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Sığır Lösemi Virüsü ile Enfekte Sığırlarda Telomer Uzunluğu ile Fizyolojik Parametreler Arasındaki İlişkinin Değerlendirilmesi

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Anahtar Kelimeler:
Yaş
Vücut kondisyon skoru
Sığır lökozis virüsü
Doğum sayısı
Göreceli telomer uzunluğu
Seropravalans
Epidemiyoloji

ÖZ

Çalışmanın amacı, sığır lökozis virüsü (BLV) ile enfekte sığırlarda relatif telomer uzunlukları ile fizyolojik parametreler arasındaki ilişkiyi araştırmak ve Türkiye'deki süt sığırlarında BLV enfeksiyonu ile ilişkili risk faktörlerini belirlemektir. Risk değerlendirmesi için yaş, parite ve vücut kondisyon skoru olmak üzere üç değişken kullanılmıştır. En yüksek seropozitiflik oranı (%39,13), vücut kondisyon skoru 3–3,5 olan ve 2–8 yaş arasındaki sığırlarda gözlenmiştir. BLV ile enfekte sığırlardaki relatif telomer uzunluklarının enfekte olmayanlara kıyasla anlamlı derecede daha kısa olduğu bulunmuştur ($P < 0,05$). Ayrıca, en kısa relatif telomer uzunlukları hem BLV pozitif hem de negatif 8 yaş üzeri sığırlarda kaydedilmiştir ($P < 0,05$). Bu sonuçlar, BLV enfeksiyonu ile telomer kısalması arasındaki ilişkinin, yaş, parite ve vücut kondisyon skoru gibi faktörlerle birlikte, hastalık kontrolü ve önleme programları için önemli olabileceğini göstermektedir.

Assessment of The Relationship Between Telomere Length and Physiological Parameters in Cattle Infected with Deltaretrovirus bovleu

Research Article

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ABSTRACT

The aim of this study was to investigate the relationship between relative telomere length and physiological parameters in cattle infected with deltaretrovirus bovleu (BLV), and to identify risk factors associated with BLV infection in dairy cattle in Turkey. For risk assessment, three variables were used: age, parity, and body condition score. The highest seropositivity rate (39.13%) was observed in cattle aged 2–8 years with a body condition score of 3–3.5. Relative telomere lengths were found to be significantly shorter in BLV-infected cattle compared to uninfected ones ($P < 0.05$). Moreover, the shortest relative telomere lengths were recorded in both BLV-positive and BLV-negative cattle over 8 years of age ($P < 0.05$). These results suggest that the relationship between BLV infection and telomere shortening, together with factors such as age, parity, and body condition score, may be important for disease control and prevention programs.

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1. Introduction

Deltaretrovirus bovleu (formerly known as Bovine leukosis virus, BLV), belonging to the family Retroviridae, subfamily Orthoretrovirinae, and genus Deltaretrovirus, is widely distributed among domesticated cattle populations worldwide (Weber et al., 1988; Aida et al., 2013). First identified in 1969 as the causative agent of enzootic bovine leukosis (EBL) (Kettmann et al., 1976), BLV is responsible for a contagious lymphoproliferative disease in cattle, characterized by B-cell lymphosarcoma. It belongs to the same viral group as human T-cell lymphotropic virus types I and II (HTLV-I and HTLV-II) and simian T-cell lymphotropic virus (STLV) (Camargos et al., 2002; Tözsér, 2010; Aida et al., 2013; Murakami et al., 2013; Polat et al., 2017). BLV infection can lead to a range of clinical outcomes, often including a prolonged latency period without persistent viremia (Aida et al., 2013). Approximately one-third of BLV-infected cattle develop persistent lymphocytosis (PL), and 1–5% may progress to malignant B-cell lymphosarcoma following a latency period of 1 to 8 years. Unfortunately, there is currently no effective treatment or vaccine available for the control of BLV (Trono et al., 2001; Watanuki et al., 2019). Given that more than 90% of dairy cattle may be subclinically infected, accurate diagnosis of BLV is critical for ensuring profitable and sustainable production (Evermann et al., 2019).

Telomerase is a conserved reverse transcriptase enzyme that elongates telomeric DNA using its own RNA template. Discovered by Greider and Blackburn in 1985, it compensates for telomere loss caused by end-replication issues (Greider and Blackburn, 1985; Blackburn, 1991). While normally active in germ and proliferative cells, elevated telomerase activity is a hallmark of many tumors and is considered a potential diagnostic and therapeutic target. High telomerase activity has also been reported in blood lymphocytes and dendritic cells of BLV-infected cattle (Suzuki et al., 2008; Szczotka et al., 2019). The oncogenic potential of BLV suggests that the virus may interact with telomerase to prevent telomere attrition, potentially leading to persistent lymphocytosis (PL) and tumorigenesis (Hemmatzadeh et al., 2015). The clinical manifestations of lymphoma associated with BLV infection are largely dependent on the anatomical location of neoplastic lesions. Frequently reported symptoms include gastrointestinal disturbances (such as indigestion and anorexia), progressive weight loss, lethargy, reduced milk production, generalized weakness, and, in some cases, neurological signs due to tumor infiltration into the central or peripheral nervous system. The sporadic form of BLV-associated lymphoma is primarily observed in juvenile cattle aged ≤ 2 years, while the enzootic form is more prevalent in adult cattle aged ≥ 3 years (Sparling, 2000).

The aim of this study was to investigate the degree to which relative telomere lengths are shorter in dairy cattle infected with bovine leukosis virus (BLV) compared to uninfected cattle, to determine whether this difference varies in relation to physiological parameters such as age, parity, and body condition

score (BCS), and whether these physiological variables constitute potential risk factors for BLV seropositivity.

