist veterinarians, producers, and reproductive specialists in understanding trends in bull fertility, optimizing the timing and interpretation of BBSEs, and improving reproductive efficiency in regional cow/calf operations.

Materials and methods

This retrospective study evaluated BBSE results of 2008-2018 conducted at the University of Tennessee Veterinary Medical Center. Faculty clinicians, clinical interns, or residents performed evaluation. Since data collected at the teaching hospital were used this study is exempt from Institutional Animal Care and Use Committee approval. Data extracted from medical records included temporal information (year, month, calendar quarter of evaluation), demographic characteristics (age in months, breed [grouped as 'other' if < 30 records] and body condition score [thin, moderate, good, or obese]), and clinical findings involving feet, legs, and reproductive tract. Reproductive parameters recorded were scrotal circumference (SC) and semen quality traits (motility and morphology), classified according to 1993 Society for Theriogenology (SFT) guidelines.[8]

Outcomes were categorized as satisfactory, unsatisfactory, or decision deferred. For data analyses, outcomes were dichotomized into **pass** (satisfactory) and **fail** (unsatisfactory or deferred). Additional variables included the primary reason for BBSE failure (grouped into 'other' if < 10 cases), the examining veterinarian (grouped into 'other' if < 20 examinations performed), and whether the bull had undergone a prior BBSE.

Data analysis

Descriptive statistics were generated for all variables, including frequencies, proportions, measures of central tendency, and dispersion. Temporal trends in failure prevalence were assessed using the Cochran–Armitage trend test. Univariable and multivariable logistic regression analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA) to identify intrinsic (e.g. age, semen parameters) and extrinsic (e.g. year, season, examiner) factors associated with BBSE failure. Variables with $p < 0.20$ in univariable analysis were considered for inclusion in multivariable modeling. Model fit and biologic plausibility guided final variable selection.

Results

Descriptive statistics

Of the 1,405 BBSE records examined, 30 were excluded due to missing data on year, evaluating veterinarian, or BBSE outcome, leaving 1,375 records for analysis. Detailed descriptive results are summarized (Table 1).

Age, breed, body condition, and source herds

Bulls were 8-120 months of age (Figure 1), with most (83.0%; 1,103/1,329) ranged 12-24 months. Angus bulls comprised 87.1% (1,172/1,346) whereas Hereford (2.3%), mixed breeds (2.5%), and multiple minor breeds (8.1%) accounted for the remainder. Breed was unreported in 2.1% of cases. Approximately 85% of bulls were classified as having a 'good' body condition, with similar proportions in pass and fail groups.

Examinations were conducted on bulls from ~ 130 farms (~ 10 bulls/farm; median: 2; range: 1-449). Five farms contributed 67.0% of all evaluations. Eighteen veterinarians performed BBSEs, with 3 examiners accounting for 83.1% of all examinations.

BBSE outcomes and reasons for failure

Overall, 76.3% (1,049/1,375) of bulls passed BBSE. Among the 326 failures, the most common reasons were: sperm morphologic abnormalities (73.3%), insufficient scrotal circumference (8.6%), penile abnormalities (5.5%), no ejaculate produced (4.6%), and lameness (3.1%). Of the bulls included in this dataset, 8.5% (117/1,375) failed previously and 60.7% of these failed again, with inadequate sperm morphology responsible for 93% of repeat failures.

Semen quality and scrotal circumference

Key semen and SC comparisons between pass and fail groups were as follows: Normal morphology: median 80% (pass) versus 46% (fail); ≥ 70% achieved in 80.5% (1,054/1,310) of evaluations. Progressive motility: median 70% (pass) versus 60% (fail); ≥ 30% achieved in 99.3% (1,311/1,375). Primary defects: median 10% (pass) versus 46% (fail). Secondary defects: median 4% in both groups. Scrotal circumference: median 37 cm (pass) versus 36 cm (fail). Gross motility differed between groups, with the pass group predominantly rated as very good (51%) or good (36.6%), and the failed group exhibiting a higher proportion of fair (27%) and poor (3.4%) classifications.