2. Materials and Method

2.1. Selection of the animals and sampling

The study was carried out in cattle farms located in the Marmara region of Türkiye, which were raised under intensive conditions and whose records were followed regularly. A total of 131 Simmental cattle of different ages (< 2, 2-8, and > 8) and different body condition scores (≤ 2, 3-3.5 and ≥ 4) comprised the animal material of the study. A purposive sampling strategy was employed to ensure that cattle representing all age categories (< 2, 2–8, and > 8 years) and body condition score groups (≤ 2.5, 3–3.5, and ≥ 4) were adequately included. Only clinically healthy animals without signs of acute disease at the time of sampling were selected. This sampling approach was chosen to provide sufficient representation of the study factors under investigation. Detailed information on cattle used in the study is presented in Table 1. The BCS procedures rely on visual, tactile, or combined evaluations of the amount of body condition (fat) carried by the cattle. Cattle are normally scored on a five-point scale (1: cachectic, 2: weak, 3: medium, 4: fat, 5: obese). Body condition scores were determined by the palpation method reported previously (Hady et al., 1994). Five ml blood samples were taken from the neck vein (vena jugularis) into tubes with anticoagulant (BD Vacutainer EDTA Tube 10 ml) and without anticoagulant (Vacuette® Tube 9 ml Z Serum Clot Activator). Blood samples were centrifuged at 3000 rpm for 10 minutes in a refrigerated centrifuge (NF 1200R, Nuve, Ankara, Türkiye), and then serum samples were transferred into sterile tubes and stored at −80 °C until the analysis.

Table 1. Number of cattle included in the study at different ages and body condition scores

BCS	**Age**		
	< 2	**2-8**	**> 8**
≤ 2.5	14	21	16
3-3.5	11	23	13
≥ 4	9	16	8
Total	34	60	37

BCS: Body condition score

2.2. Antibody ELISA test

Svanova BLV gp51-Ab ELISA, an indirect ELISA, was used for the detection of antibodies against BLV in serum samples in line with the manufacturer's protocol. The sensitivity (Se) and specificity (Sp) of the ELISA test were 100 and 99.4 %, respectively. Positive, negative, and blank controls and the samples were run in parallel. Optical density (OD) values were determined at 450 nm absorbance with an ELx800 microplate reader (BioTek Instruments, Winooski, USA). Before the interpretation of the results, all OD values in wells coated with BLV gp51 viral antigen were corrected by subtracting the

ODs of negative control from the samples' ODs (OD corrected = OD sample – OD control). Percentage positivity values (PP values) were evaluated. The PP values equivalent to or greater than 10 were considered positive for BLV infection.

2.3. DNA extraction

DNA was extracted from whole blood samples with an anticoagulant of 200 µL using High pure viral nucleic acid kit (Ref: 03038505001, Roche Diagnostics GmbH, Germany) according to the manufacturer's instructions. The purified nucleic acids were eluted in a final volume of 50 µL and stored at + 4 °C. The quantifications of all samples were performed on the same day.

2.4. Quantitation of DNA

The DNA was measured using a UV/VIS spectrophotometer (ND-1000, NanoDrop, Thermo Fisher Scientific, USA) according to the user guide. The optical surfaces of the spectrophotometer were cleaned by bathing with sterile deionized water of 2 µl before and after each measurement. And then, both surfaces were wiped with a Kimwipe (Kimberly-Clark Professional, USA). The nucleic acid samples (six replicates) of 2 µl were used to measure total DNA. Sterile DNAse/RNAse free water was used for the blank. The absorption ratios of 260/280 were verified for the measurement quality.

2.5. PCR assay for relative telomere lengths

RTLs were measured using a SYBR® Green based real-time PCR assay. This assay was performed using BIORAD-CFX-96 RT-PCR system and iTaq™ Universal SYBR® Green Supermix (Cat no: 172-5120, BioRad) as described previously (Cawthon, 2002; Seeker et al., 2016). Ten µl of iTaq™ Universal SYBR® Green Supermix and 2.5 µl of DNA (25–30 ng) were mixed in a reaction volume of 20 µl (7.1 µl of dH2O, 0.2 µl of forward and reverse primers TELO and 36B4) for each analyzed sample, and the reactions were conducted in duplicate. Primers of telomere (TELO 1b, 5'-CGGTTTGTTTGGGTTTGGGTTTGGGTTTGGGTTTGGGTT-3'; TELO 2b, 5'-GGCTTGCCTTACCCTTACCCTTACCCTTACCCTTACCCT-3') and ribosomal genes (36B4u, 5'-CAGCAAGTGGGAAGGTGTAATCC-3'; 36B4d, 5'-CCCATTCTATCATCAACGGGTACAA-3') were taken from a previously published study (Gil and Coetzer, 2004). RTLs analyses were performed with the following cycling conditions: initial denaturation at 95 °C for 3 minutes, 40 cycles of 95 °C for 5 seconds, and 60 °C for 1 minute. The average RTL per genome is represented by the T/S ratio. RTLs measurement analysis is determined according to the difference between the CTs of the telomere reaction (T) and single-copy gene (S). Therefore, the delta-delta Ct method, ($2^{-\Delta\Delta Ct}$ method), is a formula used to analyze the RTL of samples when performing real-time PCR. We calculated ΔCt for 36B4 and TELO genes. ΔCt is the difference in (36B4 or TELO) quantification cycle number between the two genomic DNA samples.

2.6. Statistical analysis

All data were analyzed using GraphPad Prism 7.04 and SPSS 16 (SPSS Inc., Chicago, USA) package. The normal distribution of the data was demonstrated by the Shapiro-Wilk normality test. The t-test was used to compare RTLs in BLVpos and BLVneg cattle. In addition, One-way ANOVA test was applied to compare RTLs among age and BCS groups. After the one-way ANOVA test, Tukey's HSD post-hoc multiple comparison test was performed to determine which groups differed significantly. A significance level of $P < 0.05$ was considered. The association of cow-level BLV seroprevalence with different risk factors was evaluated using the Cochran-Armitage trend test. The strength of the relationship between risk factors and BLV seroprevalence was determined by Phi and Cramer's V value. Chi-square and stepwise forward multivariable logistic regression were used to identify the most important risk factors associated with BLV infection. The fit of the multivariable logistic regression model was evaluated with the Hosmer-Lemeshow goodness-of-fit test.

3. Results

3.1. Antibody ELISA results

BLV seropositivity was found in 43 of the 131 serum samples tested. The prevalence ranged from 11.11 % to 39.13 % within the groups according to age and BCS, and the average seropositivity was 32.82 % (Table 2). The seropositivity rates in cattle aged < 2, 2-8 and > 8 years were approximately 26.47 %, 36.67 % and 32.43 %, respectively. The lowest seropositivity rate 11.11 % was found in BCS ≥ 4 cattle under two years of age, while the highest seropositivity rate 39.13 % was found in BCS 3-3.5 cattle aged 2-8 years (Table 2). The results showed that the number of seropositive animals increased in direct proportion with increasing age, but decreased inversely with increasing BCS. In addition, the results of the study showed a strong correlation between BLV infection seroprevalence and parity (Phi Coefficient and Cramer's V = 0.74). The final multivariable logistic regression model showed that parity and age were important risk factors for BLVpos cows (Table 3). Cows with multiple births had a greater number odds for BLV seropositivity (OR = 3.68, 95 % CI = 2.21-5.68), where cows with parities ≥ 4 had an increased risk (65 %) of being seropositive for BLV.

Table 2. Distribution of Deltaretrovirus bovleu antibody ELISA results by age and body condition score.

Body condition score	Age															
	< 2				2-8				> 8				Total			
	Heifer				Heifer				Heifer							
	Neg	Pos	%	Total	Neg	Pos	%	Total	Neg	Pos	%	Total	Neg	Pos	Avarege %	Total
≤ 2.5	9	5	35.71	14	13	8	38.10	21	10	6	37.50	16	32	19	37.25	51
3-3.5	8	3	27.27	11	14	9	39.13	23	8	5	38.46	13	30	17	36.17	47
≥ 4	8	1	11.11	9	11	5	31.25	16	7	1	12.50	8	26	7	21.21	33
Total	25	9	26.47	34	38	22	36.67	60	25	12	32.43	37	88	43	32.82	131

Table 3. Final multivariable logistic regression analysis of variables associated with cows that are seropositive for BLV infection

Variables	Estimated value	SE	OR	95 % CI	P-value
Age	1.12	0.23	1.44	0.89 – 2.37	0.001
Parity	2.25	0.17	3.68	2.21-5.68	< 0.001
Intercept	-5.23	0.86	-	-	< 0.001

SE: Standard error
OR: Odss ratio
CI: Confidence interval

3.2. Determination of RTLs

Relative telomere lengths were measured in whole blood of BLVpos and BLVneg cattle using real-time PCR method. The results showed that the RTLs of BLVpos cattle were found to be shorter than those of BLVneg cattle ($P < 0.05$) (Figure 1).

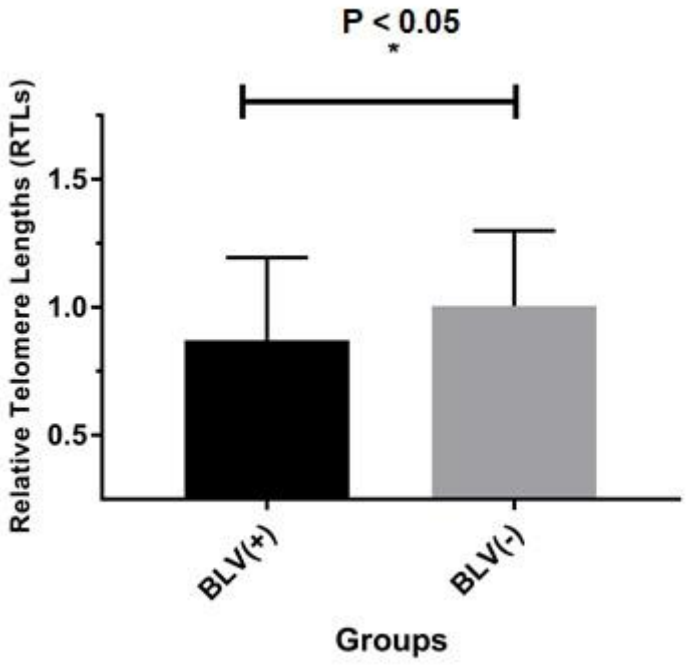

Figure 1. Relative telomere lengths in whole blood of BLV-positive (BLV^+) and BLV-negative (BLV^-) cattle measured by real-time PCR. BLV^+ cattle exhibited significantly shorter telomere lengths compared to BLV^- cattle ($P < 0.05$).

Evaluated according to age groups (< 2, 2-8 and > 8), it was observed that RTLs of BLVpos cattle older than 8 years were shorter than the others, but it was not statistically significant ($P > 0.05$) (Figure 2).