Temporal patterns

Annual BBSE volume ranged between 14 (2009) and 380 (2016) examinations. Quarterly distribution was: Q1 (50.8%), Q2 (8.8%), Q3 (7.2%), and Q4 (34.2%).

Table 1. Summary data and results of univariable logistic regression for factors associated with bulls classified as failed (unsatisfactory or deferred)

Factor	Bulls failed		Bulls passed		OR (95% CI)	p value
	Total bulls	Distribution values†	Total bulls	Distribution values†		
Age (1 month increase)	311	14 (12.50-16)	1,018	14 (13-21)	–0.1370* (–0.2197 to –0.0542)	0.0012
Age^2 (Month^2)					0.00269* (0.00075 to 0.00464)	0.0066
Age^3 (Month^3)					–0.00001* (0.00003 to –∞)	0.0337
Breed	326		1,049			
Angus	278	85.28	894	85.22	1.10 (0.69-1.77)	0.6890
Hereford	9	2.76	22	2.10	1.45 (0.59-3.56)	0.4185
Mixed	3	0.92	31	2.96	0.34 (0.01-1.22)	0.0982
Unknown	12	3.68	17	1.62	2.50 (1.05-5.95)	0.0383
Other	24	7.36	85	8.10	Referent	NA
Body condition	326		1,049			
Good	241	73.93	976	93.04	Referent	NA
Moderate	13	3.99	51	4.86	1.03 (0.55-1.93)	0.9206
Thin	1	0.31	0	0.00	∞ (< 0.00-∞)	0.9836
Obese	1	0.31	0	0.00	∞ (< 0.00-∞)	0.9836
Unreported	70	21.47	22	2.10	12.89 (7.82-21.23)	< 0.0001
Veterinarian identification	326		1,049			
19	116	35.58	319	30.41	3.33 (1.40-7.95)	0.0066
14	127	38.96	354	33.75	3.29 (1.38-7.82)	0.0071
12	12	3.68	72	6.86	1.53 (0.54-4.33)	0.4252
11	7	2.15	19	1.81	3.38 (1.01-11.31)	0.0485
09	6	1.84	55	5.24	Referent	NA
04	5	1.53	16	1.53	2.86 (0.77-10.62)	0.1157
02	42	12.88	185	17.64	2.08 (0.84-5.15)	0.1133
Other	11	2.76	29	3.37	3.48 (1.17-10.36)	0.0253
Previous BBSE	326		1,049			
Yes	71	21.78	46	4.39	6.07 (4.09-9.02)	< 0.0001
No	255	78.22	1,003	95.61	Referent	NA
Reason for failure	326		1,049			
Abnormal morphology	239	73.31	0	0.00	NA	NA
Unsatisfactory scrotal circumference	28	8.59	0	0.00	NA	NA
Penile abnormalities	18	5.52	0	0.00	NA	NA
No ejaculate	15	4.60	0	0.00	NA	NA
Lameness	10	3.07	0	0.00	NA	NA
Other	15	4.60	0	0.00	NA	NA
N/A	1	0.31	1,049	100	NA	NA
Scrotal circumference (1 cm increase)	314	36 (33.40-38.75)	1,042	37 (35-38.80)	–11.2122* (–17.8736 to –4.5509)	0.0010
Scrotal circumference^2 (cm^2)					0.2769* (0.0965 to 0.4572)	0.0026

(Continued)