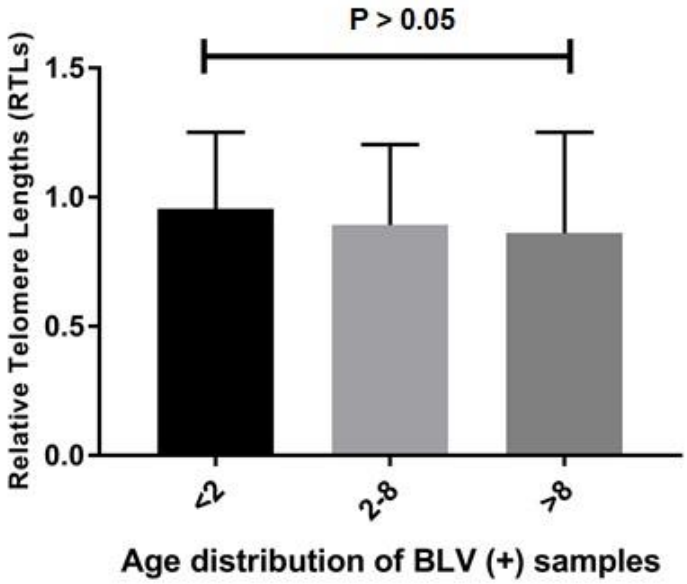

Figure 2. Relative telomere lengths of BLV-positive cattle across different age groups (< 2, 2–8, and > 8 years). Cattle older than 8 years showed shorter RTLs compared to the other groups, but the difference was not statistically significant ($P > 0.05$).

RTLs of BLVneg cattle aged > 8 years, on the other hand, were statistically substantially shorter than the age (< 2; 2-8) groups (P < 0.05; P < 0.05), respectively (Figure 3). Tukey's HSD post-hoc analysis revealed that in the BLV-negative group, cattle older than 8 years had significantly shorter RTL values compared to those aged < 2 years and 2–8 years (P < 0.05 for both comparisons). No statistically significant differences were found among BLV-positive groups or across BCS categories (P > 0.05) (Table 4).

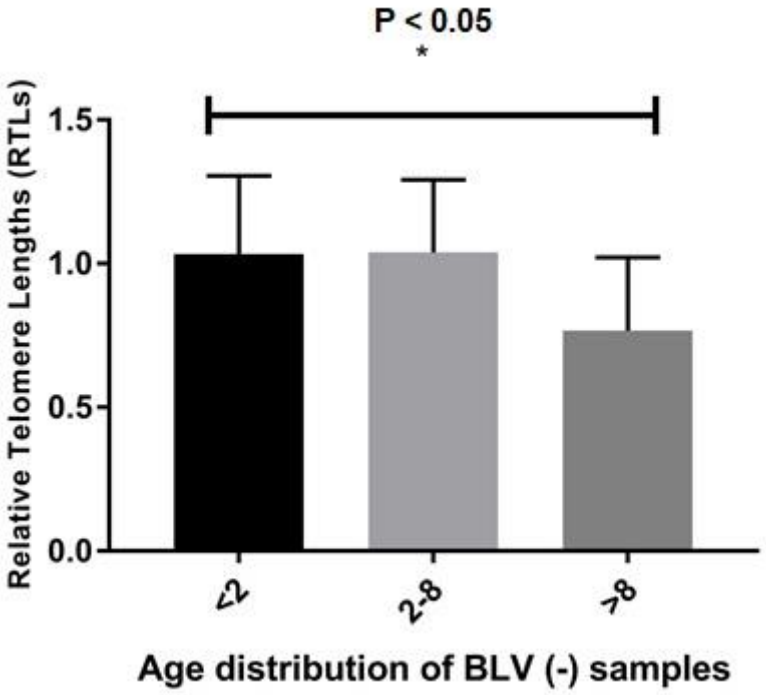

Figure 3. Relative telomere lengths of BLV-negative cattle across age groups. Cattle older than 8 years had significantly shorter RTLs compared to those aged < 2 years and 2–8 years (P < 0.05 for both comparisons).

Table 4. Tukey HSD post-hoc analysis of RTL values among age and BCS groups.

Group comparison	P value
BLV^- < 2 vs BLV^- > 8	0.012*
BLV^- 2–8 vs BLV^- > 8	0.021*
Other comparisons	> 0.05

Taking into account BCS groups (≤ 2.5, 3-3.5 and ≥ 4), RTLs of BLVpos in BCS ≤ 2.5 and BLVneg in BCS 3-3.5 cattle appeared to be shorter than the other groups, but these were not statistically significant (P > 0.05 and P > 0.05), respectively (Figure 4).

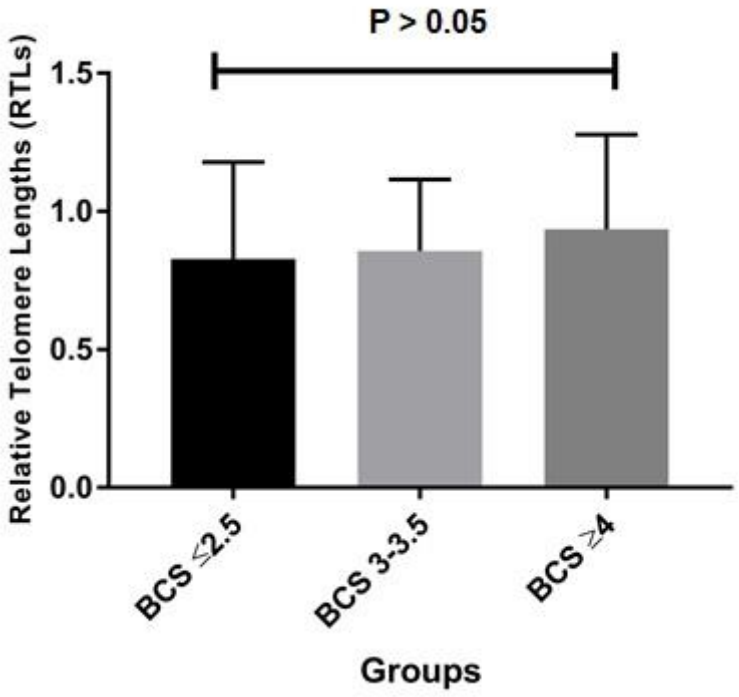

Figure 4. Relative telomere lengths of BLV-positive and BLV-negative cattle by body condition score (BCS). Shorter RTLs were observed in BLV-positive cattle with BCS ≤ 2.5 and BLV-negative cattle with BCS 3–3.5, but differences were not significant (P > 0.05).