Table 1. *(Continued)*

Factor	Bulls failed		Bulls passed		OR (95% CI)	p value
	Total bulls	Distribution values†	Total bulls	Distribution values†		
Scrotal circumference^3 (cm^3)					–0.00225* (–0.00387 to –0.00064)	0.0063
Percentage normal sperm	263	46 (25-59)	1,047	80 (75-86)	0.84 (0.82-0.86)	< 0.0001
Progressive motility	266	60 (40-75)	1,045	70 (55-85)	0.96 (0.96-0.97)	< 0.0001
Percentage primary defective sperm	263	46 (30-70)	1,047	14 (10-20)	1.17 (1.15-1.20)	< 0.0001
Percentage secondary defective sperm	262	4 (1-10)	1,047	4 (2-6)	1.07 (1.05-1.09)	< 0.0001
Gross motility	326		1,049			
Very good	66	20.25	535	51.00	Referent	NA
Good	100	30.67	384	36.61	2.11 (1.51-2.96)	< 0.0001
Fair	88	26.99	123	11.73	5.80 (3.99-8.43)	< 0.0001
Poor	11	3.37	0	0.00	∞ (< 0.00-∞)	0.9848
Unreported	61	18.71	7	0.67	38.21 (16.26-89.83)	< 0.0001
Year of BBSE	326		1,049			
2018	10	3.07	34	3.24	3.50 (1.31-9.31)	0.0123
2017	9	2.76	107	10.20	Referent	NA
2016	78	23.93	280	26.69	3.31 (1.60-6.84)	0.0012
2015	35	10.74	105	10.01	3.96 (1.82-8.65)	0.0005
2014	85	26.07	179	17.06	5.65 (2.73-11.69)	< 0.0001
2013	49	15.03	165	15.73	3.53 (1.67-7.48)	0.0010
2012	19	5.83	60	5.72	3.77 (1.60-8.84)	0.0023
2011	12	3.68	37	3.53	3.86 (1.50-9.89)	0.0050
2010	16	4.91	38	3.62	5.01 (2.04-12.27)	0.0004
2009	5	1.53	9	0.89	6.61 (1.82-23.94)	0.0041
2008	8	2.45	35	3.34	2.72 (0.97-7.58)	0.0562
Quarter of the year at BBSE	326		1,049			
First	182	55.83	486	46.33	1.77 (1.32-2.37)	0.0001
Second	34	10.43	87	8.29	1.85 (1.16-2.93)	0.0089
Third	25	7.67	74	7.05	1.60 (0.96-2.66)	0.0718
Fourth	85	26.07	402	38.32	Referent	NA

†distribution values reported are (%) with factor for categorical variables and median (interquartile range) for quantitative variables. *Parameter estimates. NA = Not applicable.

Univariable logistic regression analysis

Age had a significant cubic association with BBSE failure, with elevated failure risk in young bulls, reduced risk in mid-aged bulls, and increased risk again in older bulls (Figure 1). Significant **intrinsic** predictors of failure included SC, normal sperm morphology, progressive motility, primary and secondary defects, gross motility, breed, and body condition score. Significant **extrinsic** predictors included examining veterinarian, year and season of evaluation, and prior BBSE history. A significant temporal trend (p = 0.0299) in failure prevalence was detected, with later years exhibiting lower failure rates (Figure 2; Table 1).

Multivariate logistic regression analysis

Significant predictors retained in the final multivariable model (Table 2) were:

- **Previous BBSE:** bulls with a prior BBSE had > 6 fold higher odds of failure than bulls undergoing their first evaluation.
- **Year:** relative to 2017 (year with lowest failure prevalence, 7.8%), odds of failure were significantly higher in 2009, 2011, and 2013-2016 (adjusted OR range: 2.98-8.74).
- **Season (Quarter):** compared to Q4, odds of failure were higher in Q1 (OR = 1.88) and Q3 (OR = 2.57).

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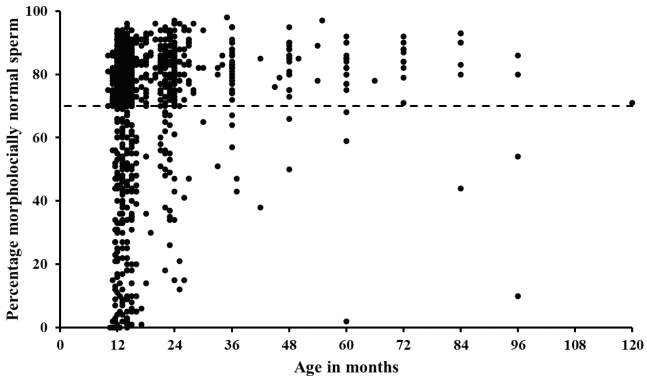

Figure 1. Distribution of percent morphologically normal sperm as bulls aged (n = 1,310). Dashed line (70%) is the minimum percent morphologically normal sperm at which bulls may be classified as satisfactory potential breeders.