4. Discussion

Enzootic bovine leucosis (EBL) is an economically significant disease in the cattle breeding industry, leading to production losses and trade restrictions. EBL is a malignant, systemic tumor disease of the reticuloendothelial system, observed worldwide and in Türkiye, particularly prevalent in regions where dairy cattle farming is well-developed (Sparling, 2000).

Several studies have reported the seroprevalence of BLV infection in Türkiye (Burgu et al., 1991; Batmaz et al., 1995; Yilmaz et al., 1997; Uysal et al., 1998; Tan et al., 2006; Yavru et al., 2007; Yildirim et al., 2008; Avcı et al., 2013; Şevik et al., 2015; Şimşek et al., 2017; Dogan et al., 2020; Ayvazoğlu et al., 2022). However, to the best of our knowledge, this is the first study in Türkiye to examine the interaction between BLV seroprevalence and relative telomere lengths. The aforementioned studies from Türkiye have reported BLV seroprevalence rates ranging from 0% to 59.2% in cattle. For example, Yildirim et al. (2008) reported no seropositivity in cattle from Kars province, whereas Avcı et al. (2013) found a seroprevalence of 59.2% in cattle from Isparta province. Nationally, overall seropositivity rates have been reported between 3.1% and 26.6% (Şevik et al., 2015). In the present study, we observed BLV seropositivity rates of 11.11% in cattle under 2 years of age and 39.13% in those aged 2–8 years. The variation in findings among previous studies may be attributed to factors such as the diagnostic methods employed, differences in geographic location, and varying population densities (Mousavi et al., 2014; Hemmatzadeh et al., 2015). Sample size recognized as an important risk factor in earlier

studies may also explain the discrepancy and relatively high prevalence observed in our study (Haghparast et al., 2012; Avcı et al., 2013; Mousavi et al., 2014; Şevik et al., 2015). This investigation was conducted on a small sample population. Additionally, the exclusion of cattle with unknown age or inconclusive ELISA results—intended to clarify the relationship between infection status and RTL—may have contributed to the higher seroprevalence reported. Therefore, the seropositivity rates identified in this study reflect the viral prevalence within the sampled subgroups rather than the overall herd-level prevalence. Our data also demonstrated a significant age-related increase in the number of seropositive cattle, consistent with the findings of numerous previous studies (Brenner et al., 1989; Wu et al., 1989; Ladronka et al., 2018).

As the likelihood of exposure to BLV increases with age in dairy cattle, the potential for BLV seropositivity also rises (Brenner et al., 1989; Ladronka et al., 2018; Wu et al., 2018). In agreement with previous studies (Haghparast et al., 2012; Mousavi et al., 2014; Şevik et al., 2015), our findings confirmed a positive correlation between age and BLV seroprevalence, suggesting that age may serve both as a major risk factor for and a consequence of BLV infection. It should also be emphasized, however, that telomere shortening is a well-documented age-related process independent of BLV infection. In cattle, relative telomere length (RTL) generally decreases with advancing age, driven by cumulative cell divisions, oxidative stress, and reduced telomerase activity, with rapid shortening in early life and slower attrition or stabilization in adulthood (Seeker et al., 2018; Zhang et al., 2023). Thus, the shorter RTLs observed in older animals, including those in the BLV-negative group, likely reflect physiological aging effects rather than solely viral influence. These overlapping effects of age and infection may complicate the interpretation of associations observed between BLV and telomere length, highlighting the need for longitudinal and age-stratified analyses to better clarify the direct impact of BLV on telomere dynamics.

In this study, which examined the relationship between BLV infection and relative telomere lengths (RTLs), the RTLs of BLV-positive cattle were significantly shorter than those of BLV-negative cattle ($P < 0.05$). When comparing BCS groups, the shortest RTLs were observed in BLV-positive cattle with a BCS ≤ 2.5 and in BLV-negative cattle with a BCS of 3–3.5, while the longest RTLs ($P > 0.05$) were found in both BLV-positive and BLV-negative cattle with a BCS ≥ 4. These findings indicate that body condition score (BCS), an indirect marker of nutritional status, metabolic activity, and systemic stress, may play an important role in telomere dynamics in cattle. Low BCS (≤ 2.5) generally reflects malnutrition, metabolic strain, and systemic stress, while intermediate BCS values (3–3.5) may involve increased metabolic activity and inflammatory burden; both conditions are associated with oxidative stress and inflammation that can accelerate telomere shortening regardless of BLV status. By contrast, a high BCS (≥ 4) has been associated with greater energy reserves and reduced physiological stress, which may contribute to the relatively longer RTLs observed in both BLV-positive and BLV-negative cattle (Seeker et al., 2021; Meesters et al., 2023; Zhang et al., 2023; Dewulf et al., 2024; Dewulf et al., 2025). Taken together, these results suggest that both intrinsic factors (age, BCS) and extrinsic factors

(BLV infection) should be considered simultaneously when interpreting telomere length differences, and more comprehensive studies are needed to clarify these interactions more conclusively.