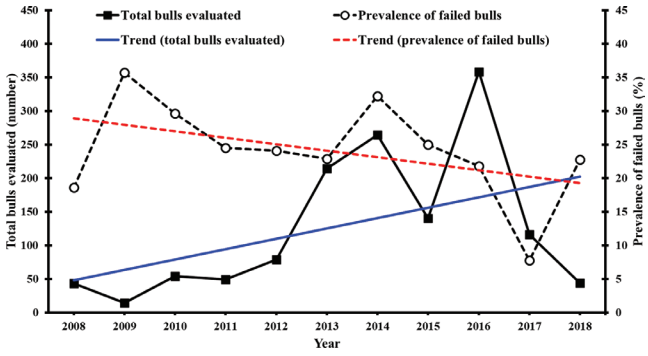

Figure 2. Yearly time series of the average number of BBSE and the prevalence of bulls failed

Model diagnostics supported good overall fit and biologic plausibility of the retained predictors.

Discussion

This 10 year retrospective evaluation of 1,375 BBSE records provided important insights to the prevalence of subfertility in bulls and the intrinsic and extrinsic factors associated with BBSE failure. In this population, 23.7% of bulls did not meet the threshold for satisfactory potential breeder, a finding consistent with reports indicating that ~ 20-40% of bulls may be classified as unsatisfactory or deferred at any evaluation.[11–16] As reported before, sperm morphology was the predominant reason for failure, accounting for > 70% of unsatisfactory classifications.[4,7,10–12,16] This reinforced the established role of morphology as a key determinant of bull fertility and a highly sensitive indicator of testicular dysfunction. Notably, intrinsic factors (age, SC, semen quality) and extrinsic factors (previous BBSE history, year, season of examination, examining veterinarian) significantly influenced BBSE outcomes.

Intrinsic factors

Age had a strong cubic relationship with BBSE outcome. Very young bulls (< 12 months) and older bulls (≥ 60 months) were more likely to be classified as unsatisfactory or deferred, aligning with reports, demonstrating higher failure rates among sexually immature bulls and those with age-related degeneration.[4,7,10,16,17] Furthermore, ~ 5.3% of bulls in this study were examined before 12 months of age; these bulls likely exhibited incomplete testicular maturation, lower SC, and poorer sperm morphology, reflecting normal developmental constraints.[18] Although some bulls may improve with age, evidence from studies is conflicting. A study reported that only ⅓ of deferred bulls achieved satisfactory status 2 months

Table 2. Final multivariable logistic regression analysis of factors associated with bulls classified as failed (unsatisfactory or deferred)

Variable	Category	OR	95% CI	p value
Previous BSE	Yes versus No	6.11	3.98-9.39	< 0.0001
Year	2008 versus 2017	3.07	0.73-12.86	0.1959
	2009 versus 2017	8.74	1.35-56.77	0.0147
	2010 versus 2017	3.56	0.98-12.90	0.0558
	2011 versus 2017	4.09	1.11-15.16	0.0284
	2012 versus 2017	2.69	0.80-9.04	0.1626
	2013 versus 2017	4.03	1.40-11.61	0.0036
	2014 versus 2017	6.54	2.39-17.92	< 0. 0001
	2015 versus 2017	3.97	1.34-11.79	0.0057
	2016 versus 017	2.98	1.08-8.22	0.0281
	2018 versus 2017	2.96	0.76-11.57	0.1815
Quarter of the year	1 versus 4	1.88	1.24-2.85	0.0005
	2 versus 4	1.35	0.67-2.73	0.6939
	3 versus 4	2.57	1.22-5.42	0.0066

after original BBSE[17] whereas in another study > 90% of yearling bulls eventually passed after multiple evaluations over a ~ 3 month interval.[11] These inconsistencies underscored that maturation alone did not guarantee improvement, particularly when persistent morphological abnormalities were present. Similar to what was observed;[15] in this study there was a predominance of young bulls in the dataset of BBSEs. This may indicate that farmers go against the recommendation to complete a BBSE on every bull every season, once the bulls have passed their initial examination.