In the age-based analysis, the shortest RTLs were detected in BLVpos cattle older than 8 years ($P > 0.05$), and in BLVneg cattle of the same age group ($P < 0.05$). Conversely, the longest RTLs were observed in both BLVpos and BLVneg cattle younger than 2 years, with statistical significance reached only in the BLVneg group ($P < 0.05$). These findings align with the well-documented progressive telomere shortening in most somatic cells (Suzuki et al., 2008; Chebel et al., 2009; Lu et al., 2013) as well as increased telomerase activity observed in lymphatic tumors of BLVpos cattle (Counter et al., 1994; Szczotka and Kuzmak, 2013; Szczotka et al., 2019). A statistically significant interaction between age and BLV infection was identified with respect to telomere shortening. Older BLV-infected cattle exhibited a marked reduction in RTLs. This study demonstrated a strong association between BLV infection and telomere shortening, consistent with previous findings; however, although these data indicate a possible relationship, further research is required to more clearly establish the causal nature of this association and to determine the extent to which other factors in the study may have influenced the results. The shortening of RTLs in BLVpos animals may be attributed to the accelerated aging of tumor cells induced by the virus (Szczotka and Kuzmak, 2013; Hemmatzadeh et al., 2015; Szczotka et al., 2019). Telomere length in blood cells varies considerably among individuals, influenced by factors such as age, antigenic stimulation of resting lymphocytes, and genetic variability (Hiyama et al., 1995; Tilesi et al., 2010). Telomerase activation is believed to be a critical step in the immortalization of tumor cells and the progression of cancer in BLVpos animals (Hiyama et al., 1995; Suzuki et al., 2008). Progressive telomere shortening, commonly observed in individuals with impaired telomerase function or defective telomere maintenance mechanisms, is a well-established marker of genomic instability and increased cancer susceptibility (Hemann et al., 2001; Armanios and Blackburn, 2012). Similar mechanisms appear relevant in BLVpos cattle, where telomere lengths were found to be significantly shorter than in BLVneg cattle, suggesting that BLV contributes to chromosomal instability. This observation aligns with findings in human hematologic malignancies, where telomere attrition and elevated telomerase activity correlate with disease progression and severity (Shay, 1995; Ohyashiki et al., 1997; Uchida et al., 1998). Therefore, monitoring telomere length and telomerase activity in BLV-infected cattle could offer valuable insights into disease dynamics and may serve as a useful prognostic tool.

At the cow level, the strongest positive association identified in this study was between BLV seroprevalence and parity. This finding is consistent with several previous studies (Erskine et al., 2012; Ladronka et al., 2018; Selim et al., 2020). Cows with a parity of ≥ 4 are at a higher risk of BLV infection compared to those with a parity of less than 3 (Yang et al., 2016). The increased prevalence of BLV in older cows may be attributed to the chronic nature of the disease and the prolonged exposure to transmission-related risk factors over time, such as direct physical contact between infected and uninfected animals.

5. Conclusion

As a result of the study, the effects of BLV infection, age and BCS on relative telomere length were revealed in Simmental cattle. To the best of our knowledge, this is the first study conducted in our country to examine these relationships. It was determined that the telomere length in BLVpos cattle was significantly shorter ($P < 0.05$) compared to BLVneg cattle. Moreover, the telomere shortening in BLVpos cattle over 8 years of age was also found to be statistically significant ($P < 0.05$) compared to BLVneg cattle in the same age group. Although a notable shortening was observed in BLVpos cattle with a BCS of ≤ 2.5 aged over 8 years, this difference was not statistically significant ($P > 0.05$). Investigating the relationship between BLV infection and telomere length, age, and BCS may contribute to the development of more effective control and eradication programs for the disease. However, further studies with larger sample sizes are recommended to support and expand upon these findings.

Statement of Conflict of Interest

The authors declare that there is no conflict of interest.

Author's Contributions

The authors declare that they have contributed equally to the article.

References

Aida Y., Murakami H., Takahashi M., Takeshima SN. Mechanisms of pathogenesis induced by bovine leukemia virus as a model for human T-cell leukemia virus. Frontiers in Microbiology 2013; 4: 328.

Armanios M., Blackburn EH. The telomere syndromes. Nature Reviews Genetics 2012; 13(10): 693-704.

Avcı O., Bulut O., Yapıcı O., Atlı K., Dik I. Sütçü ineklerin kan ve süt serumlarında bovine leukosis virus enfeksiyonunun ELISA ile araştırılması. Erciyes Üniversitesi Veteriner Fakültesi Dergisi 2013; 10(3): 171-176.

Ayvazoğlu C., Akyüz E., Kızıltepe Ş., Gökçe G. Investigation of the prevalence of enzootic bovine leukosis in cattle in Ardahan region. Journal of Advances in VetBio Science and Techniques 2021; 7(1): 1-7.

Batmaz H., Carli KT., Kahraman M., Cetin C., Kennerman E. Serological and haematological diagnosis of enzootic bovine leukosis in cattle in Turkey. The Veterinary Record 1995; 136(2): 42-44.

Blackburn EH. Structure and function of telomeres. Nature 1991; 350(6319): 569-573.

Brenner J., Van-Haam M., Savir D., Trainin Z. The implication of BLV infection in the productivity, reproductive capacity and survival rate of a dairy cow. Veterinary Immunology and Immunopathology 1989; 22(3): 299-305.

Burgu I., Urman HK., Kaaden OR., Truyen U., Akça Y., Alcigir G., Berkin S., Alkan F., Atasever A. Sero-epidemiological and pathological studies on enzootic bovine leukosis in Turkey. DTW. Deutsche tierarztliche Wochenschrift 1991; 98(6): 226-228.

Camargos MF., Stancek D., Rocha MA., Lessa LM., Reis JKP., Leite RC. Partial sequencing of env gene of bovine leukaemia virus from Brazilian samples and phylogenetic analysis. Journal of Veterinary Medicine, Series B 2002; 49(7): 325-331.

Cawthon RM. Telomere measurement by quantitative PCR. Nucleic Acids Research 2002; 30(10): e47-e47.

Chebel A., Bauwens S., Gerland LM., et al. Telomere uncapping during in vitro T-lymphocyte senescence. Aging Cell 2009; 8(1): 52-64.

Counter CM., Botelho FM., Wang P., Harley CB., Bacchetti S. Stabilization of short telomeres and telomerase activity accompany immortalization of Epstein-Barr virus-transformed human B lymphocytes. Journal of Virology 1994; 68(5): 3410-3414.

Dewulf M., Pascottini OB., Heirbaut S., et al. Shortening of the telomere length during the transition period of dairy cows in relation to biological stress. Scientific Reports 2024; 14(1): 31756.

Dewulf M., Duchateau L., Meesters M., et al. Telomere length in neonatal dairy calves in relation to lifetime parameters. Animals 2025; 15(1): 109.

Dogan F., Bilge DS., Dik B., Farzani TA., Alkan F. Detection of genotype 1 bovine leukemia virus from a C. schultzei pool: Do Culicoides spp. have a role on the transmission of bovine leukemia virus?. Infection, Genetics and Evolution 2020; 85: 104469.

Erskine RJ., Bartlett PC., Byrem TM., Render CL., Febvay C., Houseman JT. Association between bovine leukemia virus, production, and population age in Michigan dairy herds. Journal of Dairy Science 2012; 95(2): 727-734.

Evermann JF., DeAvila DM., Parish SM., et al. Evaluation of a serum ELISA for detection of bovine leukemia viral antibodies in milk samples. Journal of Veterinary Diagnostic Investigation 2019; 31(4): 598-600.

Gil ME., Coetzer TL. Real-time quantitative PCR of telomere length. Molecular Biotechnology 2004; 27(2): 169-172.

Greider CW., Blackburn EH. Identification of a specific telomere terminal transferase activity in Tetrahymena extracts. Cell 1985; 43(2): 405-413.

Hady PJ., Domecq JJ., Kaneene JB. Frequency and precision of body condition scoring in dairy cattle. Journal of Dairy Science 1994; 77(6): 1543-1547.

Haghparast A., Tabatabaiezadeh E., Mohammadi G., Kord N. Prevalence of bovine leukemia virus (BLV) antibodies in bulk tank milk of dairy cattle herds of Mashhad area, north-east of Iran. Journal of Animal and Veterinary Advances 2012; 11(2): 276-280.

Hemann MT., Strong MA., Hao LY., Greider CW. The shortest telomere, not average telomere length, is critical for cell viability and chromosome stability. Cell 2001; 107(1): 67-77.

Hemmatzadeh F., Keyvanfar H., Hasan NH., et al. Interaction between bovine leukemia virus (BLV) infection and age on telomerase misregulation. Veterinary Research Communications 2015; 39(2): 97-103.

Hiyama K., Hiyama E., Ishioka S., et al. Telomerase activity in small-cell and non-small-cell lung cancers. Journal of the National Cancer Institute 1995; 87(12): 895-902.

Kettmann R., Portetelle D., Mammerickx M., et al. Bovine leukemia virus: an exogenous RNA oncogenic virus. Proceedings of the National Academy of Sciences 1976; 73(4): 1014-1018.

Ladronka RM., Ainsworth S., Wilkins MJ., Norby B., Byrem TM., Bartlett PC. Prevalence of bovine leukemia virus antibodies in US dairy cattle. Veterinary Medicine International 2018; 2018(1): 5831278.

Lu W., Zhang Y., Liu D., Songyang Z., Wan M. Telomeres-structure, function, and regulation. Experimental Cell Research 2013; 319(2): 133-141.

Meesters M., Van Eetvelde M., Martens DS., Nawrot TS., et al. Prenatal environment impacts telomere length in newborn dairy heifers. Scientific Reports 2023; 13(1): 4672.

Mousavi S., Haghparast A., Mohammadi G., Tabatabaeizadeh SE. Prevalence of bovine leukemia virus (BLV) infection in the northeast of Iran. Veterinary Research Forum: An International Quarterly Journal 2014; 5(2): 135.

Murakami K., Kobayashi S., Konishi M., Kameyama KI., Tsutsui T. Nationwide survey of bovine leukemia virus infection among dairy and beef breeding cattle in Japan from 2009–2011. Journal of Veterinary Medical Science 2013; 75(8): 1123-1126.

Ohyashiki K., Ohyashiki JH., Iwama H., Hayashi S., Shay JW., Toyama K. Telomerase activity and cytogenetic changes in chronic myeloid leukemia with disease progression. Leukemia 1997; 11(2): 190-194.

Polat M., Takeshima SN., Aida Y. Epidemiology and genetic diversity of bovine leukemia virus. Virology Journal 2017; 14(1): 1-16.

Seeker LA., Holland R., Underwood S., et al. Method specific calibration corrects for DNA extraction method effects on relative telomere length measurements by quantitative PCR. PloS ONE 2016; 11(10): e0164046.