Scrotal circumference, a robust statistical predictor of breeding soundness; however, there was no biological difference between bulls that passed and failed BBSE because the median circumference of bulls that failed was greater than the minimum needed to be classified as satisfactory potential breeders. Although failure in BBSE due to inadequate SC (8.6%) was consistent with earlier work and frequently occurred in bulls previously deferred,[18] evidence from the current study suggested that SC was biologically not associated with BBSE outcome. However, based on a report,[19] bulls with smaller SC (≤ 34 cm) were more likely to have a greater percentage of morphologically abnormal sperm compared to bulls with larger SC (> 34 cm). Additionally, SC was positively correlated to percentage morphologically normal sperm in bulls 11-15 months of age.[19] Although it is important to identify bulls that do not meet the minimum criteria for SC by age, SC may not be as important in older bulls, as the correlation between SC and sperm production decreased with age.[20] Because SC is highly age-dependent and linked to puberty onset, repeatedly low measurements could suggest underlying developmental or endocrine limitations that are unlikely to resolve with time alone.

Sperm morphology was the most important semen characteristic influencing classification. Nearly all bulls met motility thresholds but morphological defects were common among failures, including repeat evaluations. Among bulls with prior unsatisfactory or deferred BBSE that failed again, 93% failed due to persistent morphological abnormalities, indicating long-standing or permanent testicular dysfunction. Without data on the interval between evaluations or the reasons for initial deferrals, the precise contribution of transient insults such as heat stress, illness, or nutritional stress remains unclear.[21–24] Nonetheless, the high proportion of chronic morphology abnormalities observed reinforced morphology as a key long-term indicator of reproductive fitness. Because of the retrospective nature of this study and since multiple veterinarians were involved, the specific type(s) of morphological defects observed were not consistently reported. Therefore, it was not possible to expand on the specific effects of specific defects that had on the outcomes of the BBSE.

Breed was not a strong overall predictor of BBSE outcomes, except in bulls with unknown or unreported breeds that had lower odds of satisfactory classification. Although studies have reported breed-related differences,[7,10,16] the largely *Bos taurus* composition of this population may have minimized such effects.

Bulls that had previously undergone a BBSE and failed, were over 6 times more likely to be classified as unsatisfactory or deferred again. This persistent trend suggested that underlying issues may not resolve between evaluations. In the present study, age, SC, sperm motility, and sperm morphology were the primary contributors to repeat failures. Notably, 60.7% of the bulls with prior BBSE were still not classified as satisfactory at the next repeat BBSE after an initial failure. This contrasts with findings from a report,[11] in which only 13.9% of yearling bulls failed to achieve a satisfactory classification following their next repeat BBSE after an initial failure. Ultimately, 93.1% of those yearling bulls were classified as satisfactory after up to 3 evaluations.[11] In that study, bulls were given up to 67 days between the initial and first repeat examination and up to 56 days between subsequent evaluations. In the present study, the interval between the initial and subsequent BBSEs and whether multiple reevaluations occurred could not be determined. Nonetheless, the earlier report suggested that, at least for yearling bulls, allowing more interval between evaluations and performing additional BBSEs may increase the likelihood of eventual satisfactory classification.

Extrinsic and temporal factors

Year of evaluation significantly influenced failure rates. Higher failure rates in certain years may reflect environmental pressures such as heat waves or drought, both of which impair sperm production and morphology.[16,25,26] Improvements in later years may stem from increased producer awareness, better pre-examination conditioning, shifts in herd management, or selection against chronically unsound bulls. Importantly, examiner-related variation also contributed to temporal patterns as only 2 veterinarians contributed to the dataset for the entirety of the study. Differences in training, experience, and interpretation of morphology thresholds likely introduced subjectivity. Increases in morphology-related failures may represent times when more rigorous evaluators were active. Even within standardized BBSE protocols, interexaminer differences in semen evaluation are well documented and warrant continued emphasis on calibration and quality control.