Seeker LA., Ilska, JJ., Psifid A., Wilbourn, RV., et al. Bovine telomere dynamics and the association between telomere length and productive lifespan. Scientific Reports 2018; 8(1): 12748.

Seeker LA., Underwood SL., Wilbourn RV., Dorrens J., et al. Telomere attrition rates are associated with weather conditions and predict productive lifespan in dairy cattle. Scientific Reports 2021; 11(1): 5589.

Selim A., Megahed AA., Kandeel S., Abdelhady A. Risk factor analysis of bovine leukemia virus infection in dairy cattle in Egypt. Comparative Immunology, Microbiology and Infectious Diseases 2020; 72: 101517.

Shay JW. Aging and cancer: are telomeres and telomerase the connection? Molecular Medicine Today 1995; 1(8): 378-384.

Sparling AM. An unusual presentation of enzootic bovine leukosis. Canadian Veterinary Journal 2000; 41(4): 315.

Suzuki H., Marushima K., Ohnishi Y., Horinouchi S. A novel pair of terminal protein and telomere-associated protein for replication of the linear chromosome of Streptomyces griseus IFO13350. Bioscience, Biotechnology and Biochemistry 2008; 72(11): 2973-2980.

Szczotka M., Kocki J., Iwan E., Pluta A. Determination of telomere length and telomerase activity in cattle infected with bovine leukaemia virus (BLV). Polish Journal of Veterinary Sciences 2019; 22(2): 391-403.

Szczotka M., Kuzmak J. Telomerase activity and telomere length in cattle ınfected with bovine leukemia virus (BLV). Journal of Comparative Pathology 2013; 1(148): 70.

Şevik M., Avcı O., İnce ÖB. An 8-year longitudinal sero-epidemiological study of bovine leukaemia virus (BLV) infection in dairy cattle in Turkey and analysis of risk factors associated with BLV seropositivity. Tropical Animal Health and Production 2015; 47(4): 715-720.

Şimşek A., Gürçay M., Parmaksız A., et al. Diyarbakır yöresindeki sığırların sindirim ve solunum sistemi problemlerinde enzootik bovine leukosis (EBL), bovine viral diare (BVD), infeksiyöz bovine rhinotracheitis (IBR) ve Mavi Dil (BT) enfeksiyonlarının rollerinin araştırılması. Dicle Üniversitesi Veteriner Fakültesi Dergisi 2017; 10(1): 13-18.

Tan MT., Yildirim Y., Erol N., Güngör AB. The seroprevalence of bovine herpes virus type 1 (BHV-1) and bovine leukemia virus (BLV) in selected dairy cattle herds in Aydin Province, Turkey. Turkish Journal of Veterinary and Animal Sciences 2006; 30(4): 353-357.

Tilesi F., Domenico EG., Pariset L., et al. Telomere length diversity in cattle breeds. Diversity 2010; 2(9): 1118-1129.

Tözsér J. Comparative studies on retroviral proteases: Substrate specificity. Viruses 2010; 2(1): 147-165.

Trono KG., Pérez-Filgueira DM., Duffy S., Borca MV., Carrillo C. Seroprevalence of bovine leukemia virus in dairy cattle in Argentina: Comparison of sensitivity and specificity of different detection methods. Veterinary Microbiology 2001; 83(3): 235-248.

Uchida N., Olsuka T., Arima F., et al. Correlation of telomerase activity with development and progression of adult t-cell leukemia. Leukemia Research 1999; 23(3): 311-316.

Uysal A., Yilmaz H., Bilal T., et al. Seroprevalence of enzootic bovine leukosis in Trakya district (Marmara region) in Turkey. Preventive Veterinary Medicine 1998; 37(1-4): 121-128.

Watanuki S., Takeshima SN., Borjigin L., et al. Visualizing bovine leukemia virus (BLV)-infected cells and measuring BLV proviral loads in the milk of BLV seropositive dams. Veterinary Research 2019; 50(1): 102.

Weber AF., Meiske JC., Haggard DL., Sorensen DK., Domagala AM., Flaum AM. Failure to demonstrate transmission of enzootic bovine leukemia virus infection from cows to sheep by use of common injection needles. American Journal of Veterinary Research 1988; (49)11: 1814-1816.

Wu MC., Shanks RD., Lewin HA. Milk and fat production in dairy cattle influenced by advanced subclinical bovine leukemia virus infection. Proceedings of the National Academy of Sciences 1989; 86(3): 993-996.

Wu M., Zhu Y., Cong F., et al. Rapid detection of three rabbit pathogens by use of the Luminex x-TAG assay. BMC Veterinary Research 2018; 14(1): 1-6.

Yavru S., Kale M., Simsek A., Bulut O. Comparison of BLV antibodies in late pregnant and non-pregnant holstein cows using serum and milk elisa. Veterinarium 2007; 18(1): 50-55.

Yildirim Y., Yilmaz V., Otlu S., Şahin M. The seroprevalence of Bovine Leukemia Virus (BLV) infection in imported-breed cattle in Kars district in Turkey. Kafkas Universitesi Veteriner Fakultesi Dergisi 2008; 14(1): 99-103.

Yilmaz K., Gül Y., Özdemir H., Bolat Y. Investigations on the prevalence of enzootic bovine leucosis in cattle of Elaziğ province and its vicinity. Turkish Journal of Veterinary & Animal Sciences 1997; 21(2): 115-123.

Yang Y., Fan W., Mao Y., et al. Bovine leukemia virus infection in cattle of China: Association with reduced milk production and increased somatic cell score. Journal of Dairy Science 2016; 99(5): 3688-3697.

Zhang N., Baker EC., Welsh TH., et al. Telomere dynamics in livestock. Biology 2023; 12(11): 1389.