Seasonal variation significantly affected BBSE performance. Bulls evaluated in the first and third quarters, corresponding to winter/early spring and midsummer, had higher odds of failure. This aligns with studies that suggested extreme temperatures, particularly heat stress, impaired spermatogenesis, with effects manifesting 45-60 days later.[16,25,26] Although there was no overall effect of season on percent normal sperm, specific defects (e.g. midpiece defects, vacuoles, teratoids, knobbed acrosomes) did vary seasonally.[7] These abnormalities may be linked to stress-mediated hormonal changes, including cortisol-induced suppression of testosterone production and downstream effects on spermatogenesis.[5,27–29] Increased failure rates observed during Q1 and Q3 in this study are consistent with these mechanisms, suggesting that extreme cold or heat likely contributed to morphological abnormalities.[30]

Examining veterinarian was a significant predictor of BBSE outcome in univariable analysis and likely contributed to observed temporal and seasonal patterns. Differences in training, experience, morphology interpretation, and adherence to SFT thresholds may introduce variability despite the use of standardized protocols. Given that 3 veterinarians performed more than 80% of BBSEs, examiner effects may be particularly relevant. Patterns of veterinarian involvement also displayed seasonality. Some veterinarians conducted most BBSEs during certain quarters, typically spring herd work or fall reproductive evaluations, making it difficult to fully disentangle examiner effects from seasonal effects. Similarly, age distribution varied

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by season, with younger bulls more commonly evaluated in Q1-Q2 (prebreeding and presale periods), increasing the likelihood of failures due to physiological immaturity. Collectively, these findings emphasize that timing of a BBSE should be interpreted in relation to environmental conditions, bull age, and examiner consistency.

Study limitations

Because this study was conducted at a veterinary teaching hospital, some referral bias is possible. Also, bulls suspected of subfertility may have been overrepresented whereas sound bulls evaluated on farms were not included. Thus, the study population may not fully represent the bull population in Tennessee. Missing information regarding prior BBSE findings and intervals between evaluations limited exhaustive interpretation of repeat failures. Although it is well known that white blood cells in the ejaculate can substantially affect BBSE outcomes, this measure was not consistently completed by the veterinarians involved across the study; therefore, it was not included. Additionally, this dataset was of bulls classified according to 1993 SFT guidelines and use of the more recent, 2018 SFT guidelines, may have resulted in different findings. Nonetheless, inclusion of 10 years of records and more than 1,300 examinations provides a robust dataset for identifying trends and associated factors.

Conclusion

This study demonstrated that BBSE outcomes were influenced by a combination of intrinsic bull factors and extrinsic management-related variables. Age, scrotal circumference, and sperm morphology were the most significant intrinsic predictors, with immature and older bulls exhibiting higher failure rates. Persistent morphology abnormalities in bulls with previous BBSEs highlighted the importance of morphology as a stable indicator of reproductive potential. Extrinsic factors, including season, environmental stressors, year of evaluation, and examining veterinarian, also had substantial roles, reinforcing that BBSE outcomes must be interpreted in context. Seasonal heat and cold stress, age distribution at evaluation, and examiner variability all contributed to differences in failure rates. These findings support a more nuanced and individualized approach to BBSE interpretation. Bulls failing evaluations early in life or during intervals of environmental stress may benefit from re-evaluation under more favorable conditions whereas repeated failures, particularly those due to persistent morphology abnormalities or inadequate SC may indicate irreversible infertility. Standardization of BBSE training and enhanced interobserver calibration could further improve reliability across practitioners. Collectively, these results provided veterinarians and producers with practical insights to optimize bull selection, reduce premature culling, and improve reproductive efficiency in cow/calf operations.

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Authors' contribution and agreement

CO: methodology, investigation, validation, data curation, writing original draft, reviewing, editing; **LS:** methodology, investigation, reviewing, editing; and **BW:** conceptualization, methodology, investigation, supervision, project administration, writing, reviewing, editing. Authors have read and approved final submission.

Conflict of interest

None to report.

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